CONSEJO DE SEGURIDAD NUCLEAR

Spanish National Assessment Report on Ageing Management of the Spanish Nuclear Power Plants

Topical Peer Review 2017

ÍNDEX

Preamble

Directive 2014/87/EURATOM recognises the importance of peer reviews as a tool for the on-going improvement of nuclear safety. For this reason it provides as follows in its article eight:

The member States shall ensure the following in a coordinated manner:

a. that a national assessment be carried out, based on a specific issue relating to the nuclear safety of nuclear facilities located in their respective territories;

b. that all member States be invited to the national assessment peer review mentioned in letter a), along with the Commission, to attend as an observer;

c. that adequate measures be adopted for the tracking of the respective results of the peer review process;

d. that reports on the process be published, along with the main results when these become available.

The member States shall ensure the existence of provisions allowing the first topical peer review to be initiated in 2017, with subsequent peer reviews performed at least once every six years.

The subject chosen for this first review has been the management of nuclear power plant ageing.

In compliance with this mandate, the CSN has drawn up the National Assessment Report, including analysis of the Overall Ageing Management Programme applicable by the Spanish nuclear power plants on the basis of the regulations in place in Spain, as well as its specific application for the systems, structures and components selected in the specification.

01. General information

01.1. Nuclear installations identification

As is shown below, the Spanish fleet of operating nuclear power plants is currently made up of a total seven groups at five sites:

- Trillo nuclear power plant (PWR-KWU).
- Vandellós II nuclear power plant (PWR-Westinghouse).
- Cofrentes nuclear power plant (BWR-General Electric).
- Ascó nuclear power plant (two PWR-Westinghouse groups).
- Almaraz nuclear power plant (two PWR-Westinghouse groups).

This section includes a general description of each of these facilities.

Trillo nuclear power plant (PWR-KWU).

Trillo nuclear power plant is owned by the companies Iberdrola Generación S.A., Gas Natural SDG S.A., Hidroeléctrica del Cantábrico S.A. and Nuclenor S.A.

A single three-loop power reactor of the Pressurised Water Reactor (PWR) type is in operation at the site, with a rated thermal power output of 3,027.0 MWt. The plant was designed and supplied by the German company Kraftwerk Union Aktiengesellschaft (KWU). The “main supplier” is currently the French company AREVA.

The reactor attained criticality for the first time on May 14th 1988, and commercial operation began in August 6th 1988.

Vandellós II nuclear power plant (PWR-Westinghouse).

Vandellós II nuclear power plant is owned by the electricity utilities Endesa Generación S.A. (72%) and Iberdrola Generación S.A.U. (28%).

A single three-loop power reactor of the Pressurised Water Reactor (PWR) type is in operation at the site, with a rated thermal power output of 2,940.6 MWt.

The reactor reached criticality for the first time on November 13th 1987, and commercial operation began in March 8th 1988.

Cofrentes nuclear power plant (BWR-General Electric).

Cofrentes nuclear power plant belongs exclusively to the utility Iberdrola Generación S.A.U.

A single power reactor of the BWR-6 type is in operation at the site, designed and supplied by General Electric (GE). The plant’s currently licensed thermal power output is 3,237 MWt.

The reactor reached criticality for the first time in August 1984 and commercial operation of the plant began in March 1985.

Ascó nuclear power plant (two PWR-Westinghouse groups).

Unit I of the Ascó nuclear power plant belongs to the electricity utility Endesa Generación S.A. (100%). For its part, Group II is owned by the utilities Endesa Generación S.A. (85%) and Iberdrola Generación S.A. (15%).

There are two three-loop power reactors of the Pressurised Water Reactor (PWR) type designed by Westinghouse in operation at the site, each with a rated thermal power output of 2,940.6 MWt.

Unit I reached criticality on June 17th 1983 and commercial operation began in ~~on~~ December 10th 1984. Unit II reached initial criticality on September 11th 1985 and began its commercial operation on March 31st 1986.

Almaraz nuclear power plant (two PWR-Westinghouse groups).

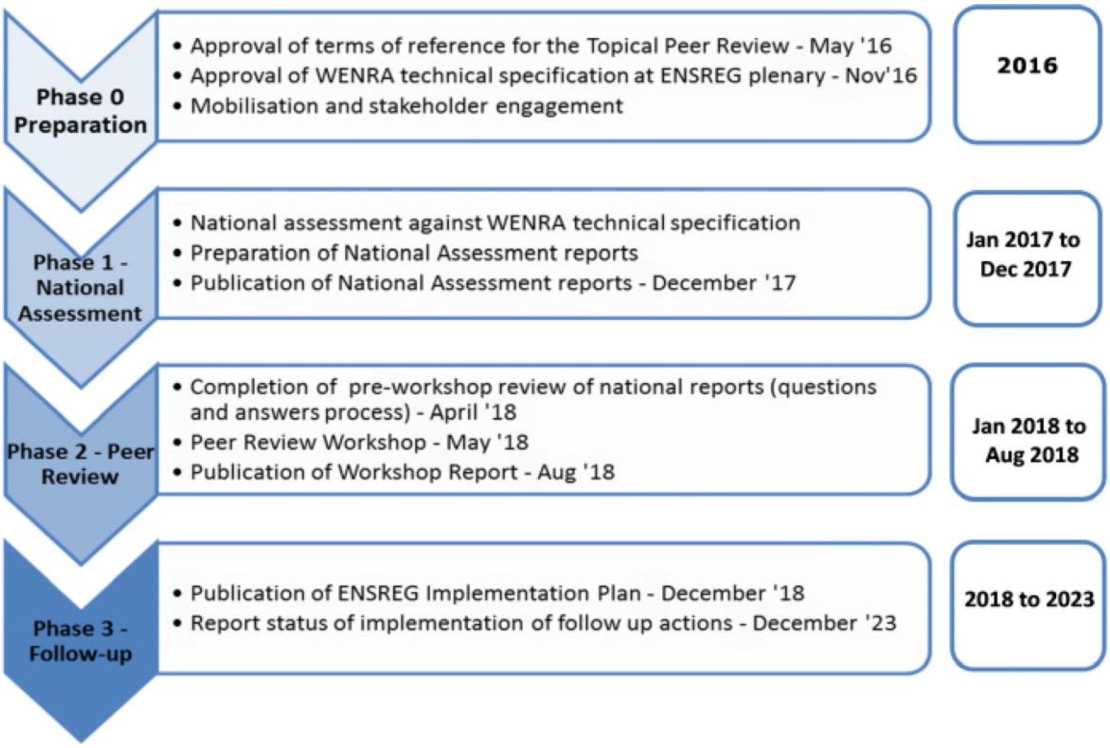
Almaraz nuclear power plant is owned by the companies Iberdrola Generación S.A., Endesa Generación S.A. and Gas Natural SDG S.A.

There are two three-loop power reactors of the Pressurised Water Reactor (PWR) type designed by Westinghouse in operation at the site, with a rated thermal power output of 2,956.6 MWt (unit I) and 2,955.8 MWt (unit II), respectively.

Unit I reached criticality on April 5th 1981 and its commercial operation began in September 1st 1983. Unit II reached initial criticality on September 19th 1983 and its commercial operation began in July 1st 1984.

01.2. Process to develop the national assessment report

In July 2015 the European Nuclear Safety Regulators Group (ENSREG), responding to a proposal by the Western European Nuclear Regulators Association (WENRA), identified the management of nuclear power plants ageing as a subject for the first topical peer review, which will be implemented via the four phases shown in the following figure.



In keeping with its participation as a member of WENRA in the aforementioned topical peer review, the Spanish Nuclear Safety Council (CSN) has established a process for the performance of Phase 1 (National Assessment Report).

Prior to initiating the development of the report on the plants, the CSN called a sector-specific meeting to explain the background of the WENRA project in question. Also explained was the final content of the technical specification “Topical Peer Review 2017 Ageing Management Technical Specification for the National Assessment Reports” [1].

WENRA identified a number of programmes for which a specific and detailed description of the process performed and results obtained was requested, in order to demonstrate the effective management of ageing effects. These programmes are as follows:

- Electrical cables (Chapter 03)
- Concealed pipework (Chapter 04)
- Reactor pressure vessels (Chapter 05)
- Calandria/pressure tubes (CANDU) (Chapter 06)
- Concrete containment structures (Chapter 07)
- Pre-stressed concrete pressure vessels (AGR) (Chapter 08)

Annex 1 of the technical specification [1] details the contents required in the national report to be submitted to WENRA for the assessments to be carried out as from 2018, specifically:

- Description of ageing management programmes
- Scope of ageing management for the applicable SSC’s
- Ageing assessment of applicable SSC’s
- Monitoring, testing, sampling and inspection activities of applicable SSC’s
- Preventive and remedial actions
- Licensee’s experience of the application of AMPs on applicable SSC´s
- Regulator assessment and conclusions regarding ageing management

On the basis of the applicability of the previous chapters to each plant, the CSN established certain timeframes (January-June 2017) in which each of the Spanish nuclear power plants were required to submit drafts for comments, in response to the technical specification [1].

With a view to carrying out a structured plan and complying with the timeframes set out by the CSN, a working group was set up, led by UNESA and a licensing representative, to represent all the plants, this also including technicians from each site.

In the case of the Spanish nuclear power plants, and given that the Spanish nuclear fleet does not include either CANDU or AGR plants, the National Assessment Report contains the information requested in relation to Chapter 02, Overall ageing management programme requirements and implementation, as well as the following chapters:

- Electrical cables (Chapter 03)
- Concealed pipework (Chapter 04)
- Reactor pressure vessels (Chapter 05)
- Concrete containment structures (Chapter 07)

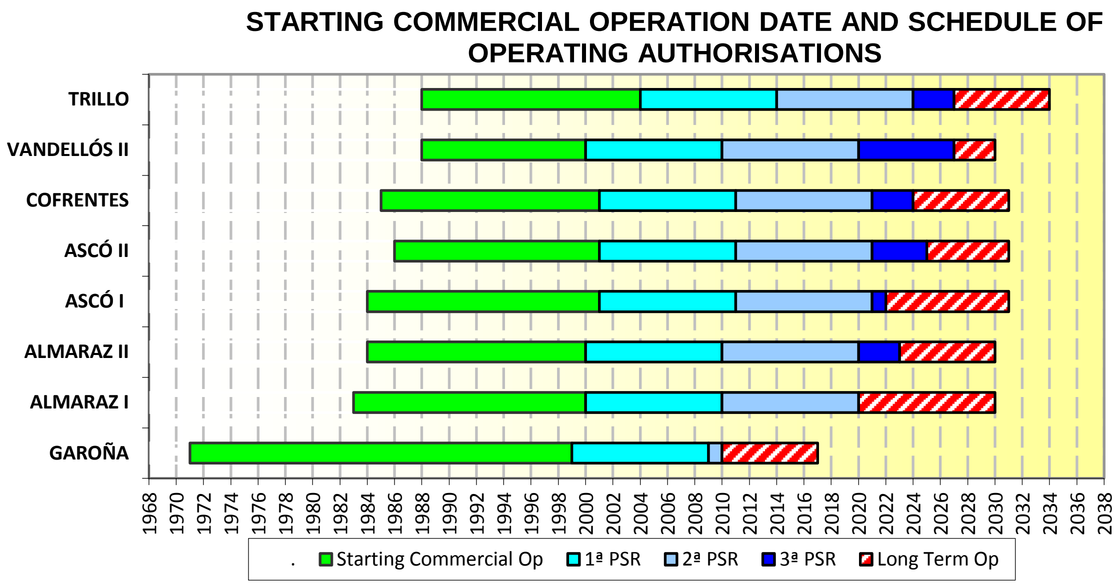
This process began with a request by the CSN to the Spanish nuclear power plants for each of these facilities to draw up a report in response to the aforementioned specification. This request materialised through the sending of letters to each licensee, with the following references:

- CSN/C/DSN/VA2/16/59 [2]

- CSN/C/DSN/TRI/16/43 [3]
- CSN/C/DSN/COF/16/45 [4]
- CSN/C/DSN/AS0/16/76 [5]
- CSN/C/DSN/AL0/16/71 [6]
- CSN/C/DSN/SMG/16/22 [7]

As a result, the licensee of each of the nuclear power plants has performed a detailed analysis of the facility's Overall Ageing Management Programme (OAMP) and Ageing Management Programmes (AMP) for the selected systems, structures and components and has subsequently submitted a report on this analysis to the Spanish Nuclear Safety Council (CSN), in accordance with the programmes established in the WENRA specification [1]. A special case was the Santa María de Garoña nuclear power plant, whose report was requested by letter [7] due to its not being in the definitive shutdown situation at the time. However, the renewal of the plant's operating permit was denied on August 1st 2017 by order ETU/754/2017. Consequently, and in accordance with the WENRA specification [1], as Santa María de Garoña NPP was in the definitive shutdown situation as of December 31st 2017, the present national report does not include this facility.

Next figure shows the schedule of starting the commercial operation and the subsequent license renewal and dates of starting the long-term operation for the Spanish nuclear power plants within the scope of the present National Report. The figure also shows the schedule of the before mentioned special case of Santa María de Garoña NPP.



During this process the CSN has held several meetings with the licensees of the Spanish nuclear power plants in order to provide guidance on the process and the drawing up of their reports. The conclusions and compromises of the aforementioned meetings are summarised in the minutes of the three meeting:

- CSN/ART/IMES/GENER/1702/02, "1st Coordination meeting held with the licensees of the Spanish Nuclear Power Plants, to perform the Topical Peer Review (TPR) National Report (TPR)" [8].
- CSN/ART/IMES/GENER/1703/03, "2ª Reunión de coordinación con los titulares de las CC.NN.EE. para la elaboración del informe nacional del Topical Peer Review (TPR)" [9].
- CSN/ART/GEMA/GENER/1705/08, "3ª Reunión de coordinación con los titulares de las CC.NN.EE. para la elaboración del informe nacional del Topical Peer Review (TPR)" [10].

In keeping with the schedule approved by ENSREG, the CSN considered that these reports should be submitted prior to June 30th 2017, these having been received by way of the following letters:

- CNV-L-CSN-6542 [11] (reference report for Ascó NPP and Vandellós II NPP: DST-2017-127 [12]).
- Z-04-02/ATT-CSN-010976 [13] (reference report for Trillo NPP: IT-17/015 [14]).
- 1799983302387 [15] (reference report for Cofrentes NPP: DISES-2017-05 [16]).
- Z-04-02/ATA-CSN-012682 [17] (reference report for Almaraz NPP: IT-17/014 [18]).
- NN/CSN/104/2017 [19] (reference report for Santa María de Garoña NPP: LP-00-524 [20]).

On the basis of the reports submitted by the licensees of the rest of the nuclear power plants, the CSN has drawn up the National Assessment Report, which will be subjected to peer reviews among the European countries.

02. Overall ageing management programme requirements and implementation

02.1. National regulatory framework

As the regulatory authority, the Spanish Nuclear Safety Council (CSN) sets out ageing management requirements in the following documents:

- CSN Instruction IS-22 on safety requirements for the management of ageing and long-term operation of nuclear power plants [21].
- Safety Guide 1.10 on nuclear power plant periodic safety reviews [22].

Likewise, article 7.19 of Instruction IS-26 on basic nuclear safety requirements applicable to nuclear installations establishes that the installation must have an Overall Ageing Management Programme that identifies the ageing degradation of structures, systems and components important to safety, specifying their possible consequences and determining their expected operating life and the activities required to maintain their operability and reliability.

IS-22 [21] is the standard developed by the Spanish regulatory authority, with the force of law, that regulates safety criteria for ageing management, including management in the case of long-term operation, this instruction being applicable to all the Spanish nuclear power plants with one or more PWR or BWR power reactors.

The requirements established in IS-22 [21] are applicable under all plant operating conditions, from initial start-up to definitive shutdown, for which reason common and specific requirements are defined for each of the two plant service lifetime phases:

- Design lifetime of the facility (40 years for the Spanish plants): this corresponds to the plant operating period estimated or calculated in the design, during which the facility is expected to fulfil its function in the terms established by the licensing basis.
- Long-term operating period: this corresponds to the plant operating period beyond the design lifetime.

Within the design lifetime period, the CSN requires the nuclear power plants to develop and implement an Overall Ageing Management Programme (OAMP), defined as the ageing management action programme in order to reach the original design lifetime of the facility without any deterioration of safety and maintaining compliance with the current licensing basis.

As regards the long-term operating period, IS-22 [21] requires the nuclear power plants to proceed as follows:

- Developing the Integrated Plant Assessment (IPA), which summarises the technical justification of ageing management with respect to the long-term operating period.
- Developing and implementing a Long-Term Overall Ageing Management Programme (LT-OAMP), based on the conclusions of the IPA and corresponding to the lifetime management actions programme during the long-term operating period.

Likewise, as a result of the requirements of their operating permit, the Spanish plants are subjected to a Periodic Safety Review (PSR) every ten years, which the scope, content, documentation and terms of presentation are established in CSN Safety Guide GS-1.10 [22]. This guide requires the presentation of current or expected ageing analyses, using the information available in the Overall Ageing Management Programmes developed during the PSR ten-year period.

In the case of the PSR prior to long-term operation, this shall include the following documents, in addition to the PSR documentation itself:

- Integrated Plant Assessment (IPA), which shall contain Ageing Management Studies and Time-Limited Ageing Analyses.
- Proposal for a supplement to the plant Final Safety Analysis Report, to include studies and analyses justifying the long-term operation of the plant.
- Proposal for review of the Technical Specifications, to include the changes required to maintain safe operating conditions during the long-term operation of the plant.
- Study of the radiological impact associated with long-term operation of the plant.
- Proposal for review of the Radioactive Waste and Spent Fuel Management Plan corresponding to long-term operation of the plant.

02.2. International standards

The methodology used for the development of the Spanish plant Overall Ageing Management Programme is based fundamentally on the American methodology described in 10 CFR 54 [23], as well as in other references including the operating experience of the nuclear industry, as shown below:

<u>References of the US Nuclear Regulatory Authority</u>

- **10 CFR Part 54,** Requirements for Renewal of Operating Licenses for Nuclear Power Plants, [23]
- **Regulatory Guide 1.188,** Standard Format and Content for Applications to Renew Nuclear Power Plant Operating Licenses,
- **NUREG–1800,** Standard Review Plant for Review of License Renewal Applications For Nuclear Power Plants, [24]
- **NUREG–1801,** Generic Aging Lessons Learned (GALL) Report [25].

<u>Industry references</u>

- **NEI 95-10,** Industry Guideline for Implementing the Requirements of 10 CFR Part 54 – The License Renewal Rule, [26]
- **EPRI-1010639,** Non-Class 1 Mechanical Implementation Guideline and Mechanical Tools, [27]
- **EPRI-1013475,** Plant Support Engineering: License Renewal Electric Handbook, [28]
- **EPRI-1015078,** Plant Support Engineering: Aging Effects for Structures and Structural Components (Structural Tools) [29].

In addition to the references indicated in IS-22 [21], consideration is given in the Spanish plant Overall Ageing Management Programme to other international references not required by IS-22 [21] and relating to nuclear power plant ageing management, such as the following guidelines or documents developed by the IAEA:

- **IAEA Safety Reports Series Nº 82,** Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL), 2015.
- **IAEA Safety Guide NS-G-2.12,** Ageing Management for Nuclear Power Plants Safety Guide. February 2009.
- **IAEA Safety Report Series Nº 57,** Safe Long-term Operation of Nuclear Power Plants. November 2008.
- **IAEA Services Series Nº 17,** SALTO Guidelines. Guidelines for peer review of long-term operation and ageing management of nuclear power plants. December 2008.
- **IAEA-EBP-SALTO,** Safety aspects of long-term operation of water moderated reactors. Recommendations on the scope and content of programmes for safe long-term operation. July 2007.
- **Technical Reports Series Nº 448,** Plant Life Management for Long-term Operation of Light Water Reactors. February 2007.
- **Safety Series No. 50-P-3,** Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing. December 1991.
- **Technical Reports Series No. 338,** Methodology for Ageing Management of Nuclear Power Plant Components Important to Safety. July 1992.
- **Safety Report Series No. 15,** Implementation and Review of Nuclear Power Plant Ageing Management Programme. April 1999.

Taking into account what has been indicated above, it may be stated that the methodology used and the activities performed for development of the Spanish plant Overall Ageing Management Programme fulfil the WENRA reference levels corresponding to ageing management and identified in the specification as the following: WENRA I1.1; WENRA I2.1; WENRA I2.2; WENRA I2.3; WENRA I2.4; WENRA I2.5; WENRA I3.2.

02.3. Description of the overall ageing management programme

02.3.1. Scope of the overall AMP

As regards the assignment of responsibilities in the licensees' organisations to ensure that the Overall Ageing Management Programmes are developed and implemented correctly and in accordance with the established requirements, it should be pointed out that by their very nature ageing management activities are multidisciplinary and require the participation of different plant organisations, as well as external organisations, depending on the tasks being performed. For this reason, the Spanish nuclear power plants have set up specific organisations for their Overall Ageing Management Programmes, these having the following functions:

- The management of and support for the Overall Ageing Management Programme via the organisational structure of the plant owners.
- The establishment of functions and assignment of responsibilities to ensure compliance with ageing management objectives.
- The definition of the channels for communication required to coordinate activities relating to ageing management.

With a view to complying with these functions, the organisations responsible for the Overall Ageing Management Programmes at the Spanish plants are structured around the following basic elements:

- Ageing Management Coordinator: responsible for the general coordination of ageing management activities at each of the plants, facilitating synergies that allow for more efficient development of each of the programmes. This person is also responsible for relationships with external organisations in matters relating to lifetime management.
- Ageing Management Committee: this is a collegiate body represented by the Lifetime Management Coordinator and having the following main functions:
    - Definition of the main courses of activity for performance of the lifetime management plan at the plant.
    - Establishment, in response to proposals by the Ageing Management Coordinator, of the support organisations required for the performance of each activity.
    - Approval of the results of lifetime management activities.
    - Analysis of the relationships between lifetime management activities and other plant activities, in order to take advantage of possible synergies between them and optimise performance of the lifetime management plan.

  The Ageing Management Committee, made up of representatives of all the sections involved in the performance of the activities, is the key element of the ageing management organisation and through it all activities are articulated and their results validated.

  The specific organisation of the ageing management committee depends on the organisational structure of each plant. In all plants, this committee includes representatives of the following plant sections:

    - Mechanical maintenance
    - Electrical maintenance
    - Instrumentation and control maintenance
    - Chemistry and radiochemistry
    - Operations
    - In-service inspection and testing
    - Plant and reactor engineering

- Engineering and special projects, special designs or projects, programmes and materials.
- Safety and Licensing

  This committee meets periodically and decisions taken are recorded in the meeting minutes.

In addition to this organisation, some plants also have the following:

- Ageing Management Plant manager: the main functions of this person are to coordinate the performance of all the activities assigned to the plant and provide support for the Ageing Management Coordinator.

- External support organisations: It is also normal for the Spanish nuclear power plants to contract external support organisations to perform ageing management activities on the basis of their specific experience in the plant and depending on their specialities.

IS-22 [21] establishes criteria for the identification of Structures, Systems and Components (SSC's) within the scope of the overall ageing management programme, the text of which is extracted below:

"*The scope of the ageing management programme, specified in point four of this Instruction, shall include the following safety-related and safety-significant SSC's:*

3.1. Safety-related (SR) elements that are required to continue operating during and after any design basis event that might occur, in order to guarantee the following functions:

- *The integrity of the reactor coolant pressure boundary,*
- *The capability to shut down the reactor and maintain it in safe shutdown conditions, or*
- *The capability to prevent or mitigate the consequences of accidents, such that off-site radioactive exposures are kept below the established limits.*

3.2 Safety relevant (NSR) elements whose failure might prevent satisfactory compliance with any of the functions identified in previous section 3.1.

3.3 Safety important elements to which credit is given in the safety assessments of the facility, relating the requirements on fire protection (FP), environmental qualification (EQ), pressurised thermal shock (PTS), anticipated transients without scram (ATWS) and station blackout (SBO) requirements.

Explained below is the process followed by the Spanish nuclear power plants to determine which components of mechanical and electrical systems and structures shall be within the scope to be managed by the Overall Ageing Management Programme and thereby comply with the current required standards.

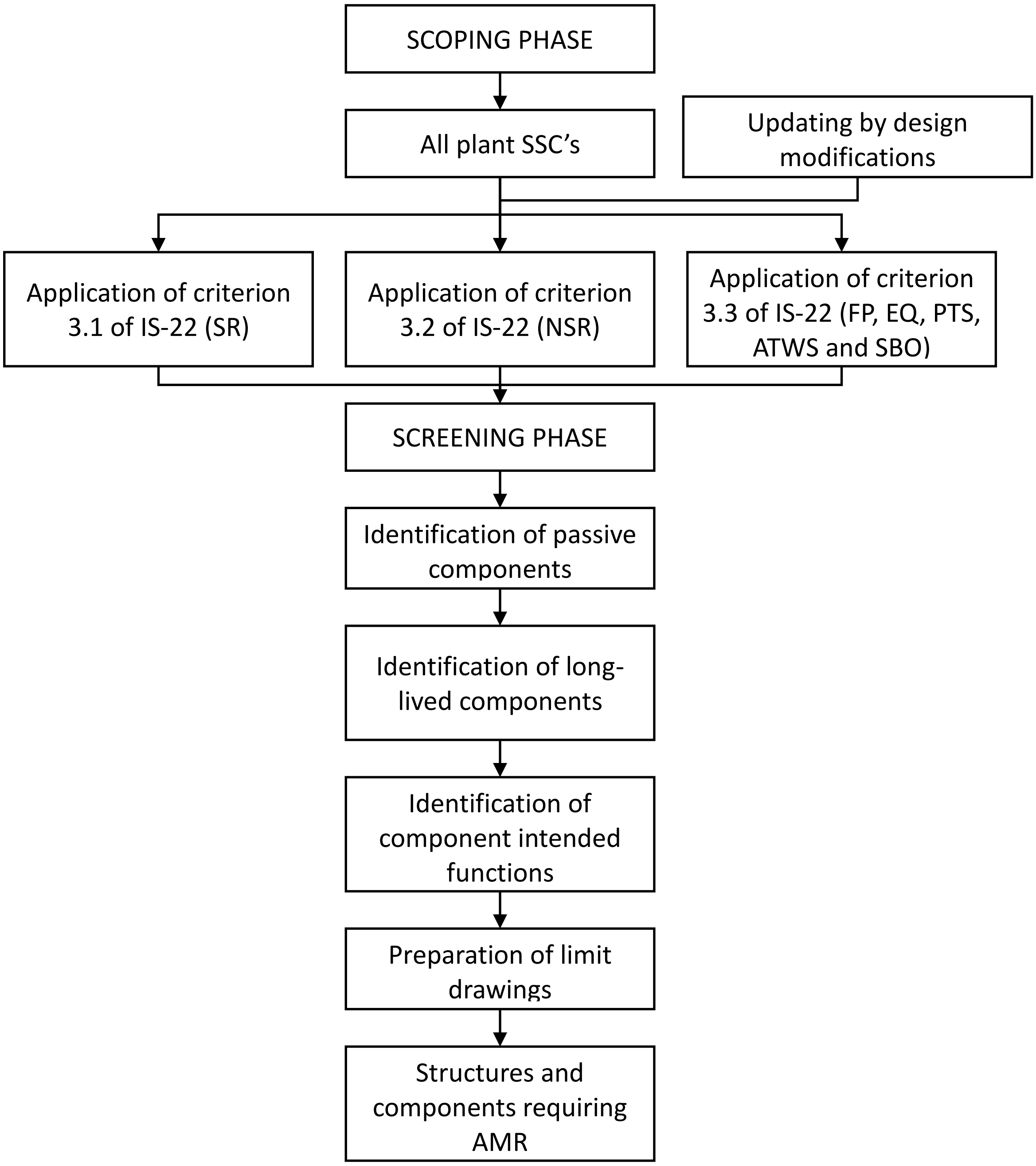


Figure 02.1. Process for Scoping and Screening of ageing management

Mechanical systems:

The first step is to identify the SSC's and their intended functions: starting from all the plant SSC's, it is determined what systems fulfil any of the criteria established in article three of IS-22 [21], i.e. SR (corresponding to the criteria explained in article 3.1 of IS-22), NSR (corresponding to the criteria explained in article 3.2 of IS-22), and SSC that fulfil requirements of EQ, FP, ATWS, SBO and PTS (corresponding to the criteria explained in article 3.3 of IS-22). The intended functions of the systems are obtained as a result.

Subsequently, the individual components required for the systems to fulfil the function by which they have been identified in the scope may be identified with the help of drawings.

Electrical systems components:

Electrical components present a specific feature, since most of them are considered to be "active" in accordance with Appendix B NEI 95-10 [26] and Table 2.1-5 of NUREG-1800 [24].

Electrical guideline EPRI-1013475 [28] provides a description of electrical type-components that are classified as passive and may commonly be found at any nuclear power plant.

Listed below are the type-components identified at the Spanish nuclear power plants.

- Insulated cables and their connections
- Electrical and instrumentation and control penetrations
- Metal enclosed bus
- Transmission conductors
- High voltage insulators
- Uninsulated Grounding Conductors
- Fuse holders

A particularly significant case is the treatment given to insulated cables and their connections, these being the most relevant of the type-components listed above in terms of number and ubiquity, with examples in practically all areas of the plant and in a wide variety of locations, environments, materials and applications. The diversity of materials and environments is the reason for using a "plant spaces approach" at the plant after the screening of the cables and connections within the scope of the Overall Ageing Management Programme. The methodology of this analysis is described in detail in section 03.1.1 of the present report.

Structural components:

The first step is to draw up the Structures Assessment Limit drawings. The limit drawings corresponding to the intended functions identified are drawn up on the basis of the building or structure ground drawings. The limit drawings define both the limits of the main structure, necessary to maintain its overall integrity, and the areas required for the performance of the structures intended functions.

Specifically, those rooms in which the existence of systems and components required to fulfil the aforementioned intended functions – i.e. to meet the criteria for inclusion in the scope (SR, NSR, FP, EQ, PTS, ATWS and SBO) - have been determined will be included within the limit drawing.

The second step consists of identifying structural components within the assessment limits. This identification of components is accomplished using the structural drawings and includes an inspection walkdown to confirm and complete the information included in the drawings.

In addition, the inspection walkdown includes identification of those components that, while not in principle being within the assessment limits:

- have a protection function of safety-related component against flooding, earthquakes, missiles, fires, etc., or
- have a spatial relationship (proximity) with safety-related components such that their failure might imply non-compliance with a safety function. This identification is especially important since generally it cannot be accomplished by simply consulting drawings.

In the case of components fulfilling either of these two conditions being identified, they will automatically be included within the assessment limits.

In addition to the above, the performance of walkdowns is also useful for the detection or checking of materials and environments corresponding to the structural components identified.

As a practical example of this identification process, in the areas marked as being within the scope on the limit drawings, it is possible that they content components of a given class that are not included within the assessment limits. This is the case, for example, of a room that is inside the assessment limits solely due to its being crossed by safety-related cables trays, but that also includes for equipment basements not included within the scope of the Overall Ageing Management Programme. In this case, only the cable trays and their supports are considered to be structural components within the scope.

The level of definition of a structural component is linked to the way in which its Ageing Management Review (AMR) is performed: they may be independent structures (such as for example the anti-missile shield) or type-components may be created, including structural components that are discrete but common to several (such as slabs, walls, pillars, doors, etc.).

In performing this component identification process, consideration is given to classifications already taken into account in the Maintenance Rule and other plant documents such as, for example, the Fire Risk Analysis or Flooding Protection Manual. The classification of component types established in appendix B of NEI 95-10 [26] and tables relating to the structures AMR in NUREG-1801 [25] are also taken as a reference.

After completion of the mechanical, electrical and structural systems scope definition phase, a screening process is performed, this consisting of selecting those components that fulfil the following criteria:

- They are passive, in other words they do not have moving parts or parts that change their configuration or properties, as set out in table 2.1-5 of NUREG-1800, since application of the Maintenance Rule (regulated in CSN Instruction IS-15) to active components guarantees that the critical functions, in components defined as being within its scope, are within acceptance levels.
- They are long-lived, in other words they are not included in any periodic replacement programme based on maintenance of its qualified lifetime or any other replacement programme. In this respect the plant maintenance and engineering documentation

is reviewed, mainly the maintenance schedules, and the plant personnel are consulted when necessary in order to identify components within the scope of the Overall Ageing Management Programme and subject to periodic replacement.

Once the structures and systems included within the scope of IS-22 [21] have been obtained, and those that are passive and long-lived have been screened, those components required for performance of the intended functions of the structure or system, and in turn the intended functions of the components themselves, are identified. The following are examples of typical component intended functions common to all the Spanish nuclear power plants:

- Electrical insulation
- Thermal insulation
- Fire barrier
- Missile shield
- Radiation shield
- Electrical connection
- Pressure envelope
- Leak tightness
- Filtration
- Structural integrity
- Heat exchange
- Flow restriction
- Anti-whipping support
- Structural support for components, equipment or structures

As a result of the above, the system and structure limit drawings are obtained, which identify all structures and components included within the scope of the Overall Ageing Management Programme.

After the screening process of structures and components inside the scope of the Overall Ageing Management Programme, the Ageing Management Review (AMR) process is applied into them. This AMR process involves, mainly, the following activities:

- Identifying the significant ageing mechanisms and effects.

- Assessment of applicable maintenance practices of the plant, to manage, mitigate and control the aforementioned significant ageing mechanisms and defining, if needed, the required improvements

- Incorporation of the aforementioned maintenance practices in the corresponding Ageing Management Programmes (AMP) to manage the significant ageing mechanisms.

The number of individual components that might, on the basis of the different scoping criteria, be included within the scope of the OAMP is in the thousands. However, the treatment of these items in activities associated with the AMR, mainly the identification and assessment of potential ageing effects and mechanisms, is accomplished with respect to aspects such as functionality, construction materials, environments and operating conditions, allowing for the grouping of structures and components facilitating their treatment.

For this reason, the Spanish nuclear power plants group structures and components (S&C) in scope as follows:

- A unique item of equipment or structure at the plant; for example “the reactor vessel”.
- A group of equipment or structures identical in their construction materials, environments and functions; for example “RHR pumps”.
- A group of components or structures of the same type and having the same function that, in accordance with the generic experience of ageing management assessments, is treated as a “Type Component”; for example piping supports, cables, anti-whipping supports.
- A group of components of different types interconnected and having the same function; for example “AF system SR piping”. This group would include the piping runs and pipe accessories jointly performing one or more safety-related system functions.

Within these first level groupings there is a second level in which the different elements making up the said group are defined on the basis of the component type, material or intended function.

The following are examples of this type of second level groupings or elements:

- Within a grouping such as “RHR pumps” the following elements may be identified: shell, nuts and bolts, bolts and locking nuts.
- Within a grouping such as “AF system SR piping” the following elements may be identified: carbon steel piping, carbon steel valves, stainless steel valves, carbon steel nuts and bolts.

Ageing effect assessments are performed on these second level groupings.

The assessment of the potentially applicable maintenance practices to the aforementioned effects is described in section 02.3.2 of the present chapter.

Regarding the quality assurance applied in the OAMP, at the Spanish nuclear power plants ageing management activities, as activities inherent to the plants, are subject to the quality assurance requirements set out in the facilities’ quality assurance manuals. These manuals were developed in accordance with the requirements established by the CSN, which as regards safety-related SSC’s are regulated in accordance with requirements equivalent to those included in Appendix B of the US standard 10 CFR 50.

As a final result from the scoping and screening processes described above, a list of structures and components that would be subjected to AMR process within the OAMP of the plant, is obtained.

02.3.2. Ageing assessment

For the development of the different activities in the Overall Ageing Management Programme (scope, AMR, etc.) the Spanish nuclear power plants have developed technical guides, in which it is defined the methodology that has to be followed to carry out each task, the starting documentation of the plant to be considered (like SSC's design documentation, maintenance activities, inspections, chemical surveillances, etc.), and the process to be followed for obtaining the expected results.

The guidelines and regulation used to prepare the OAMP's have been described in sections 02.1 and 02.2 of this chapter.

In addition, the following is used as specific documentation for development of the AMR methodology:

1) In the application of scoping criteria:
   - Guideline NEI 95-10 [26].
   - Final Safety Analysis Reports.
   - Systems Design Basis documents.
2) In the identification of ageing effects/mechanisms:
   - EPRI-1010639 Non-Class 1 Mechanical Implementation Guideline and Mechanical Tools [27].
   - EPRI-1013475 Plant Support Engineering: License Renewal Electric Handbook [28].
   - EPRI-1015078 Plant Support Engineering: Aging Effects for Structures and Structural Components (Structural Tools) [29].
   - NRC License Renewal Interim Staff Guidance (LR-ISG).
   - NUREG–1801 Generic Aging Lessons Learned (GALL) Report [25].
   - Systems Design Basis Documents (DBD).
   - Equipment construction drawings.
   - Piping and cable specifications.

3) Assessment of maintenance practices, and AMP definition. The main references in this process have been the following:
   - NUREG–1801 Generic Aging Lessons Learned (GALL) Report [25].
   - NRC License Renewal Interim Staff Guidance (LR-ISG).
   - Maintenance tasks and procedures specific to each plant.

As has been indicated in previous sections of this report, for development of the Overall Ageing Management Programme, Instruction IS-22 [21] requires that the Spanish plants include the following in this programme:

- For each component included within the scope, identification and analysis of its significant ageing mechanisms and their possible causes and effects.

- The assessment of maintenance practices in order to conclude whether they are suitable for the correct detection, control and mitigation of the aforementioned ageing mechanisms, determining, where appropriate, the improvements required.
- These maintenance practices are included in the AMP, developed in accordance with the model programmes of NUREG-1801 [25].
- In the case of ageing management considering the long-term operating period, identification and assessment of all the analyses and calculations performed by the licensee of the facility, in compliance with the definition of Time-Limited Ageing Analyses (TLAA) that is explained in section 02.4 of this chapter.

At the Spanish plants the analyses for the identification and evaluation of ageing mechanisms have been carried out taking as a basis the conclusions of generic industry documents and the results obtained from the review of plant-specific and industry operating experience.

Particularly significant among the general references used by the Spanish nuclear power plants for the identification and assessment of ageing mechanisms are the EPRI tools, which are also used as references in processes for license renewal requests in the USA, in accordance with 10 CFR 54 [23]:

- EPRI-1010639, “Non-Class 1 Mechanical Implementation Guideline and Mechanical Tools”, Revision 4, January 2006. [27]
- EPRI-1015078, “Plant Support Engineering: Aging Effects for Structures and Structural Components (Structural Tool)”, December 2007. [29]
- EPRI-1013475, “Plant Support Engineering: License Renewal Electrical Handbook”, February 2007. [28]

Below is detailed the activities performed in the AMR process, which are summarised in the next figures 02.2 and 02.3.

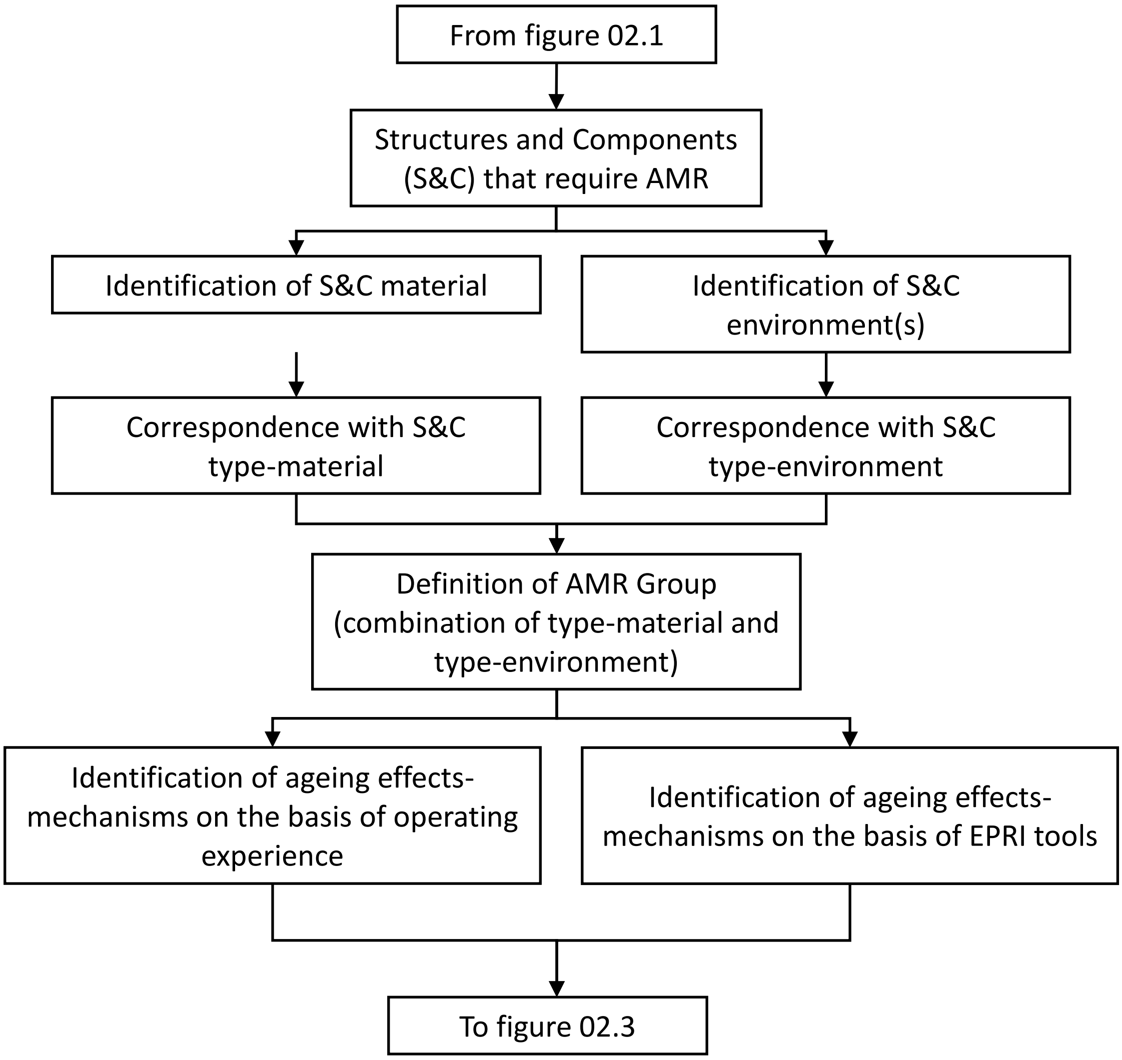


Figure 02.2. AMR groups phase

Following completion of the scoping and screening phase, the group of S&C included within the scope and consequently move on to the next phase of ageing management review is obtained.

The next task consists of identifying the materials of which the aforementioned S&C are manufactured and the environments to which they are exposed. The Spanish nuclear power plants obtain this information from documents such as the Final Safety Analysis Report, system description documents, system design basis documents and manufacturer and supplier drawings.

As a result, a large number of specific materials and environments may be identified, but these can be grouped into type materials and environments in order to allow for analysis of the applicable ageing effects and mechanisms. Consequently, the next step is to identify the correspondence between the materials and environments identified for each S&C and the type materials and environments defined in the EPRI tools.

EPRI tools (EPRI-1010639 [27], EPRI-1015078 [29], EPRI-1013475 [28]) include the results of operating experience and the R&D programmes, undertaken by the nuclear industry, to determine the ageing mechanisms that might potentially affect the structures and components, depending on the material of which they are made and the environments to which they are subjected.

An example of a construction type material might be “Carbon steels, low-alloy steels and cast irons”, in accordance with the joint consideration as a material type made in this case by EPRI-1010639 [27], which includes both forged carbon steels, cast carbon steel and cast iron.

Information on insulation and jacket materials commonly used for cables is taken from EPRI-1013475 [28], among other data. Also obtained is a discretisation of the different electrical type-components from which the electrical AMR groups are formed.

As regards environments, an example of environment type might be “Air/gas”, which, according to the definition of this type of environment in EPRI-1010639 [27], includes environments such as indoor ambient air or gas environments, among others.

Continuing with the help of EPRI tools [27] [28] and [29], the AMR groups are defined. An AMR group consists of an association between a type of construction material and a type of environment to which it might be exposed. The AMR groups are required to cover the material-environment combinations identified in the previous step.

Finally, the ageing effects and mechanisms potentially applicable according to the information contained in the EPRI tools tables are identified for each AMR group defined in the previous step.

Each of the ageing effects and mechanisms identified is described and detailed as regards both, the description of the effect-mechanism itself and the conditions under which this effect-mechanism are considered to be applicable, in accordance with what may be gathered from the EPRI tools.

Following this, those ageing effects and mechanisms that are significant are identified. To do so, the applicability of each of the potential ageing effects and mechanisms identified in the previous steps is determined based on the specific characteristics of the plant.

Finally, before going on to the next task of the AMR process, the industry operating experience identified in the EPRI tools is compared to the operating experience of the plant itself, in order to ensure that there have been no ageing mechanisms specific to the Spanish plants different from those included in the industry operating experience. A clear example of this process is the specific ageing management programme of Ascó, nuclear power plant, which has come about as a result of the ground movements.

After the aforementioned steps, the evaluation process of maintenance practices existing in plant is developed to assess their applicability to manage the significant ageing effects and mechanisms previously identified. This is required by IS-22 [21], which provides as follows: “*The objective of this activity will be to determine whether the causes and consequences of ageing (significant ageing effects and mechanisms) are* *adequately overseen, controlled and mitigated by the maintenance practices; bearing in mind that these do not include only predictive and preventive maintenance practices themselves but also inspection, testing, the control of operating parameters, surveillance, etc.*

Maintenance, inspection and testing activities required by the current licensing basis will be valid for the ageing management of the affected SSC's with respect to the ageing effects and mechanisms dealt with therein.

Evaluation of the maintenance practices will consist of a comparison between the surveillance and mitigation activities suitable for each ageing effect and mechanism (significant for each structure and component) and the actual content of the maintenance practices performed on that structure or component. The result of the evaluation will include the improvements to the maintenance processes necessary to establish an adequate ageing management and, where required, the implementation of new management practices."

Historically, most plant maintenance practices relating to ageing management were applied prior to the requirement to develop OAMP's. Examples of such practices include, among others, the in-service inspection, and the chemistry and structure maintenance programmes.

The plant maintenance practices, once assessed and improved when necessary, are incorporated to an "Ageing Management Programme Catalogue" specific for each plant.

The next task within the AMR process is the assignment of the significant effects and mechanisms identified to the AMP and/or TLAA, as is described in figure 02.3.

For the assignment process, the Spanish plants use the "commodities" concept.

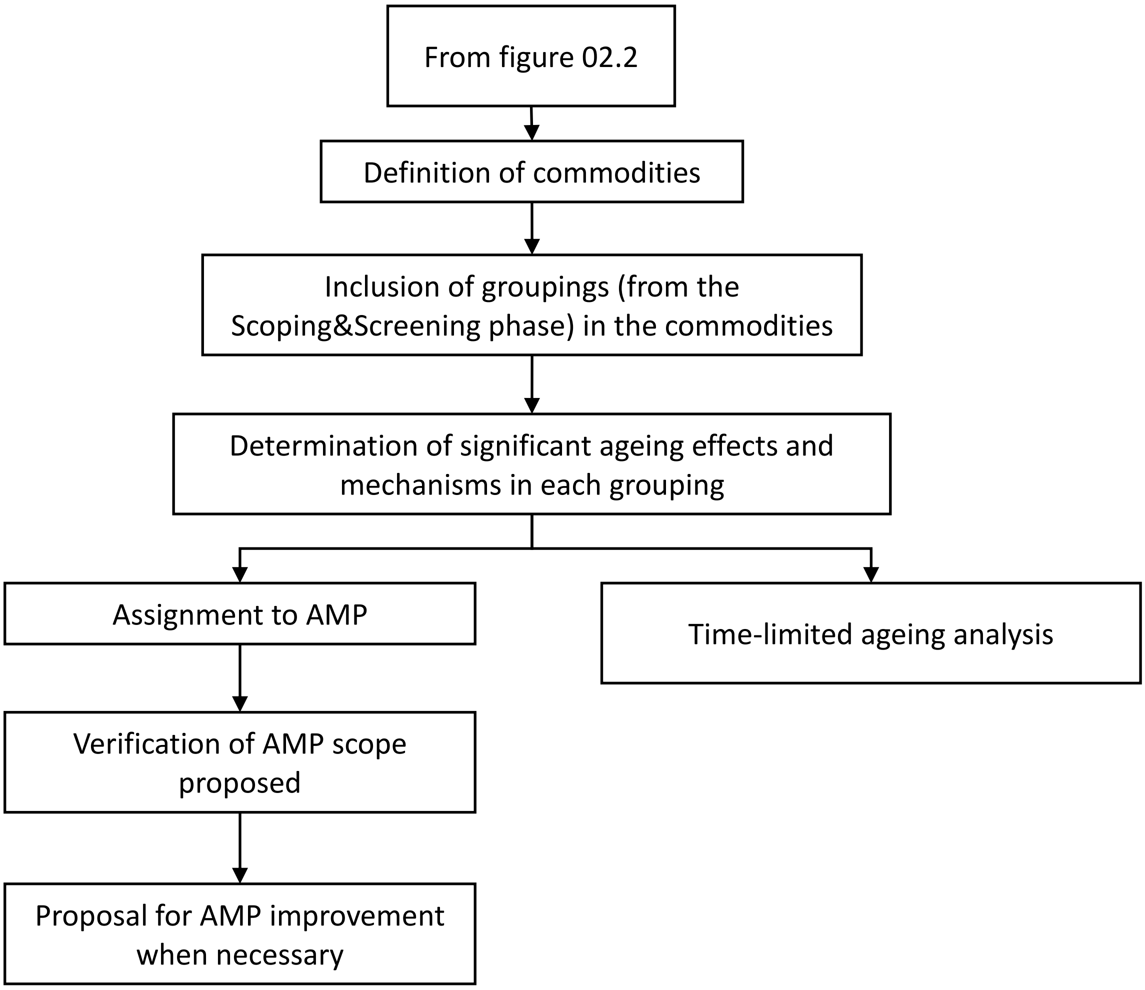


Figure 02.3. Assignment of the identified significant mechanisms and ageing effects to the AMP's

A commodity is a homogeneous set of structures or components as regards the function performed, the material of which they are made, the environment and other specific conditions to which they may be subjected (such as for example temperatures, component typology or specific composition of a material) that allows ageing effects to be analysed in the common way. The structures and components in a commodity receive equivalent treatment from the point of view of the AMR.

For the different groupings defined for structures and components within the scope (see section 02.3.2 of this chapter), the corresponding commodities are defined, and for each of them it is determined what significant ageing effects and mechanisms are applicable, according to the results of the definition of AMR groups. In general, to determine the potential applicability of an ageing mechanism it is necessary to consult the documentation that define accurately the specific environments and construction materials of the plant.

The practical reason for creating these commodities is that one same material subjected to one same type of environment may undergo different ageing mechanisms and effects depending, for example, on the ambient temperature.

The next step is to assign to the significant ageing effects and mechanisms identified for each commodity an AMP or to a TLAA's that allow their effects to be watched over and controlled and later to analyse these AMP's by comparison with the attributes of the model programmes defined in NUREG-1801 [25] (GALL report). This process is what is known as "Conciliation with GALL" (Generic Ageing Lessons Learned). AMP assignment is accomplished trying to keep as close as possible to the corresponding model AMP's included in the NUREG-1801 [25] report and also to the different LR-ISG's in force (LR-ISG-2011-01 [30], LR-ISG-2011-02 [31], LR-ISG-2011-03 [32], LR-ISG-2011-04 [33], LR-ISG-2011-05 [34], LR-ISG-2012-01 [35], LR-ISG-2012-02 [36], LR-ISG-2013-01 [37], LR-ISG-2015-01 [38], LR-ISG-2016-01 [39]) for management of the same ageing effects.

Finally, the last step consists of verifying that all the structures and components obtained from the scope and screening process are within the scope of the AMP's assigned in the previous step for the management of their ageing. If this is not the case, increasing the scope of the AMP is proposed as an improvement.

In subsequent updates of this task, AMP improvement proposals are issued in relation to the following:

- New components within the scope of a given AMP, or
- Possible changes in the identification of the ageing effects and mechanisms defined for a component, due to changes in the operating conditions of this component or changes in its material and/or specific environment.

For each of the AMP's included in the Overall Ageing Management Programme , the Spanish plants have developed, depending on the structure and degree of implementation of each AMP, the following documents:

- Base document of the AMP, which include its assessment for compliance with the attributes of the equivalent AMP of the NUREG-1801 [25] or with the attributes of the NEI-95-10 [26],
- Ageing Management Programme Manual, and
- Scope of the AMP Manual (this document only in the case of the Ascó and Vandellós II plants).

The following information is included in this documentation, associated with each AMP:

- The frequency of application of the AMP.
- Scope of the AMP (SSC's included within the scope of the AMP).
- Ageing effects/mechanisms managed by the AMP.
- Activities (inspections, tests) included in the AMP (identifying actions, their frequency and acceptance criteria).
- Responsibilities (responsibilities of the organisational unit owning the AMP and of the organisational units collaborating in the AMP).
- Requirements of the documentation on AMP results and the administrative and quality control of AMP activities.
- Relevant operating experience associated with definition of the AMP.

In addition, the Spanish plants draw up AMP tracking reports, the objectives and contents of which is indicated in section 02.4 of this chapter.

Table 02.2, included in the annex at the end of this chapter, shows a list of the AMP's currently in place at the Spanish nuclear power plants and their corresponding NUREG-1801 [25] model programmes. Also shown are the AMP's specific to each plant, which have been drawn up for the management of ageing effects and mechanisms for which there is no model programme in NUREG-1801 [25] and that have been developed in accordance with the criteria of NUREG-1800 [24].

Within their respective OAMP's and related activities, the Spanish plants establish acceptance criteria in accordance with specific regulatory requirements or the requirements set out in the SSC design or maintenance codes, as would be the case, for example, for the criteria applicable to nuclear class components designed in accordance with section III of the ASME Code and subject to inspection under ASME section XI. In other situations the acceptance criteria are defined in accordance with industry standards (for example the EPRI MRP programme applicable to the reactor vessel or internals, for PWR plants, or the BWRVIP programme applicable to the reactor vessel and internals for BWR plants) and the plant-specific operating experience.

Nevertheless, in all cases and as the OAMP's take NUREG-1801 [25] and Guideline NEI 95-10 [26] as the main reference documents, the Spanish plants have performed an assessment of their acceptance criteria for each of the AMP's defined with respect to those indicated in the corresponding model AMP's included in chapter XI of NUREG-1801 [25], verifying equivalence or justifying differences.

Taking this into account, each plant AMP includes acceptance criteria for the inspections required therein. The acceptance criteria are established in such a way as to ensure maintenance of the intended function of the component throughout its operating lifetime, in accordance with the corresponding licensing basis. This is ensured through the following:

- Each inspection procedure (or in its absence the programme itself) defines the acceptance criteria for each parameter monitored.
- The acceptance criteria are established with enough margin to ensure compliance with the intended function of the component.
- If new ageing mechanisms (or mechanisms not expected for a component) are detected, a cause extension analysis is performed in order to determine what other components might be affected by it.

As regards the use of R&D programmes, in Spain there is an association of the main electricity companies, UNESA, which includes those companies that own nuclear power plants. Through UNESA, the nuclear power plant owners and the CSN, as the regulatory authority, established in 2009 the programme named "Collaboration *agreement on between the CSN and UNESA for R&D in relation to nuclear safety and radiological protection*".

Different R&D projects have been carried out within the framework of this collaboration agreement and dealing with the assessment of nuclear power plant SCC ageing, the following projects being particularly significant:

Project	Start-end date	Project objective
Project on crack growth testing in alloy 690TT and weld metals 52/152 (Inconel 690 Project–Phase 2)	2008 - 2011	Acquisition of data on crack growth rates in alloy 690TT and weld metals 52 and 152, in PWR type reactor primary water at temperatures of between 325 and 360 ºC.
Common project for the validation of NDT systems used in ISI at Spanish NPP's	2003 - 2013	Establishment of a coordinated action by all the Spanish NPP's to optimise on the one hand the technical and economic resources to be dedicated to validation and, on the other, the activities to be carried out by organisations involved in the validation of each nuclear power plant.
Computer system for the management of in-service inspections and tests (SIGIS) at Spanish NPP's (SIGIS Project).	2004 - 2010	Unification of Spanish NPP databases and migration of current management tools to a Web environment, this facilitating fast and secure access to these tools/databases for both those responsible for NPP in-service inspections and engineering and the CSN.
Surveillance of electrical cable ageing at nuclear power plants (Cables project - Phase 1)	2002 - 2004	Definition of a common basis for action applicable to all the Spanish nuclear power plants for the systematic application of electrical cable ageing surveillance techniques in accordance with the international state of the art and in particular with the contents of IAEA-TECDOC-1188.
Application of advanced electrical cables diagnosis techniques at Spanish NPP's (Cables project - Phase 2)	2005 - 2009	Fine tuning and application of advanced non-destructive surveillance techniques for determination of the status of cable ageing at Spanish nuclear power plants.

Project	Start-end date	Project objective
Tracking and assessment of the status of electrical cables at Spanish NPP's (Cables project – Phase 3)	2014 – On-going	Determination of the status of electrical cable insulating material at Spanish nuclear power plants, based on the use of the best surveillance techniques available for material diagnosis and supervision. To accomplish this, a representative sample of original cables will be obtained from the plants, affected by quantified natural ageing. The cables will be subjected to additional ageing to the equivalent of 40, 50 and 60 years and to various tests in order to establish, where possible, a correlation between measurable parameters and the actual degree of ageing in the installed cables.
Utilization of vessel internals from the reactor of José Cabrera NPP (ZIRP project).	2007 – On-going	Recovery of part of the vessel internals from José Cabrera NPP for subsequent testing of the extracted materials in the laboratory and assessment of the degradation of their properties, following a long period of radiation in a commercial reactor. The project includes the participation of a number of international organisations; the Spanish plants participate through EPRI.
Study of the effects of ageing and other factors on concretes from José Cabrera NPP (Zorita Concretes Project)	2014 – On-going	Joint project between the CSN, ENRESA, CSIC and the Spanish electricity companies for the experimental and theoretical study of performance in relation to degradation over time of the properties of concrete subjected to the service conditions occurring during nuclear power plant operation.

Project	Start-end date	Project objective
International NEA/OECD project on "Component Operational Experience, Degradation and Ageing Programme (CODAP)", in collaboration with the CSN	2011 – On-going	Development of a database on events associated with the failure of pipes and other passive components, and sharing of know-how and operating experience, understanding of root causes and failure mechanisms and identification of effective techniques and technologies for the management and mitigation of active degradation at nuclear power plants.

Table 02.1. R&D projects performed in collaboration between UNESA and the CSN

The Spanish plants are also active members, through UNESA, in the base activities of the Electric Power Research Institute (EPRI) nuclear area, which include several research programmes, such as Long-term Operation, Primary Systems Corrosion and Plant Engineering that carry out research into the assessment and mitigation of the ageing of different types of SSC's at nuclear power plants. In addition, the plants are involved in various supplementary R&D&i programmes, such as the Boiling Water Reactor Vessel and Internals Project (BWRVIP), the Pressurised Water Reactor Materials Reliability Program (MRP), the Non-destructive evaluation (NDE), the Steam Generator Management Program (SGMP), the Nuclear Maintenance Application Center (NMAC), the Checkworks Users Group (CHUG), etc., which among other aspects cover research into the ageing of components not covered by the previously mentioned EPRI base nuclear programme .

Depending on type and scope, these projects produce experimental results that improve or extend international databases on different phenomena, recommendations, application guides, limit values, new inspection techniques, etc., that are finally incorporated in the AMP's of each plant.

In addition to the aforementioned projects, as has been pointed out in section 02.2 of this report, and without being required by IS-22 [21], the Spanish plants have participated along with the CSN in the first two phases of the IAEA's IGALL programme [40] in which many AMP's have been developed, this having provided the Spanish plants with an additional reference for the development of their own AMP's.

As regards the review of plant-specific and industry operating experience, the objective is to provide support for the conclusions of ageing mechanism assessments and identify other mechanisms not considered in generic assessments and that might be plant specific.

In taking guideline NEI 95-10 [26] as the reference document for the development of the OAMP's, the Spanish plants include the review of plant-specific and industry operating experience in the process of ageing mechanism identification and assessment, considering review periods of from 5 to 10 years, as recommended in the aforementioned guideline NEI 95-10 [26]. Nevertheless, the periods considered in analyses of the operating experience of the nuclear power plants are normally shorter than those recommended by NEI 95-10 [26].

The licensees reviewed their plant-specific operating experience during the OAMP implementation phase by reviewing the results of their maintenance activities and experiences identified at the plants themselves.

The review of industry operating experience was carried out by identifying relevant events relating to the ageing of SSC's issued, among others, by the following:

- the national regulatory authority, the CSN,
- the regulatory authorities of the countries of origin of the plant design, i.e.:
  - the NRC in the case of US technology plants (Almaraz, Ascó, Cofrentes and Vandellós II) or
  - the GRS in the case of German technology plants (Trillo),
- international operator organisations, such as INPO and WANO,
- and the main suppliers of each plant, i.e.:
  - Westinghouse in the case of American PWR technology plants (Almaraz, Ascó and Vandellós II),
  - General Electric in the case of American BWR technology plants (Cofrentes) and
  - Areva in the case of the German PWR plant (Trillo)

The Spanish plants have drawn up technical guidelines or procedures for developing both processes (plant-specific and industry operating experience analyses), these consisting fundamentally of the following:

- An initial identification of potentially significant events on the basis of the operating experience databases available at the plants. This identification includes a check on whether the event has affected a passive system, structure or component or whether it has been caused by the ageing of a structure or component.
- A subsequent assessment or characterisation of significant events. This assessment includes identification of the following:
  - the causes, indicating the ageing mechanism identified in the degradation of the component or structure,
  - the systems involved,
  - the corrective actions adopted or measures for the mitigation and control of deterioration of the component or structure, indicating whether they relate to any plant maintenance or inspection activity,
  - the potentially applicable AMP's for the management of the ageing effects and mechanisms identified.

In accordance with the process indicated in the OAMP's of the Spanish plants, the tracking reports for each AMP currently include the analysis and assessment of the programme results and plant-specific and industry operating experience that has affected the SSC's or activities included within the scope of the AMP during the period covered by the report.

As regards the storage of data and the tracking of historical maintenance and operations information, the processes established for the OAMP ensure that registers, data, trends and other actions are articulated by way of the corrective actions programmes in place at the Spanish nuclear power plants. All actions performed and documents drawn up are being placed on record.

Furthermore, the Spanish plants have developed specific databases for the management of all the information implied in the development of the OAMP. The ageing management database is the basic tool used in the processes of scoping and screening, along with the AMR process, and both its results and the assessments and references of the supporting documentation are recorded.

This databases are used to record the following processes information:

- Scoping process: identification of the systems and structures functions, justification of the application of scoping criteria and reference to the documentation for this justification.
- Screening process: identification of the components subject and not subject to the AMR, along with the corresponding justification.
- AMR process: identification of materials and environments associated with the components subject to the AMR; assignment, in accordance with the materials and environments, of significant ageing effects requiring management on the component or structure; and identification of activities and programmes accredited as being suitable for the management of those significant ageing effects.

02.3.3. Monitoring, testing, sampling and inspection activities

As regards inspection, monitoring and testing activities, in its section on the assessment of maintenance practices, IS-22 [21] identifies, as part of the scope, not only preventive and predictive maintenance activities but also activities relating to inspection, testing, control of operating parameters, etc. that allow for the detection and mitigation of ageing mechanisms that might potentially affect the structures and components included within the scope.

Described below are the aforementioned ageing management activities carried out by the Spanish plants.

In each AMP are defined the parameters to be monitored or inspections to be applied for management of the ageing of components included within its scope. These programmes are implemented by means of procedures already in place at the plant or newly developed activities. The parameters to be monitored in each AMP are directly related to the detection, management and mitigation of those ageing effects that might affect the intended functions of the components managed by the programme. Likewise, the inspections performed in accordance with the procedures included the AMP are adequately documented, including registers of degradations detected.

Described below are some examples of plant activities that periodically verify SSC performance or functionality that might be affected by ageing through tracking of the evolution of indicating parameters relating to ageing processes:

- Tracking of soiling in heat exchangers whose fluid is water in the open essential services circuit: this surveillance is performed on-line and the tracking of this trend makes it possible to determine what additional cleaning and inspection actions might be required.
- Primary containment leak testing: this is performed in compliance with the requirements of Appendix J of 10 CFR 50; the results of type A and type B tests allow for an assessment of the primary containment and its penetrations.
- Piping system pressure testing: these are performed at the frequency required by the standards and makes it possible to identify system leakages due to the failure of components at bolted joints in the system.
- Tracking of electrical parameters (insulation resistance, delta tangent, etc.) in electrical circuits: this allows for the identification of degradations in the insulation of electrical cables and connections.
- In the case of Cofrentes NPP, and as its compressed air system is safety-related, the quality of the air in this system is monitored through measurement of relative humidity and the presence of particles, this allowing the susceptibility of the system to corrosion mechanisms to be detected.

In each of the AMP's developed, the plants define the tests and inspections to be performed in order to promptly detect ageing effects that might lead to loss of the intended function of structures and components. Although the intention of the programmes is to promptly detect degradations potentially affecting the components, it should be pointed out that they do not always constitute a tool that guarantees the capability to anticipate all losses of the intended function of the structures and components. Likewise, whenever the programme so requires, the preventive actions to be taken to prevent the development of ageing effects are defined.

The most of ageing management activities are associated with inspection programmes in which the condition of the component or structure is verified by non-destructive testing (visual, surface or volumetric). At the Spanish nuclear power plants these activities are mainly included in the following programmes:

- <u>In-Service Inspection Programme</u>: This programme mainly includes inspections defined for compliance with the requirements of section XI of the ASME Code. This code defines both the scope and type of the examination (visual, surface or volumetric) and its frequency. Within the OAMP's of the Spanish plants, the in-service inspection programme includes ageing management activities associated with the reactor vessel, class 1, 2 and 3 piping systems, class 1, 2 and 3 pressure boundary mechanical equipment, class 1, 2 and 3 piping supports, metallic containment (where appropriate), concrete containment and containment penetrations.

- Vessel internals programme: This programme includes activities for the inspection and assessment of the condition of the vessel internals, in accordance with the inspection and assessment guidelines of the EPRI MRP programme, in the case of PWR technology plants (Almaraz, Ascó and Vandellós II), and the BWRVIP programme, also developed by EPRI, for BWR plants (Cofrentes). In the case of Trillo NPP, the guidelines adhered to for development of the vessel internals programme are based on the recommendations included in KTA-3204.
- Erosion-corrosion programme: This programme is aimed at controlling the condition of piping systems potentially affected by the mechanism of flow accelerated corrosion (FAC) and erosion-corrosion, with a view to determining if the degradation rate of the component will allow it to maintain its intended function until it is re-inspected. The inspections programme is defined as a result of the assessments/predictions of previous measurements and the examination is of the volumetric type (Ultrasonics (UT)).
- Structures surveillance programme: This programme is based on the Maintenance Rule activities and is based mainly on visual inspections, also including dimensional and volumetric examinations suitable for the potential ageing mechanisms.
- Painting and coatings inspection inside Containment: The scope of this programme includes Service Level I coatings, defined in the NRC Regulatory Guide 1.54. The inspection of the coatings is defined in accordance with the requirements of ASTM D 5163-96, sub-paragraph 9.2, where it is established that the parameters monitored or inspected shall be “visible defects such as blistering, fissures, flaking, peeling, oxides or physical damage”.

In those cases in which the programme requires an analysis of trends, this is carried out as part of the programme activities. The aim of this analysis is to establish trends allowing degradations to be anticipated, through study of the parameters inspected/monitored by the programme, the ultimate objective being to allow actions to be taken before loss of the intended function occurs.

Through their surveillance activities the plants periodically verify parameters that are not directly associated with the condition of the structure or components but that provide a measurement of the factors influencing their degradation. The following are included among these activities, within the plants’ OAMP’s:

- Chemical control programme: The surveillance and maintenance within the corresponding acceptance criteria of the chemical parameters included in the specifications of water and other process fluids, such as gas-oil and oil, is an activity aimed at preventing corrosion mechanisms arising as a result of contact between the material and the process fluid. The Spanish plants have procedures identifying the parameters that characterise each fluid specification and the analytical methods and frequencies, in order to verify that they are within the target or foreseen values.

- Environmental conditions surveillance programme: Defined mainly for control of the environmental qualification of electrical components, this programme makes it possible to assess the actual environmental conditions of the equipment compared to those considered in its environmental qualification process. The surveillance of environmental conditions is characterised by the temperature and radiation measured in certain areas, and data acquisition is conditioned by accessibility to these areas.
- Tracking of operational transients in Class 1 pressure-retaining components: ASME class 1 components are designed, in relation to fatigue, in such a way that their cumulative usage factor is less than 1 under the hypothesis of a series of operating transients and an occurrence defined for 40 years. The transient tracking programme allows for assessment of the actual operation of the plant compared to the design hypotheses, in order to ensure that the usage factor, according to the design bases, will remain less than 1.0.

Many of the structures and components included within the scope of the OAMP's of the Spanish plants are subject to preventive maintenance activities, which include inspection procedures allowing for verification of the condition of the passive elements of which they are formed, as well as identification of whether there have been unexpected degradations.

Among the types of components subject to this type of maintenance are pumps, heat exchangers, tanks, turbines, ventilation units, water cooling units, metal enclosed phase busses, cranes and fuel handling equipment.

In all cases, whenever an inspection, monitoring or surveillance activity leads to the detection of degradation, appropriate actions (repair, replacement...) are taken before the intended function of the component is lost, in accordance with the corrective actions defined in the AMP.

Furthermore, when the AMP requires an inspection by sampling, the locations selected for inspection shall be those that are more susceptible to the ageing mechanism that might affect the component. In the event of degradation being detected in the component inspected from the selected sample, the number of inspections shall be increased in order to rule out the possibility of degradations occurring in similar locations (e.g., Buried piping programme, cable surveillance programme).

As regards activities performed by certification organisations, the inspection, surveillance and monitoring activities included in the Overall Ageing Management Programmes of the Spanish plants, as well as other activities at these facilities, are generally subject to the Quality Assurance Manual of each plant. Consequently, the OAMP is subject to internal audits, in addition to CSN inspections, the participation of other certification organisations not being required except when this is demanded by other licensing requirements associated with these activities (such as for example the specific certification of inspectors).

02.3.4. Preventive and remedial actions

If a programme requires preventive actions, these are implemented in order to prevent or mitigate the ageing mechanisms to which the structures and components (S&C) are susceptible. The implementation of preventive actions includes the following:

- When a programme improvement is identified, this is included in the corrective action management system of the Spanish plants and, as a result, is implemented in the corresponding procedure.
- Within the action management system of the Spanish plants, each improvement action to be carried out is assigned to a responsible person or manager and a performer, such that correct implementation of the improvement identified is achieved.
- The preventive activities implemented in the AMP's are performed in accordance with the frequencies required by each programme. In the event of the activity not being carried out with the required frequency, the corresponding justification is provided during the programme implementation review.

All corrective actions on S&C are performed by way of work orders and are controlled from beginning to end by the maintenance management system, which is also subject to the requirements of the Quality Assurance Manual of the Spanish nuclear power plants, which fulfil the provisions of Appendix B of 10 CFR 50.

Furthermore, if there is a loss of intended function, an analysis is carried out on what has failed in the systematic approach of the AMP that managed the unexpected event or problem and improvements are introduced to attempt to prevent this from re-occurring.

02.4. Review and update of the overall AMP

As has been commented in the previous section of this report, the Overall Ageing Management Programmes are subject to the Quality Assurance Manual of each plant, for which reason they are periodically subjected to internal audits, the results of which are implemented in the OAMP.

Another reason for reviewing and updating the OAMP is the review of the plant-specific and industry operating experience, the objective being to analyse all applicable events relating to ageing management, for example supporting the conclusions of the assessment of ageing mechanisms and identifying others mechanisms not considered in generic assessments and that might be specific to the plant.

The results of this operating experience review are included in specific reports that are periodically issued by the plants.

These operating experience results are analysed to determine their applicability to the different AMP's in the corresponding tracking reports, for updating in this respect.

In addition, the results of applying the AMP activities are analysed in order to determine if they are effective and, if this is not the case, a decision is taken as to the need for proposals regarding the improvement of these activities or the management of effects and mechanisms not previously considered. These improvement proposals are analysed and, where appropriate, are approved by the Ageing Management committee prior to their implementation.

The Spanish plants periodically update the reports documenting the systems and structures included in the scope of the OAMP, taking into account the design modifications (DM) carried out during the period covered by this updating. Following the identification of new SSC's arising as a result of DM performance, the scoping and screening criteria included in IS-22 [21] are applied in order to determine which should be included in the OAMP.

Subsequently, following identification of the new S&C incorporated in the scope of the OAMP as a result of design modifications, the AMR process described in section 02.3.2 of the present report is repeated with respect to them; i.e., the identification of materials and the environments to which they are exposed, the identification of significant ageing mechanisms and effects and the assignment of the AMP's needed for their management.

In addition to the updating process described above, during the development of a design modification and prior to its implementation, the Cofrentes, Ascó and Vandellós II plants analyse its potential impact on the OAMP.

As regards the assessment of the time-limited ageing analyses (TLAA), and for the first application for renewal of the operating permit beyond the period of the design lifetime, IS-22 [21] requires the plant licensees to identify all the analyses and calculations performed that meet the following conditions:

1. They are related to the structures, systems and components (SSC) considered within the scope of ageing management.
2. They take into account the effects of ageing over time.
3. They maintain limited design lifetime hypotheses.
4. They conclude with the existence or not the SSC'S capability to continue to operate in accordance with their defined functions after having exceeded the limited design lifetime hypotheses.
5. The calculation or analysis was considered to be relevant by the licensee in a safety assessment.
6. The calculation or analysis is part of the current licensing basis of the facility.

The assessment of TLAA shall be accomplished, according to IS-22 [21], using one of the following methods:

- Verification that the current analyses and calculations continue to be valid for the new operating period requested and that, consequently, the performance of a new analysis is not required.
- Re-assessment of the current analyses and calculations for the new operating period requested and verification that the acceptance criteria established are met.
- Demonstration that the ageing effects may be managed adequately during the new operating period requested by means of an ageing management programme.

Chapter X of NUREG-1801 [25] provides the programmes that may be used to manage the TLAA's identified in the American industry. However, for those TLAA identified by the licensees as being specific to their plants, the guidelines established in NUREG-1800 [24] and NEI-95-10 [26] should be followed.

Furthermore, as part of the development and subsequent updating of an AMP, the Spanish plants assess the results of R&D programmes and the current state of the art of the inspection techniques applied within the framework of the programme to ensure that the best available techniques are used.

The Spanish plants have also reviewed and updated their OAMP's as a result of changes in the regulatory framework. In fact, the Spanish plants initially have developed their OAMP's in accordance with revision 1 of NUREG-1801, in the year 2005. This NRC report have been updated to revision 2 in 2010, taking into account both the American and international operating experience, fundamentally that of the NEA.

Subsequent to this edition 2 of NUREG-1801, the NRC has issued License Renewal Interim Staff Guidance documents that continue to modify or update the contents of the aforementioned revision 2 of NUREG-1801.

In accordance with the CSN requirements, the Spanish nuclear power plants have updated their OAMP'S in order to adapt to the contents of the aforementioned documents, such that they are currently updated in keeping with the regulatory framework.

As regards identification of the need for additional research and development, in response to CSN requests, the Spanish nuclear sector participates in the Technical Group for R&D&i initiatives in relation to unforeseen degradation phenomena, the objective of which is to respond to the resolution of the Spanish Congress regarding improved understanding of degradation phenomena not initially expected.

Furthermore, the Spanish plants continue to participate as full members in the EPRI Nuclear Programme through UNESA. This participation provides access to the projects and products that are considered to constitute the "basis" of the Action Plans that make up the said Nuclear Programme, which are as follows:

- Material degradation and ageing.
- Fuel reliability.
- Management of high-level radioactive waste and spent fuel.
- Non-destructive testing (NDT) and materials characterisation.
- Equipment reliability.
- Instrumentation and control.
- Safety and risk-related technologies and their applications.
- Low-level radioactive waste and radiation management.

More than one hundred “supplementary” projects are performed within the framework of the EPRI Nuclear Programme, UNESA having participated in eighteen (18) of these in 2015.

As regards OAMP updates as a result of the PSR’s, the Spanish plants also carry out an analysis of the corresponding ageing management in accordance with the CSN safety guide GS-1.10 [22], as has been explained in section 02.1 of the present chapter. An update of the OAMP’s will also be carried out as a result of the activities for preparation of the supporting documentation for long-term operation.

Regarding the incorporation of new or unexpected issues in the AMP’s results, and as has been pointed out in section 02.3.3 of the present report, whenever a case of unexpected degradation is detected during an inspection activity, appropriate actions (repair, replacement...) are taken before the intended function of the affected component is lost, in accordance with the corrective actions defined in the programme.

Likewise, if the intended function of a component is lost, an engineering assessment is performed and the actions to be taken are determined for future incorporation as AMP improvement proposals.

According to the concept of NUREG-1800 [24], once implemented the AMP’s should not become static entities but rather learn over time from the experience acquired in their application; in other words, the AMP activities and results should be monitored and attempts made to improve it, adapting it to the specific circumstances of the plant where needed. Improvement of the AMP requires feedback on whether or not there is timely prevention and detection of ageing effects and on the implementation of the corrective actions derived from the AMP.

As regards the periodic assessment and measurement of the effectiveness of ageing management, the plants draw up periodic tracking reports for each AMP, depending their frequency on the AMP’s activities’ implementation frequency. The results of the AMP’s activities and its assessment are collected in the tracking reports, as well as the identification and assessment of the plant-specific and industry operating experience that could affect the AMP.

With regard to the effectiveness of the processes, it should be pointed out that at all the Spanish plants the effectiveness of the OAMP’s is measured by means of specific indicators at each plant through tracking and assessment of the activities defined in the AMP's.

These indicator take into account both whether the AMP activities are performed or not, and the results of these activities and the impact of the operating experiences related to the AMP.

02.5. Licensee's experience of application of the overall AMP

Since the 1990's, the "ageing management" has led to a series of recurrent activities at the Spanish plants, these having arisen both from the operation of the plant itself and in order to respond to the regulatory requirements. These requirements were initially established on the basis of the specific conditions set out in the operating permits and later, as from 2009, in CSN Instruction IS-22 [21].

The main objective of the first ageing management activities applied by the Spanish plants was to keep open the option of extending operation beyond the foreseen design lifetime, with approaches similar to those implemented at US pilot plants for the application of 10 CFR 54 [23]. This gave rise to the development, with UNESA sponsorship, of an ageing management methodology inspired mainly by American experience. On the basis of this UNESA methodology the Spanish plants developed their first generic ageing management programmes, known as "Overall Ageing Management Programmes", through which OAMP's they also responded to the requirements of the regulatory authority.

The aforementioned UNESA methodology was made up of the following phases:

- Phase I

  Identification of structures, systems and components providing an ordered list of components important for ageing management and allowing efforts to be focussed on those components that are considered to be critical for ageing management, either because of their safety significance, the difficulty or cost of their replacement or their higher risk of degradation.

- Phase II

  Performing of specific studies to identify the main degradation phenomena affecting components important for ageing management, along with factors influencing the severity of the degradation.

- Phase III

  Review and optimisation of ageing tracking methods, with a view to mitigating the degradation phenomena identified. The condition of components of importance for ageing management is analysed in detail in order to optimise maintenance practices, taking into account susceptibility to certain degradation phenomena, the methods that may be used to control this degradation and the plant procedures.

- Phase IV

  Tracking of component and structure ageing.

- Phase V

  Programme of technical-economic actions for proposals regarding ageing management improvements, modification of operations, the optimisation of equipment maintenance, modernisation or repair of equipment, etc. These programmes also consider the optimum moment for the performance of the different actions.

In 2003 the decision taken by NUCLENOR, the licensee of Santa María de Garoña NPP, to include a technical justification for long-term operation in the application for its next operating permit, supported by compliance with the requirements of 10 CFR 54 [23] and the methodology in use for this purpose in the USA, constituted a milestone in reconsideration of both the methodology used by the Spanish plants for ageing management and the establishment of regulatory criteria for ageing management and long-term operation, this being defined in 2009 with the publishing by the CSN Instruction IS-22 [21].

Later, following development of the methodology for ageing management by the Spanish plants and the initial implementation of the corresponding AMP's, difficulties arose in in-plant control or tracking these AMP's due to the large number of inspection, control and monitoring activities involved. For this reason the licensees have updated their organisations, adapting them to this new reality, defining new organisational structures responsible for activities relating to ageing management and the development of tools such as databases.

Set out below are some examples of the experience of each of the Spanish plants in application of the Overall Ageing Management Programme:

- Almaraz and Trillo NPP's

  The Almaraz and Trillo plants developed their initial Overall Ageing Management Programmes over several years in accordance with the aforementioned UNESA methodology, developing the documents "Degradational Phenomena Studies" (DPS) and "Maintenance Practices Studies" (MPS) by types of components on the basis of guidelines developed by UNESA.

  <u>Change of methodology at Almaraz and Trillo NPP's</u>

  In September 2005, the CSN issued a series of Complementary Technical Instructions (CTI) for the Almaraz and Trillo plants on analysis of the applicability of the essential service water system degradation event that had taken place at Vandellós II NPP that same year. In one of these CTI's the CSN requested a review of the Overall Ageing Management Programme to verify that no safety-related SSC ageing effect had been overlooked, thereby guaranteeing the adequate management of all such ageing effects.

In response to this request, the Almaraz and Trillo plants carried out a systematic review of their OAMP’s, with the identification of ageing mechanisms and effects based on use of the methodology applied by the American plants to prepare their license renewal requests in accordance with 10 CFR 54 [23] and guideline NEI 95-10 [26].

This methodology was subsequently endorsed by the CSN with the publication in July 2009 of Instruction IS-22 [21], which is currently the Spanish nuclear industry reference for ageing management, both during the design lifetime of the facilities and for long-term operation. This first work for adaptation to the new methodology was completed in March 2007.

In this way, by changing the methodology to be adhered to in ageing management, the Almaraz and Trillo plants adapted their OAMP’s to the CSN requirements regarding the management of ageing and compliance with IS-22 [21].

Subsequently, during the period 2007 to 2009, the Almaraz and Trillo plants continued to carry out different tasks relating to their OAMP’s, such as the formalisation of the AMP and the updating of the ageing effects review.

From 2010 to 2016 the Almaraz and Trillo plants performed different tasks within the framework of their OAMP’s, such as the following:

- Complete review of their scope, in accordance with the criteria of IS-22 [21], undertaking the publishing of the specific reports on scoping and screening by systems, including the corresponding limits drawings and complete updating of the ageing effects review, taking into account the latest revision of NUREG-1801 [25].
- First systematic review of the plant-specific and industry operating experience in 2010 and subsequent updates in 2012, 2014 and 2016.
- Completion of the formalisation of all the plant AMP’s with the publishing of their corresponding manuals.
- Since late 2011 there has been tracking of the implementation and performance of the programmes at the plant.

The Almaraz and Trillo plants continue keeping their OAMP’s updated and implemented at their facilities, compiling and evaluating the results of the activities performed within the framework of their AMP’s.

Since 2015 in the case of Almaraz NPP and since 2016 in the case of Trillo, work has been performed on the review and updating of the OAMP’s in order to adapt to the new requirements defined in the NRC’s LR-ISG documents.

- Ascó and Vandellós II NPP’s

In this area the Ascó and Vandellós II nuclear power plants carried out the first phase of the named “System for the Assessment of Remaining Lifetime at LWR NPP’s” project during the years 1992 and 1994, establishing an ageing management methodology using Santa María de Garoña NPP (BWR) and Vandellós II NPP (PWR) as pilot plants.

At the Ascó and Vandellós II plants, prior to the issuing of IS-22 [21], in 2009, ageing management activities were performed, adapting the methodology established for the "Equipment Reliability" (ER) process, developed subsequent to the issuing of the document INPO-AP-913 in 2002. This document constitutes the response of the American nuclear industry to equipment and materials-related problems within the framework of the NEI Standard Nuclear Performance Model (SNPM).

Following the issuing of IS-22 [21], the obligation to develop the OAMP in accordance with the American model was established (section 5.2 of the instruction), for which reason the Ascó and Vandellós II plants migrated toward this standard and have been acting in accordance with it since the entry into force of CSN instruction IS-22 [21].

Since that time, various OAMP reviews, technical guidelines and the general procedure regulating implementation in the different divisions of the organisation have been issued. Recently, the NRC LR-ISG documents content have been incorporated in the OAMP as part of the project's continuous updating process.

- Cofrentes NPP

  Cofrentes NPP issued the first edition of its Overall Ageing Management Programme in 1996, on the basis of the UNESA methodology, and since 1998 has been issuing an annual report on ageing management activities, in accordance with the requirements established by the CSN. The most relevant milestones occurring to date within this process of evolution as regards application of the OAMP have been as follows:

  - In 2008, Rev. 8 of the "Overall Ageing Management Programme" was published, adapting the UNESA methodology to the experience of license renewal request applications in the USA.
  - In 2010, Rev. 9 of the "Overall Ageing Management Programme" was published, defined for compliance with the requirements of IS-22 [21].
  - In 2010, Rev. 0 of the general procedure "Development of the Cofrentes NPP Overall Ageing Management Programme" was published, documenting the implementation of the OAMP in the organisation of Cofrentes NPP and developing AMP effectiveness indicators.
  - In 2011, the periodic issuing of AMP tracking reports began, the results being incorporated in the "Annual Ageing Management Activities Reports" required by the CSN.
  - In 2014, in view of the foreseen long-term operation, the IPA project was defined for performance of the activities required for its preparation, including the drawing up of the corresponding Implementation Methodology document, in order to verify the requirements established in IS-22 [21] for long-term operation.

- In 2016, review of assessment of the AMP with respect to the model programmes (AMP) included in chapter XI of NUREG-1801 Rev.2 [25], in order to take into account the LR-ISG's issued by the NRC from 2011 (date of issue of Revision 2 of NUREG-1801 [25]) to December 2016.

02.6. Regulatory oversight process

In Instruction IS-22 [21] the CSN establishes the following requirements regarding the information on ageing management to be provided by the Spanish plants for supervision:

- Within the design lifetime period.
  - Every year a report describing the activities performed during the previous year within the framework of the Overall Ageing Management Programme, in reference to the surveillance, control and mitigation of SSC ageing mechanisms within the scope of IS-22 [21].
  - As part of the documentation relating to the PSR, an analysis of the ageing processes that have occurred in the plant, using the information available in the OAMP updates developed over the ten-year period covered by the PSR.
- For the application of the operating permit for long-term operation.
  - Integrated Plant Assessment (IPA).
  - Proposal for a supplement to the Final Safety Analysis Report, to include studies and analyses justifying the long-term operation of the plant.
  - Proposal for revision of the Technical Specifications, to include the changes needed to maintain safe operating conditions during long-term operation of the plant.
- During the period of long-term operation.
  - An annual report setting out the activities of the Long-Term Overall Ageing Management Plan (LT-OAMP) performed during the previous year, in reference to the surveillance, control and mitigation of SSC ageing mechanisms within the scope of IS-22 [21].

Furthermore, in Spain, ageing management is also included in the Integrated Plant Supervision System (IPSP), as a result of which every 2 years the CSN performs a periodic inspection within the Basic Inspection Plan.

On these inspections performed on each plant, the OAMP implementation and development status is reviewed, in accordance with the provisions of the CSN internal procedure PT.IV.223, "Ageing management of nuclear power plant components and structures (inspection activities)". Additionally, CSN perform assessment on ageing management in accordance with its internal procedure PT.IV.105, "Ageing management of nuclear power plant components and structures (assessment activities)" and assessments resulting from the PSR's information submitted to date in accordance with section 5.2 of Safety Guide GS-1.10 prior to the revision in force.

Furthermore, as has been pointed out throughout the present report, in the annual reports submitted by the licensees to the CSN, the plants identify the commitments made during the CSN inspections, in order to facilitate their tracking.

02.7. Regulator's assessment of the overall ageing management programme and conclusions

Regarding to the process of developing the Overall Ageing Management Programme described in this chapter, the CSN considers that the methodology applied by the Spanish plants fulfils the requirements of IS-22 [21] for activities relating to the identification of the structures and components within the scope of the OAMP, the identification of their significant ageing mechanisms and effects and the development of the AMP's required for their mitigation and control, and that furthermore it is correctly documented, as a result of which the process is considered to be adequate.

As the regulatory authority, the CSN reviews the nuclear power plant OAMP's during the two-yearly inspections performed as a result of the CSN Basic Inspection Plan. For this purpose the CSN has developed specific procedures for the performance of inspections and assessments of the ageing management activities on components and structures at the Spanish plants, PT.IV.223 "Ageing management of nuclear power plant components and structures (inspection activities)" [41] and PT.IV.105 "Ageing management of nuclear power plant components and structures (assessment activities)" [42] respectively.

In addition to these CSN inspections, the licensees' OAMP's are subject to internal audits arising from their in-plant Quality Assurance programmes.

The findings, possible improvements and commitments acquired as a result of the CSN inspections and internal audits are incorporated in the corrective actions programmes of the Spanish plants and documented in the annual reports submitted to the CSN during the first six months of the year. This provides traceability of their resolution in the manner and within the period foreseen or of possible deviations in the term for resolution.

The following are considered to be positive aspects (strengths) of the LMP development process performed by the Spanish plants:

- Special mention might be made of the specific organisational structure put into place by the licensees for plant ageing management. The key element on which this organisation is based is the multidisciplinary Ageing Management Committee, which provides for effective communications between the different departments involved in ageing management, this being fundamental for the correct implementation and follow-up of all the numerous activities that make up the more than forty AMP's in place at the Spanish plants. Another important element is the person responsible for the implementation of these programmes at the plant, for closer tracking of all the activities to be carried out with each AMP.

- Value is attached to the creation of databases developed by the licensees for management of the entire overall ageing management programme process.
- Likewise, the CSN values the development of technical guidelines defining the methodology to be applied for performance of the different tasks involved in ageing management: scoping and screening, AMR process, OE application, development of AMP manuals, drawing up of AMP follow-up reports, etc.
- In the case of the Cofrentes, Ascó and Vandellós II plants, the CSN values the performance of preliminary AMP scope modification analyses during DM development; i.e., all plant DM's will be studied from the point of view of its impact on the AMP's (changes in scope or new materials) prior to implementation.
- Also valued by the CSN are the creation of programme effectiveness indicators, which are used for periodic quantitative and qualitative assessment of the effectiveness of each AMP, and therefore the OAMP.
- Also worthy of mention is the tracking of the AMP activities performed by the plants by drawing up periodic AMP implementation reports.

In conclusion, the CSN considers that the Overall Ageing Management Programmes currently implemented are adequate to ensure management of the ageing of all the SSC's at the Spanish plants.

ANNEX TO CHAPTER 02

Spanish NPP AMP	Model AMP from NUREG-1801	Applicability	Notes
Class 1, 2 and 3 components' in-service inspection	XI.M1 ASME Section XI Inservice Inspection, Subsections IWB, IWC, and IWD	All plants	
Water chemical control	XI.M2 Water Chemistry	All plants	
Reactor Vessel Head Closure Stud Bolting inspection	XI.M3 Reactor Head Closure Stud Bolting	All plants	
Assessment and inspection of the defects on the attachment weld to the internal Surface vessel	XI.M4 BWR Vessel ID Attachment Welds	Cofrentes	
Feedwater nozzle in-service inspection	XI.M5 BWR Feedwater Nozzle	Cofrentes	
Control Rod Drive return line nozzle in-service inspection	XI.M6 BWR Control Rod Drive Return Line Nozzle	Cofrentes	
Stress corrosion cracking control and mitigation (Nureg 0313 / BWRVIP-75)	XI.M7 BWR Stress Corrosion Cracking	Cofrentes	
Vessel penetrations in-service inspection (BWRVIP)	XI.M8 BWR Penetrations	Cofrentes	
Vessel internals (BWRVIP)	XI.M9 BWR Vessel Internals	Cofrentes	
Boric acid corrosion programme	XI.M10 Boric Acid Corrosion	All plants except Cofrentes	Only applicable to PWR type.
Nickel-alloy components and surfaces near to parts from the primary circuit made of carbon Steel inspection	XI.M11B Cracking of Nickel-Alloy Components and Loss of Material Due to Boric Acid-Induced Corrosion in Reactor Coolant Pressure Boundary Components (PWRs only)	All plants except Cofrentes	Only applicable to PWR type.

Spanish NPP AMP	Model AMP from NUREG-1801	Applicability	Notes
Thermal Aging Embrittlement of Cast Austenitic Stainless Steel (CASS)	XI.M12 Thermal Aging Embrittlement of Cast Austenitic Stainless Steel (CASS)	Almaraz and Cofrentes	Ascó, Trillo and Vandellós II do not have components within the scope of this programme. In Cofrentes, the inspections required to the components within the scope of this programme are considered within the in-service inspection programme.
Vessel internal programme (PWR)	XI.M16A PWR Vessel Internals	All plants except Cofrentes	Considers LR-ISG-2011-04. In the case of Trillo, KTA-3204 recommendations are taken into account.
Flow-accelerated corrosion programme (FAC)	XI.M17 Flow-Accelerated Corrosion	All plants	Considers LR-ISG-2012-01
Bolting integrity programme	XI.M18 Bolting Integrity	All plants	
Steam generators programme	XI.M19 Steam Generators	All plants except Cofrentes	Considers LR-ISG-2011-02 and LR-ISG-2016-01. Only applicable to PWR type.
Open-cycle cooling water systems	XI.M20 Open-Cycle Cooling Water System	All plants	
Closed-cycle cooling water systems	XI.M21A Closed Treated Water Systems	All plants	
Cranes and refueling handling equipment	XI.M23 Inspection of Overhead Heavy Load and Light Load (Related to Refueling) Handling Systems	All plants	

Spanish NPP AMP	Model AMP from NUREG-1801	Applicability	Notes
Compressed air system monitoring	XI.M24 Compressed Air Monitoring	Cofrentes	Only in Cofrentes the compressed air system is related to safety, and therefore is within the scope of the OAMP. In the rest of the Spanish nuclear power plants, this system is not related to safety, and therefore this AMP is not applicable.
	XI.M25 BWR Reactor Water Cleanup System	Cofrentes	Not applicable because it has been verified that the pipes, beyond the second isolating valve are mostly made of carbon Steel, and therefore, they are considered not to be susceptible to IGSCC under the reactor water conditions. The piping of this system in Cofrentes within the scope of the OAMP are treated in other AMP’s, such as in-service inspection, etc.
Fire protection (dry)	XI.M26 Fire Protection	All plants	
Fire protection (water)	XI.M27 Fire Water System	All plants	Considers LR-ISG-2012-02
Aboveground metallic tanks	XI.M29 Aboveground Metallic Tanks	All plants	Considers LR-ISG-2012-02
Fuel oil chemistry control	XI.M30 Fuel Oil Chemistry	All plants	

Spanish NPP AMP	Model AMP from NUREG-1801	Applicability	Notes
Reactor vessel surveillance	XI.M31 Reactor Vessel Surveillance	All plants except Trillo	In Trillo there was a vessel material irradiation tracking programme according to the KTA-3203, which ended in November 1991 when it was demonstrated that after 32 EFPY the limits established in the standards would not be achieved.
One-time inspections	XI.M32 One-Time Inspection	All plants	
Selective leaching programme	XI.M33 Selective Leaching	All plants except Trillo	Considers LR-ISG-2015-01
One-time inspection of small Class 1 piping inspections	XI.M35 One-Time Inspection of ASME Code Class 1 Small Bore-Piping	All plants	
External surfaces monitoring	XI.M36 External Surfaces Monitoring of Mechanical Components	All plants	Considers LR-ISG-2012-02
"Thimbles" inspection	XI.M37 Flux Thimble Tube Inspection	All plants except Trillo and Cofrentes	Not applicable to Cofrentes because of being a BWR type. Not applicable to Trillo because of not having “thimbles” and using another system named “aeroball” to accurate determine the core power distribution

Spanish NPP AMP	Model AMP from NUREG-1801	Applicability	Notes
Internal surfaces inspection	XI.M38 Inspection of Internal Surfaces in Miscellaneous Piping and Ducting Components	All plants	Considers LR-ISG-2012-02
Oil physiochemical monitoring	XI.M39 Lubricating Oil Analysis	All plants	
Monitoring of Neutron-Absorbing Materials Other than Boraflex	XI.M40 Monitoring of Neutron-Absorbing Materials Other than Boraflex	All plants except Cofrentes	
Buried and inaccesible piping surveillance and inspection.	XI.M41 Buried and Underground Piping and Tanks	All plants	Considers LR-ISG-2015-01
Containment in-service inspection (metallic)	XI.S1 ASME Section XI, Subsection IWE	All plants	
Containment in-service inspection (concrete)	XI.S2 ASME Section XI, Subsection IWL	All plants except Trillo	
Supports inspection	XI.S3 ASME Section XI, Subsection IWF	All plants	
Leakage containment test	XI.S4 10 CFR 50, Appendix J	All plants	
Masonry walls programme	XI.S5 Masonry Walls	All plants	
Structures monitoring	XI.S6 Structures Monitoring	All plants	
Hydraulic structures inspection	XI.S7 RG 1.127, Inspection of Water-Control Structures Associated with Nuclear Power Plants	All plants	
Paintings and coatings programme	XI.S8 Protective Coating Monitoring and Maintenance Program	All plants	

Spanish NPP AMP	Model AMP from NUREG-1801	Applicability	Notes
Electrical cables monitoring	XI.E1 Insulation Material for Electrical Cables and Connections Not Subject to 10 CFR 50.49 Environmental Qualification Requirements	All plants	
Instrumentation cables monitoring	XI.E2 Insulation Material for Electrical Cables and Connections Not Subject to 10 CFR 50.49 Environmental Qualification Requirements Used in Instrumentation Circuits	All plants	
Inaccessible power cables monitoring	XI.E3 Inaccessible Power Cables Not Subject to 10 CFR 50.49 Environmental Qualification Requirements	All plants	
Metal-enclosed busses monitoring	XI.E4 Metal-Enclosed Bus	All plants except Trillo	
Fuse holders inspection	XI.E5 Fuse Holders	Cofrentes	Almaraz, Ascó, Trillo and Vandellós II do not have components of this kind within the scope of this programme
Electrical cable connections not subject to environmental qualification requirements monitoring	XI.E6 Electrical Cable Connections Not Subject to 10 CFR 50.49 Environmental Qualification Requirements	All plants	
Fatigue management programme	X.M1 Fatigue Monitoring	All plants	TLAA
Tendon containment management programme	X.S1 Concrete Containment Tendon Prestress	Ascó and Vandellós II	TLAA

Spanish NPP AMP	Model AMP from NUREG-1801	Applicability	Notes
Environmental Qualification	X.E1 Environmental Qualification (EQ) of Electric Components	All plants	TLAA
Isolators monitoring programme		Almaraz	Plant specific programme
Air conditioners monitoring		Almaraz, Trillo and Ascó	Plant specific programme
Ascó II Ground movements monitoring		Ascó	Plant specific programme
Surveillance of high voltage insulator and transmission conductors		Ascó and Vandellós II	Plant specific programme
HCU discharge lines inspection		Cofrentes	Plant specific programme
Turbine monitoring		Cofrentes	Plant specific programme
Heat exchangers' tube bundles inspection		Cofrentes	Plant specific programme
Drywell stainless Steel surfaces monitoring		Cofrentes	Plant specific programme
Diesel generators' auxiliary systems monitoring		Cofrentes	Plant specific programme
Essential water cooling units monitoring		Cofrentes	Plant specific programme
Sampling panels monitoring		Cofrentes	Plant specific programme

Table 02.2: Ageing Management Programmes of the Spanish Nuclear Power Plants

03. Electrical cables

03.1. Description of ageing management programmes for electrical cables

As has been pointed out in previous chapter 02 of this report, various programmes are in place at the Spanish nuclear power plants for management of the ageing of passive and long-lived components. Some of these programmes relate specifically to electrical cables.

The process of definition and the main characteristics of these programmes are described in the following sections of this chapter.

03.1.1. Scope of ageing management for electrical cables

The process of defining the scope of the electrical cable ageing management programmes (AMP) at the Spanish nuclear power plants begins with identification of the structures, systems and components (SSC) included in the Overall Ageing Assessment Program (OAMP) of each plant due to their fulfilling the scoping criteria defined in CSN Instruction IS-22 [21], these being detailed in section 02.3.1 of this report. These scoping criteria are consistent with those described in 10 CFR 54.4.

The initial scope of cables requiring ageing management includes, all cables associated to the components of the electrical and mechanical systems indicated in the previous paragraph and that participate in their safety functions. These cables must also comply with their intended functions.

According to what is established in documents NEI 95-10 [26] and EPRI-1013475 [28], the intended functions identified for electrical cables are the following:

- Electrical Insulation: the provision of electrical insulation to prevent short-circuiting, grounding losses or unacceptable leakage of current.
- Electrical Connection: the provision of an electrical connection to a given section of an electrical circuit to supply the rated voltage and current.

The aforementioned intended functions are performed by the insulating material of the electrical cable conductors and by the devices connecting them to the different items of equipment.

The ageing induced degradation of cable insulations and connecting devices may lead to loss of their intended functions, for that reason these elements must be subjected to an Ageing Management Review (AMR) process. Cable jackets and shielding serve only to protect the insulation, as a result of which they do not participate in the intended function of the cable and do not require this process of AMR.

Ageing-induced degradation may occur in cables and connections located in plant areas, where the environmental conditions are more severe than those that their degradable materials can withstand.

According to the industry guidelines (EPRI-1013475 [28], NEI 95-10 [26]) and NUREG-1801 [25], the degradation factors to be considered for cables and connections are mainly, temperature, radiation and humidity. These factors affect only the organic materials (insulation). The other elements (conductor, connectors, terminals) are made of metallic or inorganic materials and, except at points for connection to the equipment, are not affected by these degradation factors.

The electrical connections ageing management review is performed with respect to their inorganic or metallic materials and environments, and gives rise to an ageing management programme different and independent from the programme for cables, which is not part of the contents requested for this report.

In this report, the organic materials of the connections (insulating tape, Raychem sleeves, etc.) are considered, from the point of view of ageing management, in the same way as the insulating material of the cable on which they are installed.

The number of electrical cables and connections included within the scope of IS-22 [21] is large, and these items are installed in practically all areas of the plant, with a great deal of variety as regards location, environment, materials and applications. For this reason, the method commonly used by the Spanish nuclear power plants to identify cables and connections, without environmental qualification requirements (non EQ cables), susceptible to degradation and consequently requiring a process of AMR, is the one known as “Plant Spaces Approach”, formally accepted by NUREG-1800 [24], which follows the methodology and criteria described in documents NEI 95-10 [26] and EPRI-1013475 [28]. This approach comprises the following activities.

I. Identification of plant areas with adverse environments for cables and connections.

In accordance with the provisions of NUREG-1801 [25] an adverse environment is considered to be one in which there is exposure to temperature (T), radiation (R) or humidity (H) values that might affect the properties of the insulating materials of electrical cables and their connections and, consequently, the guarantee of compliance with their intended function. The threshold temperature and radiation values as from which an environment is considered to be “adverse”, are those corresponding to the design normal operating conditions (T, R) in each plant area.

Adverse environments affecting cables and connections may be uniform, affecting the entire area analysed, or localised (hot spots) when in a given location of the area the environmental conditions are significantly more severe than those existing in the rest of the areas, the localised adverse environments are normally due to point-specific sources of radiation or thermal emissions, caused by proximity to high energy piping, high process temperature components, or radiation sources, the anomalous operation of ventilation systems or local leakages of steam from nearby equipment.

The identification of hot spots is accomplished by means of walk downs on different areas of the plant, focussing on those locations in which operating experience and the plant documentation (design drawings, radiological maps, Environmental Qualification

Report) indicate the possible existence of particularly severe environmental conditions. Thermographic cameras are normally used to detect hot spots in cables and connections located close to high temperature sources or piping.

Some Spanish nuclear power plants have used recommendations included in the UNESA guideline E13/IT-02-0503, “Guideline on the Surveillance of Electrical Cable Status”, and in the UNESA procedure ES13/IT-03-0903, “Technical Procedure for the identification of Environmental and Service Parameters”, to define areas of adverse environments, and inspection walkdowns for the identification of hot spots.

Other plants have based these tasks on the recommendations of the following EPRI documents:

- EPRI-100333317 “Cable system Ageing Management”.
- EPRI TR-109619 “Guidelines for the management of adverse localized equipment environments”.

Additionally, areas through which there are cable runs that might be submerged or affected by significant humidity, such as underground ducts, trenches or galleries, are also considered as localised adverse environments areas. These areas are identified by means the plant documentation (design documents, wiring and systems drawings, etc.), operating experience data and Maintenance Rule inspections results.

Following identification of the adverse environment areas and using the specific plant documentation (cable databases, electrical diagrams and wiring layout cable run drawings) as a basis, the cables and connections included within the scope of IS-22 [21] and located in these areas are identified.

II. Identification of the insulating materials of plant electrical cables/connections

For each insulating material (obtained from cable specifications and other plant documents) of cables and connections included within the scope, the “limiting conditions” are determined; i.e., the maximum temperature value and the maximun integrated dose value that the material is capable of withstanding, for a given period of time, while conserving the properties that guarantee compliance with its intended function.

In this respect the Spanish nuclear power plants have used radiation and temperature limiting conditions for a period of 60 years, as specified in EPRI-1013475 [28].

III. Performance of “Plant Spaces Approach” with respect to radiation

For each of the plant areas identified as being an adverse environment, the integrated radiation dose value, expected over 60 years, is calculated. To do this, the design value (dose over 40 years) is determined and then multiplied by a factor of 1.5.

Following this, for each of the cables and connections existing in the area, the integrated dose value over 60 years is compared to the limiting dose value of the material, obtained from EPRI-1013475 [28].

In the case of insulating materials whose limiting dose values are lower than those calculated for their location area, it is considered that they may undergo ageing degradation due to exposure to radiation, which would affect the fulfilment of their intended function and consequently require a process of AMR during their installed lifetime.

IV. Performance of "Plant Spaces Approach" with respect to temperature

In a manner equivalent to what has been indicated in the previous point, for each of the plant areas identified as being an adverse environment, the existing cables and connections, its insulating materials and the operating temperature, are identified.

The operating temperatures of energised cables and their connections are corrected taking into account resistive heating, which according to the document EPRI-1013475 [28], gives a maximum insulation temperature of 72ºC, for power cables at an ambient temperature of between 40 and 50ºC. Resistive heating is not considered to be relevant in the case of instrumentation and control cables, where amperages are low compared to power cables. However, when such cables are installed on trays alongside power cables, the heating of the latter may increase the temperature of the insulation of the instrumentation and control cables. The document EPRI-1013475 [28] establishes 12.5ºC as the value of this temperature increase, when ambient temperature is 40ºC.

In the case of energised cables located at hot spots, operating temperatures are calculated in a manner similar to that described above, taking into account temperature increases in the insulation due to resistive heating.

Following this, for each cable and connection the operating temperature is compared to the "60 year limiting temperature value" of its insulating materials, obtained from EPRI-1013475 [28]. In the case of cables and connections whose limiting temperature values are lower than the operating temperatures in their location area, it is considered that they may undergo ageing degradation, which would affect the fulfilment of their intended function, and consequently require a process of AMR during their installed lifetime.

V. Performance of "Plant Spaces Approach" with respect to humidity

Using the documentation of each plant (buildings layout, galleries, trenches and, cable run drawings) as a basis, an analysis is performed to identify cables existing in underground galleries, trenches or buried inside ducts in which water may accumulate and the cables be submerged, or lead to a concentration of humidity capable of creating the phenomenon of water treeing in the insulation. Any cables identified in such a conditions, may undergo ageing degradation which would affect the fulfilment of their intended function and consequently require an AMR process during their installed lifetime.

The "Plant Spaces Approach" methodology described above, has been used by the Almaraz I and II, Ascó I and II, Trillo and Vandellós II plants and, as has been previously pointed out, is only applicable to non EQ cables.

Nevertheless, due to the issuing of NRC Regulatory Guide RG 1.211 and also to the results of recent international R&D programmes (NEA-OECD, IAEA, NRC, Japan JNES) described in the following reports:

- SCAP Report: NEA/CSNI/R (2010)5: “Technical basis for Commendable practices on Ageing Management-SCC and Cable Ageing Project” (2011).
- IAEA Nuclear Energy Series Report NP-T-3.6: “Assessing and Managing Cable Ageing in NPP” (2012).
- CADAK PRG: “OECD Cable Ageing Data and Knowledge Project” (draft report). (2012-2014)
- SAND 2013-2388: “NPP Cable Materials: Review Of Qualification And Currently Available Aging Data For Margin Assessments In Cable Performance”
- JNES-SS-903: “Assessment of Cable Aging for Nuclear Power plants”(2009)

which have highlighted “uncertainties” in the qualified lifetime values resulting from application of past cable environmental qualification standards (IEEE-Std-383-1974: “IEEE standard for Type test of Class 1E electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations”), CSN has encouraged Spanish NPP to include EQ cables within the scope of their ageing management programmes.

The identification of EQ cables, their characteristics and materials is obtained, for each plant, from the information included in its specific “Plant Environmental Qualification Report”.

In the case of the Cofrentes plant, the Plant Spaces Approach process described above has also been used, but with the following differences:

In accordance with the plant’s supply specifications, all the installed cables (power, control and instrumentation cables) including those that are not safety related, correspond to cable types environmentally qualified for a lifetime of 40 years, and, for this reason, they might not be degraded throughout this period, under temperature and radiation conditions corresponding to normal plant operation.

As a result of the above, the “Plant Spaces Approach” methodology at the Cofrentes plant does not identify locations inside the plant in which, the normal operation environmental conditions, exceed the temperature and radiation values for which the cables are qualified over 40 years.

Regardless of the above, operating experience and the plant environmental conditions surveillance programme, have detected certain areas with occasional localised adverse environments, located in the Drywell and the Steam Tunnel, in which the temperature values exceed the cable 40-year qualification temperature values. Consequently, the cables existing in these areas must be the subject to ageing management review activities.

In addition, and as a result of the plant operating experience, the scope of the ageing management review also includes the containment building electrical penetrations cables, located in the annulus area, since during certain periods of operation, high humidity conditions have been detected in this area, producing condensation on the cables and leading to their failure.

As a result of the "Plant Spaces Approach" process at each Spanish plant, a list of cables (EQ and non EQ cables) is obtained, these to be subjected to a process of AMR during their installed lifetime.

Following the 40 years of operation of the plants, and in the event of a long-term operating license application, EQ cables must be analysed once more, in order to determine whether they will require additional AMR activities during the period of long-term operation. This new analysis, known as "Time-Limited Ageing Analysis" (TLAA), must be performed in accordance with the criteria of IS-22, and using the cables environmental qualification process documentation in each plant.

Table 03.1 in the annex to this chapter specifies the type of cables that are installed at the Spanish plants, indicating their function, manufacturer and insulating and sheathing materials. Tables 03.2 and 03.3 identify for each plant the types of cables that, in view of the scoping and screening process performed, require ageing management, along with their insulating materials. These cables are of both, the qualified and non-qualified types.

For performance of the cable ageing management review activities at the Spanish plants, the cables are grouped on the basis of functional criteria (power, control, instrumentation cables) and location criteria (areas with similar environmental conditions, Primary Containment (PWR), Drywell (BWR), Steam Tunnel, trenches and outdoor areas, etc.), this resulting in the three following groups:

Group 1- Cables subjected to high temperature or radiation adverse environments. This group includes low voltage (0.3, 0.6 and 1kV) and medium voltage (6 to 10 kV) power, instrumentation and control cables, with different insulating materials located inside the buildings.

- the cables included in example 1 of the TPR specification "high voltage cables of more than 3 kV subjected to adverse environments", are considered in Spain to be medium voltage, and their ageing management is accomplished in this group.

Group 2- "High voltage and low signal level instrumentation cables", subjected to adverse environments as a result of high temperatures or radiation levels. This group includes the organic insulation cables of the in-core instrumentation systems (NIS) and radiation measurement systems.

- the cables included in example 3 of the TPR specification, "neutron flux measurement instrumentation cables", are included in this group for the purposes of ageing management.

Group 3- Power cables in inaccessible or underground locations (trenches, channels, galleries, ducts, etc.) susceptible to flooding or significant levels of humidity. This group includes low voltage power cables (more than 380 V) and medium voltage cables of 6 to

10 kV feeding the motors of pumps in different systems (essential services water, circulating water, fire-fighting, etc.).

- the cables included in example 2 of the TPR specification, “medium voltage 380 V to 3 kV cables, in trenches or buried, are included in this group for the purposes of ageing management.

03.1.2. Assessment of ageing of electrical cables

The ageing management review process, applied by all the Spanish nuclear power plants to electrical cables, consists of the following activities:

- Identification of significant ageing mechanisms in cable insulating materials.

- Identification and assessment of maintenance practices (cable inspections, electrical tests and checks) in place at each plant, for management of the aforementioned significant ageing mechanisms, applying the necessary improvements where appropriate.

- Development of ageing management programmes (AMP), including the aforementioned maintenance practices and their assignment to the different cable groups.

<u>Identification of significant ageing mechanisms and their effects on cables</u>

Once the cables and connections requiring ageing management have been determined, their insulating materials are identified, along with the environments acting on them in their location at the plant.

Taking into account the possible combinations of insulating materials and environments, the different Ageing Management Review Groups (AMRG) are defined. For each group the different applicable ageing mechanisms are identified in turn, along with the resulting ageing effects on their insulating material.

In all cases, the Spanish plants have defined the following AMRG’s affecting the cables:

- outdoor insulating material/ambient air
- indoor insulating material/ambient air
- insulating material/moist air

The ageing mechanisms associated with the aforementioned AMRG’s have been identified in accordance with the information contained in NUREG-1801 [25] and EPRI-1013475 [28], and are as follows:

- Exposure to heat
- Exposure to radiation (including ultraviolet radiation)
- Exposure to humidity in the presence of voltage
- Humidity intrusion

These mechanisms produce the following significant ageing effects on the insulation:

- Reduction of insulation resistance due to irradiation (embrittlement, cracking, melting and decolouring).
- Reduction of insulation resistance due to exposure to heat (embrittlement, cracking, melting and decolouring).
- Reduction of insulation resistance due to humidity intrusion.
- Reduction of insulation resistance, localised damage and breaking of insulation due to exposure to voltage, in the presence of significant humidity or flooding (water treeing).
- Changes in material properties. Electricity continuity loss.

The application of the above to the cables included in the examples of the TPR specification [1] is as follows:

Example 1: "High voltage cables of more than 3 kV subjected to adverse environments". In the case of the Spanish plants this example corresponds to medium voltage power cables of 6 to 10 kV with EPR insulation, located inside or outside buildings, and Kapton or Kerite insulation cables (in electrical penetrations).

Example 3: "Neutron flux measurement system instrumentation cables". In the case of the Spanish plants this example corresponds to 300 and 600V instrumentation cables and coaxial and triaxial cables with different insulations, such as XLPE, XLPO+Alkane Imida, ETFE, PVC or silicone, located inside the containment building (PWR) and drywell (BWR).

These cables (examples 1 and 3) are affected by the following ageing mechanisms and effects:

- Reduction of insulation resistance due to exposure to heat and/or irradiation (embrittlement, cracking, melting and decolouring).

Example 2: "380 V and 3 kV cables, buried or in trenches". In the case of the Spanish plants this example corresponds to low voltage (380 V and 400 V) power cables with EPR, EPDM and XLPE insulations materials, located in trenches, galleries or underground ducts, in areas outside buildings in which water may accumulate.

These cables are affected by the following ageing mechanisms and effects:

- Reduction of insulation resistance or localised damage, and breaking of the insulation due to exposure to voltage in the presence of significant humidity or flooding, as a result of water treeing inside the insulation.

The AMR process acceptance criterion for electrical cables and connections, is that the significant ageing mechanisms and effects identified for them must be managed suitably by means of the corresponding AMP's, in order to guarantee compliance with their intended functions.

As a conclusion to the cables and connections AMR process performed, and for its application to management of the significant ageing effects and mechanisms identified, the Spanish plants have developed three cable AMP's, described in section 03.1.3 of this report, which are based on the model programmes AMP XI.E-1, AMP XI.E-2 and AMP XI.E-3 of NUREG-1801 [25] and fulfil the 10 attributes established in NUREG-1800 [24] and guideline NEI 95-10 [26], in order for the AMP to be effective.

For the surveillance of ageing of the metallic parts of electrical connections, the Spanish plants have developed a specific AMP, based on AMP XI.E-6, "Electrical Cable Connections not subject to 10 CFR 50.49" of NUREG-1801 [25]. As has been pointed out above, this AMP is beyond the scope required for this report.

<u>Main tools used in the AMR process</u>

For the performance of the general activities of the AMR process, the Spanish nuclear power plants have used basically the following reference documentation:

- **10 CFR Part 54.** "Requirements for Renewal of Operating Licenses for Nuclear Power Plants" [23]
- **NEI 95-10,** Rev. 6 .June 2005. "Industry Guideline For Implementing The Requirements of 10 CFR Part 54-The License Renewal Rule", June 2005 [26]
- **NUREG-1800,** Rev. 2: "Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants", December 2010. [24]
- **NUREG-1801, Rev. 2**, Generic Aging Lessons Learned (GALL) Report, December 2010 [25]
- **EPRI-1013475:** "Plant Support Engineering: License Renewal Electrical Handbook", February 2007. [28]

Additionally, the following documents have been used for the performance of the cables and connections AMP's:

- **R.G. 1.211,** Qualification of Safety-Related Cables and Field Splices for Nuclear Power Plants, U.S. NRC.
- **RG-1.218 "**Condition-Monitoring Techniques for Electric Cables used in Nuclear Power Plants". U.S. NRC
- **RIS-2003-09**. Environmental Qualification of low-voltage instrumentation and control cables. U.S. NRC.
- **GL 2007-01,** "Summary Report, Inaccessible or Underground Power Cable Failures that Disable Accident Mitigation Systems or Cause Plant Transients", November 12, 2008. U.S. NRC
- **NUREG/CR-7000**. "Essential Elements of an Electric Cable Condition Monitoring Program"
- **NUREG/CR-6704,** "Aging of Cables, Connections and Electrical Penetration Assemblies used in Nuclear Power Plants". June 1990.
- **NUREG/CR-5643,** Insights Gained from Ageing Research, U.S. NRC.
- **IEEE Std. 1205-2000. "**Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.
- **IEEE, Std. 400-2001** "IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems", 2002.

- **IEEE, Std.400.3-2006** "IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment", 2007.
- **IEEE, Std. 422-1977**, "IEEE Design and Installation of Cable Systems in Power Generating Stations", 1977.
- **IEC 270, "**High-voltage Test Techniques" Ed. 1 (1983).
- **SAND 96-0344.** "Aging Management Guideline for Commercial Nuclear Power Plants Electrical Cable and Terminations" September 1996.
- **EPRI 1006534,** "Infrared Thermography Guide" (Rev. 3). Mayo 2002.
- **EPRI 1003317**-"Cable System Ageing Management". April 2002.
- **EPRI TR-109619**. June 1999. "Guideline for the Management of Adverse Localized Equipment Environments".
- **EPRI 1003663**. "Integrated Cable Systems Aging Management Guidance. Low voltage cable". January 2003.
- **EPRI 1003664, "**Medium-voltage Cables in Nuclear Plant applications-State of Industry and Condition Monitoring".
- **EPRI. 1020804**, June 2010."Plant Support Engineering: Aging Management Program Development Guidance for AC and DC low-voltage, power cable systems for Nuclear Power Plants".
- **EPRI. 1020805**, June 2010. "Plant Support Engineering: "Aging Management Program Development Guidance for Medium-Voltage cable Systems for Nuclear Power Plants".
- **EPRI TR-103841** July 1994. "Low-voltage Environmentally Qualified Cable License Renewal Industry Report. Assessment of environmental".
- **UNESA document ES13/IT-02-0503**, "Guideline for Monitoring of the Status of Electrical Cables".
- **UNESA document ES13/IT-03-0903**, "Technical Procedure for the Identification of Critical Environmental and Service Parameters".
- **UNESA document Nº ES13/IT-04-0903**: "Selection of Circuits and Definition of the Surveillance Programme".
- **UNESA document Nº ES13/IT-06-0903**: "Technical Procedure for the Mechanical Characterisation of Cables".
- **UNESA document Nº ES13/IT-05-0903**: "Technical Procedure for the Electrical Characterisation of Cables".

Main plant documents (manufacturing and operation)

- Cable manufacturer supplier specifications.
- Plant Environmental Qualification Report.
- Final Safety Assessment.
- Reference books.
- Electrical circuit diagrams.
- Cable tray layout drawings.
- Cable environmental qualification dossiers.

Cable databases

For the performance of all the activities relating to the identification of the cables and connections subject to ageing management and its subsequent AMR activities, each Spanish plant has developed a cable database containing all its cables, with their materials specifications, routings, channels drawings and connections. This database allows for the selection of cables/connections existing in the areas with adverse environmental conditions fulfilling the criteria described in the "Plant Spaces Approach method.

Use of research and development programme results in ageing management review activities

In 2003, the CSN and UNESA (Spanish Electricity Industry Association) initiated a joint research project (JRP) on the ageing of electrical cables at nuclear power plants, made up of the following phases:

Phase 1. PCI ES-13: "Surveillance of electrical cable ageing at nuclear power plants".

The main objective of this phase of the project carried out in 2004, was to define a "common basis action plan", applicable to all the Spanish plants for the performance of systematic cable ageing surveillance programmes. The aim was, for these programmes, to be aligned with the international state of the art in this area, and in particular with the recommendations and contents of the IAEA TECDOC-1188, "Assessment and Management of Ageing of Major NPP Components important to Safety: In-Containment I&C cables".

Performed as an initial activity of this project was an in-depth review of the national and international literature (IAEA, NUREG, EPRI, Sandia reports, NRC documents, etc.) on cable ageing, with a report being drawn up.

As a basic conclusion to this phase of the project, it was determined that the ageing surveillance techniques potentially appropriate for the types of cables in place at the Spanish plants were: measurement of the compression module (Indenter method), thermogravimetriy (TGA) and induced oxidation time and temperature (OIT, OITP).
Likewise, the following documents were drawn up for application at the different plants:

- **UNESA document Nº ES13/IT-01-103:** "National and International Research and Development Status Evaluation Report"
- **UNESA document Nº ES13/IT-02-0903:** "Guideline for Monitoring of the Status of Electrical Cables.".
- **UNESA document Nº ES13/IT-03-0903:** "Technical Procedure for the identification of Critical Environmental and Service Parameters".
- **UNESA document Nº ES13/IT-04-0903:** "Selection of Circuits and Definition of the Surveillance Programme".
- **UNESA document ES13/IT-05-0903:** "Technical Procedure for the Electrical Characterisation of Cables".
- **UNESA document ES13/IT-06-0903:** "Technical Procedure for the Mechanical Characterisation of Cables".

Phase 2. PCI ES-24 "Application of Advanced Techniques for the Diagnosis of Electrical Cables at Nuclear Power Plants"

The basic objective of this phase of the project carried out over the period 2006-2009, consisted of determining, in a practical manner, the applicability of the ageing surveillance techniques identified in previous phase 1, for monitoring of the status of the cables in place at the Spanish nuclear power plants.

The project was performed by way of the following activities:

- Collecting of cable samples (new and naturally aged) representative of those installed at the Spanish plants.
- Thermal and radiation-induced ageing of these samples, for periods of 20, 40 and 60 years.
- Acquisition of values of elongation at break (EAB) and tensile strength (TS) of aged samples.
- Application of selected techniques (Indenter method, TGA, OIT, OITP) to aged samples. Acquisition Validation and adjustment of results.
- Comparison of the results of the techniques applied to the corresponding values of EAB and TS, obtaining correlation factors between the test values and the degradation of the aged cables.

As a result of this project phase it was possible to determine the degree of applicability of the techniques used, to the different types of cables tested, and their effectiveness for identification of the ageing of their insulating materials. Also determined for each type of cable were the reference values (acceptance criteria) of the results of application of each technique.

Phase 3. PCI ES-27: "Tracking and Assessment of Electrical Cables Status at the Spanish Nuclear Power Plants".

This phase of the project began in 2014, and is currently being carried out by UNESA and the Spanish plants. The project is performed in response to the recommendations of the CSN to verify the validity of the cable environmental qualification processes performed in accordance with IEEE-383-1974, as a result of the "uncertainties of these qualification processes" identified by recent international research programmes (IAEA, NRC, NEA, Japan) on the ageing of cables.

The main objective of the project is to obtain "condition indicators" (CI) for the cables, making it possible to effectively control their ageing status throughout the long-term operating (LTO) period.

In this respect, new qualification tests will be performed, limiting the effect of the aforementioned uncertainties, on a representative sample of the cables in place at the Spanish plants.

The tests will be performed on naturally aged (30 years) samples of cables taken from the plants, their ageing being completed to 40, 50 and 60 years by means of a sequence of accelerated ageing tests (thermal + radiation) with low factors of acceleration and dose rates. Subsequently, the accident radiation test and finally the LOCA and Post-LOCA tests, will be applied.

During the process, samples aged to 40, 50 and 60 years will be extracted and different surveillance techniques (elongation at break, Indenter, insulation resistance, polarisation index, etc.) will be applied to them, obtaining the corresponding values prior to and following LOCA. In this way, the "critical level of degradation" for ageing management of the cables throughout the long-term operating period will be determined.

The ageing test phase of the project, was initiated in 2017. The completion of the project is scheduled for the year 2020.

Use of operating experience review results on cables.

The review of the plant-specific operating experience applicable to cables, includes the evaluation of the information stored in the "maintenance history records" of each Spanish plant.

The following issues are particularly significant in this review and led to changes and improvements in cable ageing management activities.

Cofrentes NPP:

- Degradation was detected in EPR/CSPE cables feeding electrical actuators of motor-operated valves (MOVS). The degradation occurred as a result of hot spots (due to degraded high energy piping insulations and steam leakages in nearby equipment) combined with mechanical stresses due to excessive bending of the cable at its connection to the actuator. The following activities were carried out as a result of the above:
  - Cables were replaced in more than 150 Limitorque actuators.
  - Improvements were introduced in the plant's Environmental Conditions Surveillance Programme.
  - A programme was implemented for the review of thermal insulation status for piping and equipment.
  - A programme was implemented for the surveillance of equipment steam leaks.
  - A programme was implemented for the surveillance of cooling units.
- Electrical penetrations cables (General Electric) located in the annulus and affected by the intrusion of humidity, causing the subsequent failure of certain relief valves (SRV). As a result, the following activities were carried out:
  - Modules of penetrations susceptible to the problem were changed.
  - A programme was developed for surveillance of conditions of humidity in the annulus.
  - Cable inspection activities (insulation resistance testing and visual inspection) were improved.

Almaraz NPP:

- Cracking has been observed in electrical penetration feed power cables during the early years of operation of group 1.

- Cable degradation has been observed inside containment, affecting in particular to triaxial cables connected to neutron detector chambers located in wells adjacent to the Reactor Vessel. The affected cables were replaced.

Trillo NPP:

- Prematurely aged cables were found in the feed for the pilot solenoids of main steam system isolation and safety valves, as a result of the high temperatures reached by these solenoids when being continuously energised, and of the high temperature of the process steam. The cables in question were replaced with new cables, which are now changed every 6 years.
- As a result of the review of certain operating experiences at German plants, the possibility of the appearance of secretions or exudations in low voltage PVC cables was assessed. The problem was not considered to be generic in Germany and had been detected only in the cables of certain manufacturers and certain manufacturing batches/series.
    - In any case, and as a result of the above, Trillo NPP has included a new activity in its cable AMP for the visual inspection every 10 years of a sample of its PVC cables.

03.1.3. Monitoring, testing, sampling and inspection activities for electrical cables

As has already been pointed out in section 03.1.2 of this report, the Spanish nuclear power plants have developed the three following ageing management programmes for application to the management of significant ageing effects and mechanisms identified in electrical cables:

AMP-1 “Surveillance of Electrical Cables”, based on model programme XI.E-1 of NUREG-1801 [25] "Insulation material for electrical cables and connections not subject to 10 CFR 50.49 environmental qualification requirements”.

This AMP is applicable to the ageing management of cables included in example 1 of the TPR specification (Cables with voltages of >3kV in adverse environments).

The programme is based on the periodic visual inspection of a sample of accessible cables, representative of those included in the scope of the AMP and selected on the basis of the following criteria:

- the sample must include cables representative of the different specifications for insulating materials and for the environments in which they are located;
- the information obtained on the ageing of the cables inspected, must be representative of the condition of all other cables having the same characteristics;
- all the cables in the sample must be inspected at least once every 10 years.

In addition to visual and tactile inspection, and with a view to complementing their results, the Spanish plants also apply different electrical and/or mechanical tests on the cables included within the scope of this AMP, as described in table 03.4 of the annex to this chapter.

In the case of Cofrentes plant, the methodology used for the development of this cable AMP is different, and is made up of the following phases:

- Application of the cable inspection and surveillance activities, established in the maintenance schedules and procedures for testing electrical equipment (motor-operated valves, electrical penetrations, electrical cabinets and panels and low and medium voltage motors) circuits. These activities affect all the cables within the scope of the AMP and consist of the visual inspection of the cables at their connection or of insulation resistance and polarisation index measurements tests, in motor feed circuits. These schedules are applied at a frequency of approximately 2 years, although this may vary depending on the maintenance plan for each item of equipment.
- In the case of cables in which the aforementioned inspections and tests detect incipient degradation, the following "additional tests" are performed, depending on the type of cable:
    - Visual inspection.
    - Electrical testing: insulation resistance and polarisation index test, Tan delta test or partial discharges test.
    - Mechanical testing: Indenter module.
- If the aforementioned additional tests results do not meet the required acceptance criteria, the affected cables are included in an "aged cables and connections replacement plan", which will be implemented in the following operating cycles.

AMP-2, "Surveillance of instrumentation cables", based on model programme XI.E2 of NUREG-1801 [25] "Insulation material for electrical cables and connections not subject to 10 CFR 50.49 environmental qualification requirements used in instrumentation circuits".

This AMP includes in its scope the cables of radiation measurement, and in-core and ex-core nuclear instrumentation systems and is therefore applicable to the ageing management of the cables included in example 3 of the TPR specification [1] (neutron flux instrumentation system cables).

In this AMP and in accordance with the model programme in NUREG-1801 [25], two methods may be used to identify cable degradation due to ageing.

- The first method consists of evaluating the results of the calibration tests and/or instrumentation system surveillance tests (cables+connectors), in accordance with the plant procedures. The tests are complemented with a visual inspection of the status of the cables and connectors.
- When the calibration or surveillance tests do not include the instrumentation system cables, or as an alternative to them, electrical tests are applied to detect the degradation of the insulation of the cables, such as insulation resistance measurement, polarisation index or reflectometry tests (TDR).

The aforementioned tests and checks are performed during each refuelling outage, as a result of which their frequency varies from one plant to another (12 to 24 months), although all the cables included within the scope of the programme must be tested at least once every 10 years.

The specific application of this AMP in each Spanish plant, for the neutron flux measurement system, is as follows:

- At Cofrentes NPP (BWR), surveillance is performed on the source range monitoring sub-system (SRM), intermediate range monitoring sub-system (IRM) and local power range monitoring (LPRM) sub-systems, located all them in the Drywell.
  Visual inspections are performed on the cables, connectors and detectors, along with functional tests, to verify the performance of these components, applying the following maintenance schedules and procedures:
  - o <u>Inspection of SRM and IRM detectors</u>. A check is made of the condition of the insulation of the detectors of these sub-systems, as well as of their cables and connections, in order to prevent current leakage.
  - o <u>Review of SRM and IRM cables and connectors</u>. Tests are performed to verify that the cables and connectors of the channels of these sub-systems operate in accordance with the requirements specified by the manufacturer.
  - o <u>Inspection of LPRM detectors</u>. The condition of the detectors is verified, the connection and condition of the cables are checked and the insulation resistance between the cable shielding and ground is measured.
  - o <u>Acquisition and checking of cable parameters and cable plot.</u> Ohmic resistance, reactance, quality factor, insulation resistance and polarisation index measurements are performed, and the analysed cable plot calculated.

  The frequency of application of the aforementioned inspections and tests activities is every one refuelling outage (2 years).

  The acceptance criteria for the aforementioned activities are established in the schedules/procedures themselves, and are specific for testing of the circuits of each detector.

- At the Spanish PWR plants, the source range (SRM), intermediate range (IRM) and power range (PRM) neutron flux system channels are monitored, and the following activities are performed:

  <u>Almaraz I and II NPP</u>: Testing of interelectronic resistance, leakage current, sensitivity, capacity, DC. current characterisation and reflectometry during each refuelling outage (18 months).

  <u>Trillo NPP</u>: An electronic functional test is performed on the complete loops of the system, once per refuelling outage (12 months). Certain of the system cables have mineral type insulation, or are replaced every 4 years and, consequently, do not require ageing management.

  <u>Vandellós II NPP and Ascó I and II NPP:</u> The following electrical inspections and tests are performed along the entire length of the selected cables and on all the cables included in the programme (NIS, power, intermediate and source range loops) and with a frequency of at least once every 6 refuelling outages (9 years).
  - Insulation resistance measurement: the test is performed at a voltage of 500 Vdc, with the following resistance measurements taken:
    - o Between conductor and inner shielding

    - Between inner and outer shielding
    - Between outer shielding and ground
- Reflectometry measurement (TDR).

AMP-3, "Surveillance of Inaccessible Power Cables", based on model programme XI.E3 of NUREG-1801 [25], "Inaccessible Power Cables Not Subject to 10 CFR 50.49 Environmental Qualification Requirements". This AMP is applicable for the ageing management of the cables included in example 2 of the TPR specification [1] (Cables with voltages of between 380 V and 3kV, buried or in trenches).

The objective of the inaccessible power cables surveillance AMP is, to provide reasonable assurance that the inaccessible power cables included within its scope and that might be exposed to conditions of significant humidity, will remain in conditions ensuring compliance with their intended function. Significant humidity is understood as referring to conditions in which the cable is wet or submerged, for several days. The AMP is based on the following activities:

- Visual inspection, review, cleaning and repair of all outdoor or underground cable run constructions (trenches, ducts, access boxes, galleries, etc.), verifying their condition as regards soiling and deterioration, the presence of water and the correct operation of the drainage systems. According to the model programme of NUREG-1801 [25], this activity must be performed at least each year.
- Application of electrical tests, in order to check the condition of the cable insulation, such as reflectometry (TDR), insulation resistance and polarisation index tests, in the case of low voltage cables, and in addition Tan Delta test and partial discharges test, for medium voltage cables. All the cables within the scope of this AMP should be tested at least once every 6 years.

Summarised below are the characteristics of the different activities (tests, checks and inspections) applied in the three AMP's indicated above and included in tables 03.4 and 03.5 of this chapter.

The performance and programming of these activities is accomplished taking into account the contents of section B of NRC regulatory guide RG-1.218 and chapter 3 of NUREG CR-7000. The practical application of the electrical tests and checks is normally carried out by the electrical and instrumentation maintenance department at each plant. In most cases the cable visual inspection and mechanical testing activities are performed by contracted specialist companies.

Visual and tactile inspection

The information used for the selection of the sample of cables to be inspected, is obtained previously by means of plant walkdowns, with the aim to choose the most compromised cables as regards their environment (hot spots), accessibility and materials and also to determine the specific points on the cable runs for inspection performance.

Magnifying glasses, cameras or torches may be used for the inspection, and the following activities are carried out:

- Study of cable run and identification.
- Dimensional control of the cable.
- Visual inspection of cable jackets, searching for cracking, humidity, decolouring, deposits, physical damage, the presence of contamination, the appearance of exudations of plasticising materials.
- Checking of the degree of cable rigidity.

In the case of cables not directly accessible for visual inspection, because of being located inside ducts or trays, attempts are made to carry out the inspection at their ends, at their point of connection to penetrations, junction boxes or equipment and at the exit points from the tray. If needed, complementary electrical tests are applied to the cable.

The AMP's of the Spanish plants include provisions for augmenting the cable inspection sample for cases in which, during inspection, a previously selected cable is discovered not to be physically accessible (obstructed) or when any of the tests are discovered to be impracticable. Such provisions allowing for the selection of another cable of the same type and family or from a similar environment for inspection.

Acceptance criteria: absence of fissures, cracks, decolouring, deposits, physical damage, mechanical rigidity or humidity, indicating signs of deterioration of the cable insulating material. In order to facilitate evaluation of the results, certain plants (Almaraz, Trillo) have "standard pieces of cables taken from the plant and subjected to different degrees of thermal and radiation-induced ageing.

Frequency: Visual inspections are performed periodically during refuelling outages, with a frequency that varies from one plant to the next (normally every 1 or 2 outages). In the case of cables located at hot spots areas, the period between inspections may be less (every refuelling outage).

Compressive modulus test (Indenter method):

By means of this technique, applied to the sheath of the cable, the compressive modulus of the insulation is measured. Measurements are taken at different points along the cable run and are applied at 5 positions in each cable section selected. The degradation of the insulation is correlated to the values measured at the cable jacket. The geometry of the cable and the temperature and humidity during the test influence the test results. As has been seen during the aforementioned Spanish PCI ES-27 project, this technique is applicable and effective for most of the materials of cables installed at the Spanish plants.

Frequency: The test is normally applied jointly with visual inspections, every 1 or 2 refuelling outages.

Acceptance criteria: Any increase in the value of the modulus over the reference value, indicates degradation of the insulation. For most of the cable materials in use at the Spanish plants, a value of 20 N/mm is considered as the threshold for the start of degradation (UNESA procedure ES 13/IT-06-0903).

Insulation Resistance (IR) and Polarisation Index (PI) tests:

Insulation resistance measurement determines the dielectric integrity of the cable and is applicable to medium and low voltage cables and all insulation materials. It consists of applying a direct current in the cable, while the value of the current over time is recorded. Insulation resistance is determined as the resistance calculated one minute after the application of voltage. Temperature and humidity conditions existing during test may affect the test results, for which reason this aspect should be taken into account in determining their accuracy.

The polarisation index (variation of IR measurement each minute in periods of 10 min) is more effective than IR for the detection of insulation cracking due to thermal degradation and radiation, to humidity or to the contamination, on cables.

<u>Frequency:</u> At most Spanish plants the tests are performed at a variable frequency (every 1 or 2 refuelling outages).

<u>Acceptance criterion</u>: The Spanish plants establish a minimum insulation resistance value calculated in accordance with different documents: IEEE 43-1974, UNESA procedure ES-13/IT-05-0903, etc.

For insulation resistance the acceptance values (megaohms) vary depending on cable type (low or medium voltage) and function (power, control, instrumentation).

In the case of polarisation index, PI values of less than 1 are considered to be indicative of insulation degradation.

Tan delta test (TD):

At the Spanish plants this technique is used in the diagnosis of medium voltage cables. It consists of assessing dielectric losses in the cable, by determining the capacitive and resistive currents obtained when applying an AC voltage to the cable. TD is the result of the quotient of resistive current to capacitive current. The test is capable of detecting cracking in the cable insulation, induced by thermal or radiation effects, mechanical damage, water treeing, the intrusion of humidity and superficial contamination. The tests are performed in accordance with the criteria of IEEE Std. 400-2001.

<u>Frequency</u>: The frequency of performance varies from one plant to the next (1 or 2 refuelling outages).

<u>The acceptance criterion</u> is based on study of the trends of the calculated value in successive tests, and their comparison with reference results from similar cables. The value depends on the type of cable insulation and the variation in % of TD (dissipation factor), which should not exceed 1%.

Partial Discharges (PD):

This technique is applicable to shielded medium voltage cables and to all types of insulation and jacket materials. It detects embrittlement induced by thermal or radiation effects and water treeing. It is simple to apply, does not require access to the entire length of the cable and locates the position of insulation defects (position of discharges). The technique consists of determining the level of partial discharges caused through the insulation as a result of application of the voltage and the production of partial and temporary dielectric rupturing of the insulation. The tests are performed in accordance with the criteria of IEEE Std. 400.3-2006.

Frequency: The frequency of performance varies from one plant to the next (1 or 2 refuelling outages).

Acceptance criterion: Spanish plants use the values indicated in IEEE Std. 422-1977 and guidelines EPRI 1020804 (LV cables), EPRI 3002000554, EPRI-3002000557 and IEC-270 (MV cables).

Reflectometry test (TDR):

This diagnostic test is applicable to low and medium voltage cables, with all types of insulation and sheathing materials. The test consists of applying short pulses or voltage steps allowing for the location of defective sections (cracking induced by temperature, radiation and mechanical effects or the presence of water) in the cable run, detected by means of other surveillance techniques.

Frequency: The frequency of performance varies from one plant to the next (1 or 2 refuelling outages).

Acceptance criteria

Determination of the results of the reflectometry test requires an engineering assessment. The results must be compared to those from previous tests performed on the same cable or to a reference reflectogram. The following may be considered as general acceptance criteria:

- Absence of sudden increases in the voltage plot, indicating an increase in characteristic impedance or an open circuit condition.
- Absence of sudden reductions in the voltage plot, indicating a decrease in characteristic impedance or a short-circuit condition.

03.1.4. Preventive and remedial actions for electrical cables

Preventive actions

As regards Example Groups 1 and 3 (cables of more than 3 kV located in adverse environments and neutron flux system instrumentation cables), the corresponding cable AMP´s in NUREG-1801, require only inspection and testing activities and do not specify preventive or mitigation actions for ageing-induced degradation.

However, the cable AMP of the Spanish PWR plants, include actions such as the implementation of programmes for the surveillance of environmental conditions and periodic walkdowns for the identification of hot spots or other relevant events in the cable runs. These activities may be considered as being preventive actions to avoid or mitigate cable ageing.

In the specific case of Cofrentes NPP, its cable AMP´s include preventive activities for the mitigation of local adverse environmental conditions affecting the cables, these consisting on the evaluation and application of the results of the following programmes:

- Surveillance of plant environmental conditions (temperature and radiation). Temperature data are acquired daily or weekly during months representative of each season of the year, while the radiation doses affecting the equipment are estimated annually.
- Maintenance of the thermal insulation of piping and equipment in cubicles of the reactor, auxiliary and heaters buildings in which local adverse conditions have been identified.
- Maintenance of cooling units. The correct operation of the air-conditioning units in areas identified as having local adverse conditions allows the temperature to be maintained within the established limits in these areas.
- Identification of leakages of fluids that might affect the wiring.
- Surveillance of conditions of humidity in the annulus. A check is made for leakage or condensation potentially affecting the modules of the penetrations or their wiring. This task is carried out monthly.

As regards Example Group 2, cables with voltages of between 380 V and 3kV buried or in trenches, all the Spanish plants perform periodic actions in their AMP's aimed to prevent inaccessible cables from being exposed to high levels of humidity, such as, for example, the inspection of the ends of cable ducts manholes for water collection, and draining water as needed. The inspection frequency for the collection of water is established on the basis of the specific operating experience of each plant as regards humidity or the flooding of cables in the manholes (depending on the accumulation of water over time and events such as heavy rainfall or flooding). In any case, periodic inspections are performed at least once a year. Periodic tests are also carried out every 15 days on the operation of the pumps and drainage devices in the cable ducts and galleries.

<u>Corrective actions</u>

The cable ageing management programmes of the Spanish plants establish, that all the results of inspections and/or tests performed on cables that do not meet the corresponding acceptance criteria, shall be subjected to an engineering assessment. This assessment shall take into account the age of the cable and its operating environment, as well as the severity of the anomaly and whether the latter has been related previously to the degradation of the insulation of the conductor. The person responsible for the assessment shall analyse the anomalies detected and define the corrective actions to be taken. These corrective actions may include the performance of additional inspections or tests, the installation of protections or some other way of mitigating the adverse environment on the cables, or the relocation or replacement of the affected cable or cables.

At all the plants, the corrective actions performed on the cables are carried out via work orders and are controlled from beginning to end by the plant maintenance management system, by way of the Corrective Actions Plan (CAP).

Furthermore, all the aforementioned actions are subject to the requirements of the plant Quality Assurance Manual, which meets the requirements of appendix B 10 of 10CFR 50

03.2. Licensee's experience of the application of AMPs for electrical cables

Cable ageing management activities were initiated at the Spanish plants as from 2006, in accordance with the UNESA methodology, and as from 2011 application of the AMP's drawn up in accordance with NUREG-1801 [25] began, in compliance with CSN instruction IS-22 [21]. Consequently, there is currently limited experience as regards the results of implementation of these AMP's.

At the Spanish nuclear power plants and for each of the 3 cable AMP's developed, tracking reports shall be drawn up periodically, their frequency being variable (1 to 3 years). The tracking reports shall describe the AMP activities performed during the period and assess their results. Also included in those reports are the results of the review of the plant specific and industry operating experience, that might have affected the AMP and, where applicable, the tracking and evaluation of the trends of specific parameters assessing the evolution of certain ageing effects on the cables.

The evaluations included in the tracking reports are the basis for the continuous updating of the AMP's through the definition of improvements to them (improvements in AMP scope, in inspection activities, etc.), these being controlled during implementation by way of the corrective actions programme of each plant.

Likewise, the tracking reports evaluate the effectiveness of the aforementioned AMP's by means of an indicator; for example in the case of Cofrentes plant, it is a numerical indicator (from 0 to 100) that values the results of application of the AMP activities, the degree of compliance of these activities and their correct registration and the incorporation of the applicable results of the plant-specific and industry operating experience review in the AMP activities.

The behaviour observed to date, regarding the ageing of the insulations of cables and connections included within the scope of the different AMP's is similar at all the Spanish nuclear power plants and is as expected, no situations of generalised ageing requiring special attention or detailed analysis having been identified. In any case, certain isolated issues of incipient degradation (hardening, cracking and decolouring in jackets) have been detected in cables located in adverse temperature and radiation environments, for which the necessary corrective actions have been applied (tracking of degradation by means of new inspections or tests, or replacement of the cable).

Section 03.1.2 of this report (use of operating experience), provides further information on the issues indicated and the actions taken.

As regards inaccessible or underground cables, located in trenches , galleries or ducts, cables showing signs of having been subjected to conditions of significant humidity have been detected at all the plants in the past, but in no case was there any significant age-induced deterioration. Tracking activities were scheduled for these cables consisting of inspections and tests during the following refuelling activities.

In view of all the above, the Spanish plants consider that their cable ageing management programmes are suitable for application throughout their remaining operational lifetimes, guaranteeing compliance with the intended functions of these cables.

03.3. Regulator's assessment and conclusions on ageing management of electrical cables

As regards the process of managing the ageing of electrical cables described in this chapter, the CSN considers that the methodology applied for the identification of the cables requiring ageing management review, the identification of significant ageing effects and mechanisms on these cables, and the development of the ageing management programmes required for the mitigation and control of these effects and mechanisms, fulfils the requirements of IS-22 [21] and is also correctly documented, as a result of which the said process is considered adequate.

The CSN tracks electrical cable ageing management activities via assessments and inspections periodically performed at each of the Spanish nuclear power plants.

The CSN assessment activities are performed based on the contents of the "annual ageing management report" submitted by each plant in compliance with IS-22 [21], which describes, among other aspects, the specific activities (documentation, updating and implementation) performed with respect to the cable AMP's.

Furthermore, the CSN carries out two-yearly inspections on the Overall Management Ageing Programmes of the Spanish plants, in accordance with the Basic Inspection Plan in place. These inspections, performed at the sites and developed in accordance with CSN procedure PT.IV.223 [41], include checks at both, documentary and implementation level, on a sample of the AMP's in place at each plant, among others those corresponding to electrical cables.

The process of drawing up the current cable AMP's was initiated by the Spanish plants in the wake of the issuing of IS-22 [21] in 2009, and these AMP's were subsequently updated in order to adapt them to the requirements of NUREG-1801 [25] rev.2 in 2010. The implementation of the inspection and testing activities included in these AMP's began in 2012.

During the latest inspections performed by the CSN at the plants, as from 2012, checks have been made on the reports issued by the licensees on the specific cable inspections carried out in compliance with the requirements of the corresponding AMP's, verifying that they have all been implemented and that, in no case, have been detected degradations of a degree such that they might compromise compliance with the intended functions of the affected cables.

The following are considered to be positive aspects (strengths) of the cable AMP's developed by the Spanish nuclear power plants:

- Value is attached to the response of the plants to the CSN recommendation for including EQ cables within the scope of their AMP's, since such a cables are not included within the scope of the model programmes (AMP.XI-E1, AMP. XI-E2 and AMP XI-E3) of NUREG-1801 [25]. In this way it is possible to monitor the actual condition of these cables throughout their design lifetime, controlling the uncertainties regarding their qualified lifetime that have been identified in recent international programmes on the ageing of electrical cables.

- Also valued, is the performance by all the plants of cable AMP updating and on-going improvement activities, based on the results of plant-specific and industry operating experience reviews and of specific national (PCI ES 13/ 24) and international (IGALL [40]) R&D programmes, on the incorporation of new regulatory requirements and on the incorporation of improvements deriving from experience in the application of the AMP itself.
- Also valued is the performance on the cables of activities additional to those specifically required in the model AMP's of NUREG-1801 [25], such as the periodic performance of cable run walkdowns to identify hot spots and the application of tests (mechanical and electrical) additional to the visual inspection required for the cables included in AMP 1 "Cable surveillance", described in section 03.1.3 of this report.

Notwithstanding the above, certain aspects are observed for which there is a margin for improvement. Specifically, the surveillance of cables located inside metallic ducts or cable trays and consequently not accessible for visual inspection should be improved. Although the plants perform electrical tests on these cables, such as reflectometry to spatially locate defects, the efficiency of other tests such as IR and PI is questionable when it comes to the quantification of ageing-induced degradation in these defective sections. These issues might be the subject of future research activities aimed at determining effective ageing surveillance techniques for this type of cables.

In any case and as a final conclusion, the regulator considers that the cable ageing management programmes currently implemented by the Spanish plants are suitable to ensure compliance with the intended functions of these cables throughout their service lifetime.

ANNEX TO CHAPTER 03

Table 03.1

CABLE TYPES IN SPANISH NPP's

Cable Type	Insulation Material	Jacket material	Manufacturers
Power Medium Voltage	EPR	AFUMEX	Pirelli
	EPR	NEO	Roque, Saenger; Pirelli
	EPR	CSPE	Pirelli, Saenger; Fercable
	EPDM	CSPE	Fercable
	BR	-	Unknown
Power Low Voltage	EPR	CSPE	Pirelli; Roque; Saenger; Cablenor
	XLPE	CSPE	Roque
	EPDM	CSPE	Habia-Fercable
	EPR	AFUMEX	Pirelli
	ETFE	CSPE	Ralocar
	EPDM	NEO	Cablenor
	AFUMEX	AFUMEX	Pirelli
Instrumentation and Control	XLPE	AFUMEX	Pirelli
	XLPE	CSPE	Saenger, Pirelli
	XLPE	NEO	Roque, Pirelli
	XLPE	EVA	Siemens
	PVC	PE	Pirelli
	PVC	PVC	Siemens
	EPDM	CSPE	Boston Insulated Wire; Fercable, Pirelli
	PTFE	-	Gore
	EXANE	EXANE	ITT
	EPR	PCP	Pirelli; Roque
	EPR	AFUMEX	Pirelli
	EPR	PE	Pirelli
	EPR	CSPE	Pirelli; Roque; Fercable
	ETFE	ETFE	Ralocar
	ETFE	AFUMEX	Pirelli
	AFUMEX	AFUMEX	Pirelli
	ETFE	ETFE	System Cable
Coaxial/Triaxial	XLPE	CSPE	Boston Insulated wire
	XLPE	XLPE	Rockbestos
	PE	PVC	Simple wire and cable Company
	ALKANE IMIDA	CSPE	RAYCHEM
Thermocouples	POL	SR	Pirelli
	EPR	CSPE	Pirelli

Cable Type	Insulation Material	Jacket material	Manufacturers
	XLPE	AFUMEX	Pirelli
	XLPE	CSPE	Roque, Pirelli
	EPDM	CSPE	Boston Insulated Wire
	ETFE	CSPE	Boston Insulated Wire

GLOSSARY OF TERMS

Alkane-Imida: Aliphatic Polymide
BR: Butil rubber
CSPE: Chlorosulfonated Polyethylene
EPDM: Ethylene PropyleneDiene Monomer.
EPR: Ethylene Propylene Rubber.
ETFE: Ethylene Tetrafluorethylene
EVA: Ethylene Vinyl Acetate
PE: Polyethylene
PCP: Polychloroprene
PTFE: Polytetrafluorure Ethylene
PVC: Polyvinylchloride
SR. Silicon Rubber
XLPE: Cross Linked Polyethylene.
XLPO: Cross Linked Polyolephine
EXANE: Commercial name of XLPO
AFUMEX: Material commercial name property of Pirelli, halogen free and flame retardant. Afumex used in cable insulation is an EPR base material plus additives. Afumex used in jackets is an EVA base material plus additives.

Table 03.2

Insulating material	Cofrentes NPP					Ascó/Vandellós II NPP				
	MV	LV				MV	LV			
		Power	Control	Instrum.	COAX/TRIAX		Power	Control	Instrum.	COAX/TRIAX
EPR	*	*	*	*		*	*	*		
EPDM							*	*	*	
XLPE				*			*	*	*	
XLPO				*	*					
XLPO + Alkane/imide				*	*					
PVC								*	*	
Poliolefine									*	*
LE Polymer										*
EFTE/TEZFEL		*	*	*						
Silicone							*	*	*	
Rayoline					*					
Kapton (1)	*	*	*	*		*	*	*	*	

(1)- In electrical penetrations, Conax and Auxitrol

Table 03.3

Insulating material	Almaraz I and II NPP					Trillo NPP				
	MV	LV				MV	LV			
		Power	Control	Instrum.	COAX/TRIAX		Power	Control	Instrum.	COAX/TRIAX
EPR	*	*	*	*		*	*	*		
EPDM				*						
XLPE		*	*		*					
EFTE/TEZFEL				*					*	
Exane II				*						
PVC									*	
Goretex-PTFE										*
PE									*	
polymer									*	*
Kapton (1)	*	*	*	*		*	*	*	*	

(1)- In electrical penetrations, Conax and Auxitrol

Tables 03.4 and 03.5: Inspections, tests and checks on electrical cables

	Almaraz I and II NPP					Trillo NPP				
	MV	LV				MV	LV			
		Power	Control	Instrum.	COAX/TRIAX		Power	Control	Instrum.	COAX/TRIAX
Visual inspection	*	*	*	*	*	*	*	*	*	*
Indenter Hardness		*	*	*			*	*	*	
Insulation resistance	*	*	*	*	*	*	*	*	*	*
Polarisation index		*	*	*			*	*	*	
Reflectometry TDR		*	*	*	*		*	*	*	
TD/ dielectric losses	*					*				
Partial discharges	*					*				
System surveillance tests				*	*				*	*
Calibration tests				*	*				*	*

	Cofrentes NPP					Ascó I and II NPP/ Vandellós II NPP				
	MV	LV				MV	LV			
		Power	Control	Instrum.	COAX/TRIAX		Power	Control	Instrum.	COAX/TRIAX
Visual inspection	*	*	*	*	*	*	*	*	*	*
Indenter/ Hardness		*	*	*			*	*	*	
Insulation resistance	*	*	*	*	*	*	*	*	*	*
Polarisation index	*	*				*	*	*	*	
Reflectometry TDR					*	*	*	*	*	*
TD/ dielectric losses	*					*				
Partial discharges	*					*				
Leakage current	*									
System surveillance tests				*	*					
Calibration tests										

04. Concealed piping

04.1. Description of ageing management programmes for concealed piping

As indicated in the previous chapter 02 of this report, in the Spanish plants there are several programs that manage the aging of passive and long-lived components. Some of these programs are specific to concealed pipelines.

The definition process and the main characteristics of these programs are described in the following sections of this chapter.

04.1.1. Scope of ageing management for concealed piping

The piping included within the scope of this chapter are the buried and underground piping in a condition of restricted access and fulfilling the following characteristics:

- Buried piping are those that are located under ground level and are in direct contact with soil or concrete (e.g., a wall penetration).
- Underground piping are also below ground level, but are located within a tunnel or vault such that they are in contact with air and are located where access for inspection is restricted.

In order to determine the scope of the concealed piping AMP´s, the licensee first identifies the concealed piping k subject to ageing management review (AMR). This identification process is described in summary below; a detailed description may be found in chapter 02 of the present report.

Since concealed piping components fulfil the screening criteria of IS-22 [21], due to their being passive and long-lived, all the components identified during the scoping phase go on to the subsequent phase of ageing management review (AMR). The intended function associated with concealed piping is to act as a "Pressure Boundary", this implying the maintenance of a fluid inside a pressure-retaining boundary, ensuring the required flow at a given pressure, or the storage of a volume free from leakage or the maintenance of any leakage within the limits established in the design.

The significant ageing mechanisms and effects affecting each of the combinations of materials and environments present in concealed piping are described in section 04.1.2 of this chapter.

It should also be pointed out that, the sections of piping with inaccessible or restricted access, may be associated with any safety-significant system and that their identification is normally based on specific plant walkdowns for confirmation, during the process of scoping and screening of structures, systems and components (SSC). This is due to the fact that, in general, flow diagrams do not accurately identify the part of the system that is buried or inaccessible.

The materials of the piping included within the scope of this programme are carbon or stainless steel.

The Spanish plants) have undertaken groupings for application of the AMR process for piping included within the scope of their Overall Ageing Management Programme

(OAMP). The criteria used are assigned depending on whether the internal or external surface of the piping is managed and on whether the piping in question is buried or is affected by restricted access.

The systems that include safety-significant concealed piping included within the scope of ageing management, for each of the Spanish nuclear power plants[1], are shown in table 04.1. This table uses an “x” symbol to indicate that the applicable NUREG-1801 [25] model programme is AMP.XI.M41 (buried and inaccessible piping) and an “o” symbol when the applicable model programme is AMP.XI.M36 (outer surfaces). In all cases the piping is made of stainless steel or carbon steel with an outer protective covering, and is buried or located below ground with restricted access.

SYSTEMS INCLUDED IN THE SCOPE	VA2	AS	AL	TRI	COF
Auxiliary Feedwater	x o		x		
Condensate Storage & transfer	x o				x
RWS - Refuelling Water Storage	x	o			
EDG fuel Storage & Transfer	x o	o	x	x	x
Fire Protection (water)	x o	x o	x	x	x
Fire Protection (dry)		x			
Essential Service Water		o	x	x	
Demineralised Water	o		x		
High Pressure Core Spray					x
RCIC – Reactor Core Insolation Cooling					x
Component Cooling Water		o			
Compressed Air		o			
Water Pre-treatment, Storage & Transfer	o				

Table 04.1. Systems within the scope of the concealed piping programme for each Spanish nuclear power plant.

As can be seen in the previous table, the systems that most commonly include concealed piping at the Spanish NPP’s are the Fire Protection System (FPS), the gasoil storage and transfer system for the emergency diesel generators (EDG Fuel Transfer) and the Essential Service Water system (ESW).

There aren´t concealed piping included in in the Spanish plants OAMP`s that carry radioactive effluents.

Finally, after having performed the scoping and screening and ageing management review (AMR) phases, the suitable AMP’s taken from the catalogue of each plant are

[1] Abbreviations: Vandellós 2 NPP (VA2). ASCÓ I & II NPP (AS). Almaraz I & II NPP (AL). Trillo NPP (TRI).

assigned for management of the applicable ageing effects, for both the external and internal surfaces of the concealed piping.

04.1.2. Ageing assessment of concealed piping

As regards the process of AMR, only the material/environment combinations of the screened pipes are considered. No differentiation has been made on the basis of system type (EWS, FPS, EDG Fuel System, etc.).

The process implemented by the Spanish plants for the AMR phase of the components "concealed piping" type consists of the following:

- Identification of the potential significant ageing mechanisms and effects applicable to each combination of materials and environments (tables 04.2 and 04.3).
- Designation of suitable AMP's for surveillance of each of the previously identified significant ageing mechanisms and effects.

The following information has mainly been used for identification of the aforementioned ageing mechanisms and effects:

- Chapters II to VIII of the NUREG-1801 [25] report.
- NRC documents LR-ISG 2015-01 "Changes to Buried and Underground Piping and Tank Recommendations", y LR-ISG 2012-02 "Aging Management of Internal Surfaces, Fire Water Systems, Atmospheric Storage Tanks, and Corrosion Under Insulation".
- The results compiled in the document EPRI-1010639 "Non-Class 1 Mechanical Implementation Guideline and Mechanical Tools" [27].
- Plant-specific and industry operating experience.

In addition to the aforementioned references, the Almaraz and Trillo plants have used the following:

- NEI 09-14 Rev. 3. Guideline for the management of underground piping and tank integrity. April 2013.
- BPWorks 2.1TM Build. 2.1.0. September 2012.

Likewise, each plant uses plant-specific support documentation, such as for example the KTA standards in the case of Trillo NPP, which is of German design.

As regards identification of the applicable ageing mechanisms and effects, the Spanish plants separate their management depending on whether the external or internal surface of the piping is affected.

04.1.2.1. External surface

Table 04.2 shows the ageing mechanisms and effects considered at each Spanish plant for each concealed piping steel type and external environment.

All potential associated ageing mechanisms affecting the external surface of concealed piping give rise to the loss of material as an effect of ageing.

MATERIAL	EXTERNAL ENV.	MECHANISM	Effect	VA2	AS	AL	TRI	COF
Carbon Steel	**BURIED**	**general corrosion**	**loss of material**	x	x	x	x	
		crevice corrosion						
		pitting corrosion						
		MIC						
Stainless Steel		**crevice corrosion**		x		x		
		pitting corrosion						
		MIC						
Carbon Steel	**AIR/MOIST AIR (IN TRENCH/ OUTDOOR)**	**general corrosion**		o	o	x	x	x
		crevice corrosion						
		pitting corrosion						
Stainless Steel		**crevice corrosion**		o	o			x
		pitting corrosion						

Table 04.2. Ageing mechanisms and effects. External surface.

The previous table uses the symbol "x" if the applicable NUREG-1801 [25] programme is AMP.XI.M41 (concealed piping) and the symbol "o" if the applicable programme is AMP.XI.M36 (external surfaces).

The AMR analyses performed by the Spanish plants to identify ageing effects in piping embedded in concrete (CEP, concreate encased piping) have concluded that these effects are not significant. These conclusions are based on the reference documentation EPRI-1015078 "Plan Support Engineering: Aging Effects for Structures and Structural Components" [29], ACI-318 (low water/cement ratio, low permeability and incoming air), as established in NUREG-1557 "Summary of technical information and agreements from Nuclear Management and Resources Council industry reports addressing license renewal", and also on the basis of the characteristics of the concretes to which this piping is actually exposed, and likewise on the absence of adverse operating experience data. In this respect, in the case of mechanical components penetrating concrete walls, the Spanish plants have not identified any ageing effects inside the concrete requiring management.

The following considerations may be deduced from the previous 04.2 table:

- Carbon and stainless steel piping, both buried and contained in trenches or tunnels, share the same ageing mechanisms, with the exception of general corrosion and microbiologically-induced corrosion (MIC).
- General, crevice and pitting corrosions cause a loss of material on the external surface of both, carbon and stainless steels piping, regardless of whether or not they are in contact with the ground.
- General corrosion affects only carbon steel piping, regardless of whether or not they are in contact with the ground, and MIC affects piping made of both types of steel if they are in contact with the ground.

Once the ageing mechanisms and effects affecting piping indicated above have been identified, their management is accomplished by means of one or several ageing management programmes (AMP's).

The AMP assigned by each Spanish plant for the management of ageing mechanisms and effects affecting the external surface of concealed piping is based on the revised version of AMP-XI.M41 "Buried and Underground Piping and Tanks", included in LR-ISG-2015-01, which is generally known as 'Surveillance and inspection of buried and inaccessible piping'.

In the case of the Ascó and Vandellós II plants, and in addition to AMP-X1.M41, a plant AMP based on the revised version of AMP-XI.M36 "External Surfaces Monitoring of "Mechanical Components", included in LR-ISG-2012-02 is used. This AMP known as Monitoring of external surfaces", is used for underground piping included in galleries or similar constructions restricted access.

The scope of AMP.XI.M36 referring to this chapter will include only restricted access piping (in contact with the air). The Almaraz and Trillo plants, on the other hand, use the risk-based methodology in accordance with guideline NEI 09-14 "Guideline for management of underground piping and tank integrity", revision 3, and the programme BPWorks 2.1.

Listed below are the AMP´s applicable at each Spanish plant:

- Ascó and Vandellós II plants s:
  - AMP-19 "Surveillance and inspection of buried and inaccessible piping", for buried piping.
  - AMP-27 "Monitoring of external surfaces", for underground piping in accessible galleries or in galleries with non-routine or restricted access.
- Almaraz and Trillo plants: AMP-23 "Surveillance and inspection of buried piping".
- Cofrentes plant: AMP-029 "Inspection of outdoor piping (underground and surface-mounted/air piping)".

The documentation used to perform the detailed analyses of the ageing mechanisms and effects, for the external surface of this type of piping, is based on a number of reference documents, the following being especially significant:

- **EPRI-1021175** "Recommendations for an Effective Program to Control the Degradation of Buried and Underground Piping and Tanks", December 23, 2010.

- **NFPA-25** "Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems", 2008.
- **NACE SP0169** "Control of External Corrosion on Underground or Submerged Metallica Piping Systems", 2007.

Additional documentation has been also taken into account, depending on the characteristics of each plant, such as the document EPRI-3002000596 "Cathodic protection application and maintenance guide", Vol. 1, Buried Piping, 2013, used by the plants fitted with cathodic protection systems (CPS), this being the case at Ascó and Almaraz NPP's.

04.1.2.2. Internal surface

Table 04.3 shows the ageing mechanisms and effects considered at each Spanish plant applicable to the concealed piping steel type and internal environment.

This table uses the symbol "x" if the applicable NUREG-1801 [1] programme is AMP.XI.M41 (buried and inaccessible piping) and the symbol "o" if the applicable programme is AMP.XI.M36 (external surfaces).

MATERIAL	INTERNAL ENV.	MECHANISM	EFFECT	VA2	AS	AL	TRI	COF
Carbon steel	**demineralised water**	**general corrosion**	**loss of material**	x o	o	x		x
		crevice corrosion						
		pitting corrosion						
		erosion *only AS and VA2*						
		galvanic corrosion *only COF*						
	gasoil	**general corrosion**		x o	x o	x	x	x
		crevice corrosion						
		pitting corrosion						
		microbiologically-induced corrosion (MIC) *Only TRI and AL plant.*						
	CO_2 and FE-13	**general corrosion**			x			
		crevice corrosion						
		pitting corrosion						
		general corrosion and fouling						
	raw water	**general corrosion**		o		x	x	x
		crevice corrosion						
		pitting corrosion						
		erosion *only TRI and AL*						
		aqueous under-deposit corrosion (localized wet corrosion) *only TRI and AL*						
		microbiologically-induced corrosion (MIC)						
	air	**general corrosion**			o			
		crevice corrosion						
		pitting corrosion						
Stainless steel	**treated water**	**crevice corrosion**						x
		pitting corrosion						
	air	**crevice corrosion**			o			
		pitting corrosion						
	borated water	**general corrosion**		x o	o			
		crevice corrosion						
		pitting corrosion						
		stress corrosion cracking (SCC)	**cracking**					

Table 04.3. Ageing mechanisms and effects. Internal surface.

As regards the ageing mechanisms that might occur on the piping internal surface, indicated in table 04.3, it may be deduced that general, crevice, pitting and MIC corrosion are the predominant mechanisms causing loss of material at the Spanish plants. MIC corrosion affects only the carbon steel of piping carrying raw water or gasoil. It should be pointed out that, in this type of piping, only those made of stainless steel and carrying borated water are affected by cracking.

The AMP's assigned for the management of these effects and mechanisms affecting the internal surface of concealed piping vary from one plant to another. Table 04.4 shows the NUREG-1801 [25] ageing management programmes (AMP's) used as a model for the different programmes applied at the Spanish plants.

NUREG-1801 AMP's applicable to the INTERNAL surface	VA2	AS	AL	TRI	COF
AMP.XI.M2 Water Chemistry	x		x		x
AMP.XI.M17 FAC & LR-ISG-2012-01[2]	x				x
AMP.XI.M20 Open-Cycle Cooling Water System		x	x	x	
AMP.XI.M26 Fire Protection (dry)		x			
AMP.XI.M27 Fire Water System & LR-ISG-2012-02	x	x	x	x	x
AMP.XI.M30 Fuel Oil Chemistry	x		x	x	x
AMP.XI.M32 One-Time Inspection	x		x	x	
AMP.XI.M38 Inspection of Internal Surfaces in Miscellaneous Piping and Ducting Components & LR-ISG-2012-02		x			

Table 04.4. AMP's used for the management of the internal surface of concealed piping.

The fluid circulating inside concealed piping determines, commonly, the applicable AMP for the management of the ageing mechanisms and effects applicable to its internal surface.

For example, in the case of piping transporting gasoil, AMP.XI.M30 is used for the monitoring of the fuel-oil chemistry, to allow the control of degradation of the internal surface, regardless of whether the piping in question is surface-mounted/aerial, underground or buried.

As may be seen in table 04.4, between the eight ageing management programmes applicable for the monitoring and control of the internal surfaces of concealed piping, only the AMP corresponding to the FP system (water) is applicable at all the plants.

[2] FAC = Flow-Accelerated Corrosion.
LR-ISG-2012-01 "Wall Thinning Due to Erosion Mechanisms".

AMP.XI.M32 programme “One-time Inspection” is used to verify the effectiveness of other AMP’s which, in this case, would correspond to the water and fuel-oil chemical programmes.

The activities associated with the management of ageing mechanisms and effects shown in table 04.4 are mainly preventive (monitoring and control of the chemistry of the fluids in each system) and as well periodical inspections, in accordance with the provisions of NUREG-1801 [25] or the LR-ISG documents issued by the NRC.

04.1.2.3. Operating experience

The review of the plant-specific and industry operating experience is incorporated in the systematic process of ageing management at the Spanish plants, as shown in chapter 02 of the present report.

As described above, the Spanish plants periodically analyse a series of previously selected industry operating experience documents with the objective to complete and verify the consideration of the events identified in the ageing management base documentation.

Spanish NPP’s and the CSN participate in the NEA’s CODAP “Component Operational Experience, Degradation and Ageing Programme” project, included in table 02.1, and the CODAP events are taken into account, as industry operating experience, with regard to their interest for the in-service inspection and piping ageing management programmes.

Based on their analysis of this documentation and for the specific case of concealed piping, the Spanish plants consider that the AMP´s currently implemented are suitable for the management of the identified significant ageing mechanisms and effects, consequently the possibility of a loss of the system intended functions have being reduced.

Furthermore, as described in section 04.4 of this chapter, the review and assessment of plant-specific operating experience has allowed the plants to confirm to date the suitability of concealed piping programmes.

The operating experience relating to concealed piping is included in the periodic AMP tracking reports corresponding to each plant (buried and inaccessible piping AMP and external surfaces AMP), in which its applicability is analysed by the plant responsible person for each AMP .

04.1.3. Monitoring, testing, sampling and inspection activities for the concealed piping

In this section the monitoring, testing, sampling and inspection activities affecting concealed piping are separated, depending on whether they are applicable to external or internal surfaces.

04.1.3.1. External surface

The activities applicable at each plant for the management of those ageing mechanisms that might potentially affect the external surface of concealed piping are summarised in table 04.5.

This table uses the symbol “x” if the applicable NUREG-1801 [1] programme is AMP.XI.M41 (monitoring of buried and inaccessible piping) and the symbol “o” if the applicable programme is AMP.XI.M36 (monitoring of external surfaces).

As may be observed in this table, the activities relating to both programmes are diverse, and vary from one plant to another depending on the scope of their programmes and the characteristics of the piping. For example, at the Ascó plant, visual inspections are performed, either when the opportunity arises, opportunistic inspections are conducted by visual examination of the external surface of pipe or coatings, using samples of buried pipes, or are scheduled in the case of pipes in trenches or similar elements (non-buried restricted access piping) or in the case of accessible sections such as piping manholes. Also the FP water system pressuriser pump is monitored and flow tests are carried out for the detection of leakage. However, at the Cofrentes plant only visual inspection is performed on 100% of the piping, as this plant’s programme includes only piping located in trenches with removable covers in their entire route.

	EXTERNAL SURFACE ACTIVITIES AMP.XI.41	VA2	AS	AL	TRI	COF
a	**Monitoring of Fire Protection pressuriser pump**	x	x			
b	**Opportunistic direct inspections**	x	x		x	
c	**Flow/ pressure tests**	x	x	x		
d	**Cathodic Protection System**		x	x		
e	**Visual inspections of accessible sections**		x	x		
f	**Visual inspections prior to long-term operation**		x	x	x	
g	**Groundwater inspection**			x		
h	**Inspection for piping run indications**			x		
i	**Visual inspection of piping in trenches or similar**	o	o			x

Table 04.5. Monitoring, inspections or tests associated with the concealed piping programme. External surface.

Described below are the activities identified in the preceding table activities, (a to i) with detailed information on the monitoring, testing or inspection method, its frequency and the corresponding acceptance criteria:

a. Monitoring of Fire Protection System pressuriser pump

- Monitoring of the number of start-ups and operating time of the pressuriser pump (checking for leakage).
- Frequency: continuous or monthly.
- Acceptance criteria: An evaluation is performed of any variation in the functioning of the pressuriser pump. The personnel performing the evaluations must be qualified to determine whether there are any anomalies in the operation of the FPS system pump.

For instance: the following criteria should not be exceeded every 12 hours, unless there is a known situation:

- Maximum 2 start-ups.
- Maximum 15 minutes of pump operation per start-up.

b. Opportunistic direct inspections

- Direct visual inspection made by qualified personnel of the backfill and coating materials of buried piping, that become accessible for whatever reason. If indications are detected, the inspection is extended to the line itself.
- Frequency: There is no established frequency since, by nature, these inspections are carried out whenever the opportunity arises.
- Acceptance criteria:
    - Backfill: The backfill material of piping trenches should fulfil the conditions indicated in the design specifications of the site. The backfill will not be acceptable if damage caused by it, is observed in the piping or its coating.
    - Coating: Coatings will be acceptable as long as the continuity of the covered surface is maintained; i.e., there is no exposed base metal. Small blisters will be acceptable as long as they are few in number, are completely surrounded by coating in good condition, are connected to the substrate and are fully justified.
    - Base material and welds/joints: No signs of corrosion or loss of material will be acceptable. If such indications exist, an analysis will be required to assess the condition of the component.

c. Flow/ pressure tests

- Periodic pressure testing on a test volume, corresponding to a given percentage for each type of material (carbon steel and stainless steel), at 110% of the design pressure of the piping section to be tested, during 8 hours, in order to assess the integrity of the system and the leaktightness of welded accessories.
- Frequency: Every 5 years on 25% of the sample selected, distributed more or less homogeneously.
- Acceptance criteria: The test will be considered acceptable if there are not indications of leakage not attributable to the boundary valves, or there is not a decrease in the pressure of the inspected volume.
- In the case of Ascó plant, this is a flow test for the detection of the FP systems (water and dry) leakages.

d. Monitoring/surveillance of cathodic protection

- Reading of current and voltage parameters in rectifier boxes, consumption measurement at anodes and potential measurement at test stations.
- Frequency:
    - Measures are taken of the consumption of the anodes and potentials in the test stations every two months in the case of the Ascó plant, and the effectiveness

of the cathodic protection is verified quarterly and annually in the Almaraz plant.

  - Overall inspections: annual.

- Acceptance criteria: in the case of Ascó plant, the cathodic protection is acceptable if 2 of the following criteria are fulfilled:
  - Measurement of potential, in areas at a specifical distance from the cathodic structure and in areas close to it.
  - Measurement of potential with respect to the natural value (cathodic protection system out of service).
  - Checking of current input in test pieces.
  - Measurement of depolarisation in test pieces one hour after disconnection from the structure.

  According to the recommendations of the applicable standard, NACE SP0169-2007, cathodic protection is considered suitable as long as the measurements of potential are within the expected values.

e. Visual inspection of accessible sections

- Inspection of the accessible piping sections inside manholes or in the entry points of aerial piping sections in buried areas, in order to:
  - Identify submerged areas and/or possible leakage from buried piping (humidity on manholes walls, oxidation stains from wall reinforcements, flooded manholes, etc.).
  - Identify problems in accessible sections of piping inside manholes (external surface of the piping corroded or rusted in penetration area, etc.).
- Frequency: every 5 years.
- Acceptance criteria: engineering criterion.

f. Visual inspections prior to long-term operation

- Before the plant initiates long-term operation (LTO), direct visual inspections (sampling) are performed on buried pipes to check on their condition. A sample inspection is carried out on one or more piping sections, in which at least 3 metres of the uncovered pipe, the general condition of the ground, and the presence of humidity or particles from the protective coating, are checked. Connections and bolts are also checked with a view to detecting any imperfections.
  - If, following the visual inspections, the protective coating in any area of the line is discovered to have lost its intended function, volumetric inspections are performed.
- Frequency: every 10 years at a selected piping points (sample).
- Acceptance criteria:
  - Acceptable: if there are no signs of degradation, loss of material or corrosion.

- Acceptable with deficiencies: when signs of degradation are identified but there are no signs of corrosion or significant loss of material. Those deficiencies shall give rise to corrective actions in the medium term.
- Unacceptable: if degradations are detected. In general, an analysis by qualified personnel is required to evaluate the condition of the component and define short-term corrective actions.

g. Underground water inspections

- Checking that water tables phreatic level in water tables and chemical parameters are suitable.
- Frequency: the chemical analysis of underground waters is performed every 3 months.
- Acceptance criteria: the chemical parameters of the underground waters must be within the expected values according to the plant procedures.

h. Inspection for piping run indications

- Inspections of the conditions of the ground surface above the buried piping run locations, to detect signs of humidity, subsidence, etc.
- Frequency: 3 years are required to cover the entire piping run.
- Acceptance criteria: each indication identified in the piping run shall be assessed independently.

i. Visual inspection of piping in trenches or similar

- Visual inspection of the external surface of 100% of piping installed in trenches or similar locations with restricted access, in areas where the trench is fitted with removable covers.
- Frequency: Each two or five years, depending on the plant. This frequency may be modified, up to once every ten years, by means of a safety assessment based on the results of previous inspections.
- Acceptance criteria:
    - Acceptable: piping not displaying any of the signs of degradation indicated in table 04.2. For example, piping with painted surfaces, is considered to be acceptable when the continuity of the entire coating or layer of paint is maintained across the surface of the piping t treated (absence of base metal exposed to the atmosphere or outside air).
    - Acceptable with deficiencies: when the piping does not meet the requirement described above but, following a subsequent assessment or complementary test (VT-1, UT, etc.), it is determined that the defects detected, will not compromise piping functionality and/or integrity during the period remaining until the next inspection.
    - Unacceptable: when the piping does not fulfil its function or the defects detected will compromise its functionality and/or integrity during the period remaining until the next inspection.

All the results of the previous activities are recorded for the performance of periodic transversal assessments and trend analyses (e.g., pressuriser pump operating times) making it possible to identify incipient degraded conditions and implement actions up front.

04.1.3.2. Internal surface

The management of the degradation of piping internal surfaces, is accomplished in accordance with the methodology described in the model programmes of NUREG-1801 [25], depending on the nature of the fluids running through the concealed piping included in the scope of the ageing management review.

Table 04.6 shows the AMP's of NUREG-1801 [25] or the LR-ISG's used as a basis for developing the AMP's associated with surveillance of the internal surface of the concealed piping systems applied by the Spanish plants.

AMP.XI / SYSTEMS	M2 Water chemistry	M17 FAC & LR-ISG-2012-01	M20 Open-Cicle Cooling Water System	M26 Fire Protection (dry)	M27 Fire Water System & LR-ISG-2012-02	M30 Fuel Oil Chemistry	M32 One-Time Inspection	M38 Inspections of Internal Surfaces in Miscellaneous Piping and Ducting Components & LR-ISG-2012-02
Auxiliary feedwater	X						X	
Condensate Storage & Transfer	X				X		X	
RWS - Refuelling Storage Water	X						X	
EDG Fuel Storage & Transfer						X	X	
Fire Protection (water)		X			X			
Fire Protection (dry) **(CO2 and FE-13)**				X				X
Demineralised Water	X							
High Pressure Core Spray	X							

AMP.XI / SYSTEMS	M2 Water chemistry	M17 FAC & LR-ISG-2012-01	M20 Open-Cicle Cooling Water System	M26 Fire Protection (dry)	M27 Fire Water System & LR-ISG-2012-02	M30 Fuel Oil Chemistry	M32 One-Time Inspection	M38 Inspections of Internal Surfaces in Miscellaneous Piping and Ducting Components & LR-ISG-2012-02
RCIC – Reactor Core Insolation Cooling	X	X						
Essential Services Water			X					

Table 04.6. AMP.XI applicable to the internal surface by systems within the scope

As regards control, inspection and mitigation activities, frequencies and acceptance criteria for the ageing mechanisms postulated for the internal surface of pipings included within the scope of this programme, it may be pointed out in general that:

The water and fuel oil chemistry preventive programmes, follow the latest revision of the EPRI chemistry guidelines[3], and the standards ASTM D 4057-95 "Standard Practice for Manual Sampling of Petroleum and Petroleum Products", ASTM D 6304-04 "Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils and Additives by Coulometric Karl Fischer Titration", ASTM D 2276-00 "Standard Test Method for Particulate Contamination in Aviation Fuel by Line Sampling" and ASTM D 2709-96 "Standard Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge", respectively, as is established in NUREG-1801 [25].

Likewise, the objective of the inspections performed on piping internal surfaces, is to monitor the integrity of either the coating or the base material through the performance of visual and, where necessary, volumetric inspections on the basis of the applicable codes ASME XI and ANSI B31.1.

The control of biological soiling, by means of periodic chemical inspection and analysis, of concealed ESW piping in channels/vaults/tunnels, is accomplished in accordance with the recommendations of GL 89-13.

The surveillance of the internal surfaces of FP system piping is based on different NFPA standards, on the specifications of each plant and on RD 1942/93 (Regulation governing FP facilities, national standards) and consists on the continuous monitoring of the system pressure, the cleaning of collectors, periodic flow testing, periodic functional testing, visual inspections and ultrasonic thickness measurement in certain piping sections.

[3] BWR: BWRVIP-190 (EPRI-1016579) & PWR: EPRI-1014986 "PWR Primary Water Chemistry Guidelines" y EPRI-1016555 "PWR Secondary Water Chemistry Guidelines".

In addition, visual inspections are performed on a representative sample of components, including piping, with the objective to check either that certain ageing effects do not occur or that, if they do, they develop so slowly that will not affect the intended functions of the piping during LTO.

04.1.4. Preventive and corrective actions for concealed piping

Described below are the preventive activities and corrective actions, applicable to the external or internal surface of piping within the scope of this chapter. This is accomplished in a general manner, considering the common practices at the Spanish plants.

04.1.4.1. External surface

Management of the loss of material from the external surfaces of steel and stainless steel piping included within the AMR scope, resulting from generalised corrosion (in carbon steel only) or microbiological, interstitial or pitting corrosion are accomplished by means of preventive measures (inspecting the coating, backfill and the type of soil), pressure testing, monitoring of the FP pressure pump and FP system leakage and opportunistic visual inspection of the piping.

These preventive actions assess aspects such as the following:

- Coating and Backfill materials specifications, in accordance with table 1 of LR-ISG-2015-01.
- Need for a Cathodic Protection System depending on the following:
  - the aggressiveness of the soil (concentration of sulphates and chlorides),
  - the measurement of the mean resistivity of the ground, and
  - the exhaustive assessment of adverse operating experience.
- Backfill characteristics, with assessment regarding appendix B of LR-ISG-2015-01 (granulometric limits and properties).
- Surveillance of water accumulation in trenches containing this piping and checking of the operability of the drainage pumps and devices installed for its removal.

The acceptance criteria vary depending on the AMP of each Spanish plant; nevertheless, they are described, for the purposes of guidance, in section 04.1.3.1 on monitoring, testing, samplings and inspection activities for the external surfaces of concealed piping.

The corrective actions of programmes managing the external surface of buried piping consider the following:

- Hydrostatic and leakage testing: performance of appropriate engineering analyses to assess the root cause and, where appropriate, define the actions to be taken to ensure piping system operability (sample-based inspections), assessment of the impact on other systems under identical conditions, etc.). If sample-based inspections of the external surfaces of the lines are required, these are carried out in accordance with the opportunistic inspection criteria.

- If replacement or repair of the piping is required, this shall be performed in accordance with the ASME XI or ASME B31.1 design code, as applicable.
- Monitoring of the pressuriser pump: In the event of leakage, an engineering analysis shall be performed based on the system leakage history, type of ground and, in general, whatever plant information that might help to determine the actions to be implemented to restore the system pressure boundary (application of underground leakage detection techniques, sample-based inspections, etc.). If sample-based inspections of the external surfaces of lines are required, these shall be performed in accordance with opportunistic inspection criteria.
- Direct opportunistic inspections:
  - Backfill: If damage of the backfill is detected, an assessment shall be performed to check whether this circumstance is an isolated issue or is generalised for the piping included within the scope. The conclusions of this assessment will serve as operating experience within the programme and as information for future assessments.
  - Coating: Cleaning of the area in which the discontinuity has been detected in the pipe coating and visual inspection of the base metal and uncovered welds. Replacement of the coating in accordance with the specifications of the plant.
  - Base material and welds/joints: Detailed inspection of the affected area, circumscribing the indication by means of ultrasonic inspections (UT) and assessing the acceptability of the pipe on the basis of the design code (ASME III or ASME B31.1).

    A root cause assessment should also be performed in order to determine whether or not there is a need for an extension of the visual inspections required for the piping included in the scope. The extension criteria will depend on the result of the assessment.

Additionally, if degradations are detected in the pipes inspected, an engineering assessment shall be performed in order to determine whether such degradations are applicable to other non-inspected pipes, such as interfered pipes, and determine where necessary, the actions to be taken to check the condition of these pipes.

Any defects in the inspected piping will require a subsequent assessment or a complementary test (VT-1, UT, etc.) to determine whether, in accordance with the applicable acceptance criteria, these defects will or will not compromise the functionality and/or integrity of the piping during the period prior to the next inspection.

In the case of painted piping, the actions to be applied shall consist of cleaning the affected area and visually inspecting the uncovered base metal. Subsequently, the pipe coating should be repaired in accordance with the applicable technical specification.

As regards characterisation of the risk, for piping included in the AMP for the Almaraz and Trillo plants (based on AMP.XI.M41 and NEI 09-14 & BPWorks2.1), consideration is given to the quality of the backfill material in contact with the buried piping. This backfill should be compact and present suitable characteristics, without excess grass, roots or other vegetation.

04.1.4.2. Internal surface

The preventive actions for management of the ageing of the internal surface of concealed piping are based on the corresponding AMP.XI of NUREG-1801 [25] applicable to each system and plant in accordance with table 04.6.

The main preventive actions for each AMP.XI programme are as follows:

AMP.XI.M2 Water Chemistry

This programme includes the periodic surveillance of the chemical parameters and the control of chemical species causing harmful effects, for which reason their concentration in water is maintained below certain threshold values, thereby preventing corrosion and stress corrosion cracking (SCC).

The programme includes specifications for chemical species, sampling frequencies and analysis and corrective actions for the chemical control of the reactor water. The chemistry of the water in the system is controlled in order to minimise the concentration of contaminants, and mitigate the loss of material due to generalised, crevice and pitting corrosion, as well as the initiation and propagation of cracks caused by SCC.

The water chemistry control programme for Boiling Water Reactors (BWR) is based on the monitoring and control of the chemistry of the reactor water, in accordance with the provisions of the Boiling Water Reactor Pressure Vessel and Internals Project BWRVIP-190 (EPRI-1016579). This BWRVIP-190 project provides three types of guidance: one for the primary water, another for condensate and feedwater system and a third for the Control Rod Drive Mechanism (CRDM) cooling water.

The water chemistry control programme for Pressurised Water Reactors (PWR) is based on the monitoring and control of the chemistry of the reactor water, in accordance with the industry provisions for the chemistry of the primary and secondary water defined in the EPRI guidelines, PWR Primary Water Chemistry Guidelines (EPRI-1014986) and PWR Secondary Water Chemistry Guidelines (EPRI-1016555), respectively.

AMP.XI.M17 FAC & LR-ISG-2012-01

The objective of this programme is to manage the loss of material due to flow-accelerated corrosion (FAC), by means of periodic wall thickness measurements performed using ultrasonic testing on a sample of piping areas and systems equipment susceptible to degradation mechanisms caused by FAC. This is an analysis, inspection and verification programme, as a result of which no preventive actions are performed.

On the other hand, the Spanish plants perform the control of the parameters of the water, with a view to using them as input data for prediction of loss of thickness rate, by means of codes such as COMSY or Checkworks. The results obtained allow the plants to define the inspections programmes and to take decisions regarding the replacement of piping affected by the phenomenon of erosion-corrosion.

AMP.XI.M20 Open-Cycle Cooling Water System

The preventive measures imply the control of the chemistry of the water in the systems and the monitoring of its corrosion. For example:

- The Trillo plant, modified its water system chemistry with chemical additives (corrosion inhibitors, biocides and dispersing agents) to prevent corrosion.
- The Almaraz plant controls biological fouling of piping of the essential services water system, through periodic inspections and chemical analysis, in accordance with the recommendations of GL 89-13.

Chemical analyses are also performed on samples of water coming from the river, in order to identify modifications to the physical-chemical parameters and check for the absence of macro-organisms. Furthermore, the Almaraz plant periodically puts into service the redundant loops of the EW system, in order to prevent the accumulation of sediments.

AMP.XI.M27 Fire Water System & LR-ISG-2012-02

The objective of this programme is to ensure, that no significant ageing mechanisms occur, as a result of generalised and micro-bacterial corrosion in the Fire Protection water systems, for which periodic blowdown flushing operations and functional tests are performed in accordance with the recommendations of NFPA-25.

By way of an example, for concealed piping, the Vandellós II plant performs periodic FP loop and hydrant blowdown flushing operations as a preventive measure, this being carried out at a frequency of 3 years, and periodic functional tests in accordance with NFPA-25, in order to ensure the correct functioning of the system.

AMP.XI.M30 Fuel Oil Chemistry

The programme reduces the possibility of exposure of the internal surface of the fuel oil storage tank to be contaminated with microbiological water organisms, thereby reducing the possibility of ageing-related degradation of the piping and other components exposed to fuel oil; and of the transport of corrosion products, sludge or particles to components fed by the fuel oil storage tanks. As a preventive measure, all the plants, except Vandellós II and Cofrentes, add biocides and corrosion inhibitors, although this action is also carried out if the periodic analyses show biological activity or signs of corrosion. Another measure considered to be efficient for mitigating the corrosion produced inside fuel oil tanks is their periodic cleaning, since this makes it possible to remove sediments. and drain the water present in the tank bottom, minimising the quantity of water and contact time.

04.2. Licensee's experience of the application of AMPs for concealed piping

The Spanish plants analyse the results of the activities performed in the AMP's in order to identify whatever expected and unexpected ageing effects for concealed piping, have been experienced at the plant, and to assess the effectiveness of the AMP's.

The AMP´s tracking reports deal with both, plan-specific and industry operating experience and its effects on the activities included in the AMP in question.

Consequently, the assessment of the AMP activities results, the analysis of the results trends, the suitability of the samples and the historical data obtained since AMP initial implementation, provide conclusions regarding the effectiveness of the programme and compliance with its expectations and the tasks foreseen.

As a result, the Spanish plants obtain improvement proposals that, following analysis, may lead to modifications to the AMP's, its scope, its supporting documents (procedures, schedules, etc.) and its activities (inspection methods, etc.). The improvement proposals require tracking up to implementation and are consequently managed within the framework of the plant corrective actions programme.

Before going on to deal with the specific experience of each plant in relation to concealed piping, it should be pointed out that in view of the generalised ESW system corrosion event that occurred in 2004 at Vandellós II plant[4], following which this plant installed a new ESW system. The rest of the plants in response to CSN requirements, carried out an "Action Plan" implying a significant development of their concealed piping surveillance and control practices.

Among other activities, the CSN required the following from the plants:

- Elaborate a list of safety-related or significant risk systems, including Bonna type buried or underground piping, susceptible to corrosion.
- Identify which of these systems were included in the In Service Inspection (ISI) programme or were subject to other surveillance activities.
- Perform visual inspection of all accessible pipes, proposals for alternative surveillance for inaccessible pipes and the creation of a suitable action plan for non-monitored piping systems.

With the exception of Vandellós II, the Spanish plants are not located next to the sea and, as a result, are not exposed to particularly aggressive environmental conditions.

As regards monitoring, inspections and testing activities, the Spanish plants included ultrasonic thickness measurements in order to ensure that the monitoring was enough to prevent corrosion in nuclear Class 3 piping systems and, in certain cases, additional specific programmes were carried out on the ISI programme based on ASME XI, which included visual inspections and ultrasonic thickness measurements of risk-significant non-nuclear class piping systems, such as the Fire Protection system.

As a result of the previously mentioned Action Plan required by CSN, the Spanish plants performed visual inspections on piping located in trenches, manholes and galleries to detect the presence of water and, where necessary, carry out ultrasonic piping thickness measurements.

Corrective measures such as the following were performed at all the plants as a result of the application of this Plan:

[4] IRS-7663 CIRCUMFERENTIAL BREAK OF ESSENTIAL SERVICE WATER (ESW) PIPE AT VANDELLÓS 2 NPP WHILE OPERATING AT RATED POWER. Date of Receipt: 2004-12-09. Last updated on 2005-06-27.

- cleaning and painting of outdoor carbon steel piping, that was either not painted or had a degraded protective layer,
- replacement of piping sections with others made of more corrosion-resistant materials,
- removal of buried piping,
- improvement of surveillance and control activities:
    - improvement of internal or external visual inspection methods,
    - new leak testing parameters, and
    - performance of scheduled or opportunistic sampling for visual inspection.

As regards the Cathodic Protection System, the two Spanish plants that are equipped with such a system incorporated enhancements to improve its effectiveness.

In relation to experience specific to concealed piping surveillance activities, the following events are shown below, plant by plant:

Vandellós II NPP
There have been no events relating to buried stainless or carbon steel piping in the last 10 years.

Nevertheless, in 2005, as a result of the aforementioned CSN Action Plan, corrosion was detected in sections of buried piping corresponding to the Fire Protection System. For this reason the system loop was modified, such that most of its pipes now run through galleries and are made of stainless steel. In those cases in which the piping run has remained buried, the piping material has been changed to high density polyethylene (HDPE).

Ascó NPP
In 2015, a leak of water was detected in a buried section of piping corresponding to the FP System, due to a pitting type perforation. The defect was characterised by means of a volumetric inspection and no generalised degradation of the internal surface of the piping was observed. The leak was finally repaired by means of a welded band.

Almaraz NPP
As a result of the measurements obtained by means of the Cathodic Protection System to check the status of the monitored piping, an assessment is currently being carried out in order to determine whether or not any modification needs to be performed on the protection of areas having a potential of less than +850mV.

During the period 2007 to 2011, the direct visual inspections performed following sampling of sections of FP System piping revealed only superficial oxidations that did not affect the integrity of the piping. In 2010 two buried lines were detected with generalised corrosion of the metallic parts on the interface (aerial-buried) locations of the system. The corrective actions applied consisted of the cleaning and painting of the affected sections.

Trillo NPP

Sampling performed in 2011 led to the detection of localised corrosion-induced loss of material in a piping section of the FP System, in the form of small circular perforations. Additionally two sampling performed that same year found two leaking pipes in the same system. In both cases the corrective actions consisted on replacing the piping.

In 2009, 2010, 2014 and 2015, small localised areas were observed, in certain unearthed buried sections of the FPS piping showing signs of deterioration on the coating and slight surface oxidation, without any loss of material. The piping surfaces were cleaned and subsequently painted.

In 2015, one sample was performed in order to locate a leak in buried FPS piping. The degraded section was subsequently replaced.

Cofrentes NPP
There have been no events relating to buried stainless or carbon steel piping in the last 10 years.

From the analysis of all this operating experience it may be deduced that, no ageing effect or mechanism has been detected affecting the concealed piping at the Spanish plants, that had not been previously identified as result of the AMR process or in the industry operation experience.

04.3. Regulator’s assessment and conclusions on ageing management of concealed piping.

Regarding the process of ageing management of concealed piping the CSN considers that the Ageing Management Programmes applied by the Spanish plants, its scope and main activities which have been dealt with in this chapter, are adequate.

For the tracking of these AMP´s, the CSN performs two-yearly inspections on Overall Ageing Management Program (OAMP) of all the plants in accordance with the Basic Inspection Plan established. These inspections, performed at the plant sites and developed in accordance with CSN procedure PT.IV.223, include checks on documentation and implementation of a sample of the AMP’s in-situ at each plant, and also those corresponding to concealed piping

Likewise, an analysis is performed on the annual ageing activities report, submitted to the CSN by the Spanish plants, in response to requirements of IS-22 [21], describing the activities of the OAMP and the specific results of each AMP application.

The latest CSN inspections carried out at each of the Spanish plants, in 2016 and 2017, included a review of the implementation level of the AMP’s applicable to concealed piping and their results.

As has been pointed out above, the CSN inspections include checks on the documentation supporting each AMP, on the status of the corresponding improving proposals, and on the AMP exceptions to the corresponding model AMP on NUREG-1801 [25].

These CSN inspections showed that the samples selected for the visual inspection of buried Fire Protection System piping were not effective, since there have been repeated issues of leakage or degradation detected via indirect methods, such as monitoring of the jockey pump or indication-based inspections, in the Almaraz and Trillo plants.

This plant-specific operating experience led these plants to modify their AMP activities associated with monitoring of the FP system piping, in accordance with NEI 09-14. This methodology, developed by EPRI, classifies buried piping on the basis of risk and uses the BPWorks software. Although this methodology has been widely used at US nuclear power plants with good results, its effectiveness has not yet been demonstrated at those Spanish plants that have opted for it.

It has been detected that, on occasions, the performance of corrective actions by the plants, was not prioritised in such a way as to guarantee suitable management of the degradations detected. Nevertheless, in any case that degradation issues have compromised the safety function of the affected piping.

Although the development of the concealed piping AMP's has now been completed, the grade of implementation of its activities varies from one plant to another. Base on the CSN assessments and inspections, the AMP's defined are generally operating in an acceptable manner, and are accomplishing their mission of monitoring and controlling the ageing mechanisms and effects in this type of components. Nevertheless, the CSN has requested that the licensees fully implement all the activities included in the concealed piping applicable AMP's, before initiating long-term operation.

As regards buried piping embedded in concrete, or piping penetrating walls, for which any ageing effect in their external surface has not been identified as a result of the AMR process, the CSN considers that licensees must perform an in-depth analysis of this issue. Therefore the plants will verify, through unique inspections, the non-existence of aging effects, through visual examinations of the pipe in the transition area where the pipes penetrates the concrete.

A potential weakness is the difficulties found in the inspection of buried piping, due to the difficulty involved in identifying the routes followed by the piping and, on the other hand, to lack of knowledge on the characteristics of the backfill and coating materials used during construction of the plant. This aspects complicates the selection of sampling locations, making it difficult to guarantee that the samples will be effective for the identification of piping degradations. To improve the knowledge of the backfill and coatings of the piping, the CSN proposes to increase the number of programmed visual inspections (by samples).

05. Reactor pressure vessels

05.1. Description of ageing management programmes for RPVs

As has been pointed out in chapter 02 of this report, several programmes are in place at the Spanish nuclear power plants for management of the ageing of passive and long-lived components. Some of these programmes refer specifically to the reactor vessel.

The definition process and main characteristics of these programmes are described in the following sections of this chapter.

05.1.1. Scope of ageing management for RPVs

The reactor vessel is a basic component included in the Overall Ageing Management Programme (OAMP), since the integrity of the pressure boundary is one of the intended functions that must be ensured, and furthermore it fulfils the screening criteria for being included in de OAMP, since it is a passive and long-lived component.

As has been indicated in section 01.1 of this report, there are seven nuclear power plants in operation in Spain, corresponding to three different designs. For this reason, a brief description of the most outstanding characteristics of the reactor vessels is included, these being grouped on the basis of the plant design technology.

Westinghouse (W) design PWR vessel

- Reactor: **Ascó I and II NPP, Vandellós II NPP and Almaraz I and II NPP**
- The RPV is cylindrical with a hemispherical bottom head and a flanged and gasketed upper head. The shell is manufactured by material plates, specified by American Society for Testing and Materials (ASTM) SA-533 Grade B, Class 1, which are joined by means of longitudinal and circumferential welds. The hemispherical lower head (bottom head) is joined to the cylindrical part by means of a circumferential weld.
- At the upper side of the RPV there is a removable hemispherical head (vessel closure head) that is joined to the vessel shell by means of the closure flange and bolts.

  At all the aforementioned plants, with the exception of Ascó NPP unit 1, the original component has been replaced by a new design.

  The main characteristic of the new design is the use of nickel alloys less susceptible to Primary Water Stress Corrosion Cracking (PWSCC) mechanisms for the material of the control rod drive mechanism (CRDM) penetrations and its welds (J-Weld) to the vessel head (Alloy 690/52/152). Other characteristic is that closure head is manufactured of a single forged part, with the exception of the heads installed in the RPV of both units of Almaraz NPP, which have a circumferential weld between the upper dome and the flange.

  As regards the vessel closure head at unit 1 of Ascó NPP, it was replaced by one that had been manufactured for another Spanish plant, but had never been put into service. Unlike the new heads installed, in this case the material for the CRDM penetrations is Inconel 600/82/182.

- In the cylindrical part there are six nozzles, inlet (3) and outlet (3), manufactured of low alloy steel with a stainless steel cladding.
- In the lower head there are bottom-mounted instrumentation (BMI) nozzles penetrations. The BMI penetrations were constructed from Alloy 600 and connected to the reactor vessel lower head by an Alloy 82/182 J-groove weld.. There are usually fifty BMI penetrations.
- The inner surface has a stainless steel cladding measuring between 3 and 10 mm in thickness.

KWU design PWR vessel

- Reactor: **Trillo NPP**
- The cylindrical part of the vessel consists of forged rings of 20 MnMoNi 55 (a material similar to ASME SA 508, class 3) joined between them by means of circumferential welds. In the lower part of the vessel there is a hemispherical bottom head attached to the cylindrical part by welding.
- The RPV has six nozzles, inlet (3) and outlet (3), which are manufactured by low alloy steel with a stainless steel cladding, attached to shell with weld.
- The vessel closure head is made up of two parts, head and flange, joined by between them by a circumferential weld. The head is fitted with penetrations for the control rods and instrumentation, manufactured from a nickel-based alloy (Inconel or Incoloy), these being attached to the head by means of a conical pre-stressed thread with a sealing weld at the lower end. The vent orifice is made of austenitic stainless steel welded to the internal part of the head. The closure head and vessel are sealed by means of two concentric toroidal gaskets, with leakage channelled via two small diameter lines.
- The inner surface has a stainless steel cladding measuring between 3 and 10 mm in thickness.

General Electric (GE) design BWR vessel

- Reactor: **Cofrentes NPP**
- The cylindrical part of the vessel is made from SA-533 Grade B, Class 1 SA-533 ferritic steel sheets joined between them by means of longitudinal and circumferential welds, this being attached to the bottom head by means of a circumferential weld. The inner surface includes a stainless steel cladding.
- The vessel closure head is made from welded low alloy steel plates forming a hemispherical head that is attached to a flange by means of a circumferential weld. The closure head has two orifices for venting lines and is joined to the vessel by means of closing bolts, flange sealing being maintained by means of two concentric toroidal gaskets.

- Most of the existing nozzles are of Class 2 SA-508 type low alloy steel, although other materials are also used, such as SA-182 F304 stainless steel and SB-166 type nickel alloys.
- The bottom head is fitted with penetrations for the control rod drive mechanisms, as well as for the neutron flux monitors inside the vessel, which are welded to the inner part of the head.

Annex 1 of this chapter includes drawings of the most significant components of the reactor vessel described above.

The RPV components included within the scope of the aging management has been screened on the basis of the criteria of CSN Instruction IS-22 [21], which has as its reference the contents of the US standard 10 CFR 54 [23], and according to the methodology described in chapter 02 of the present report.

The main documentation used to determine the scope and screening is as follows:

- Plants' Final Safety Analyses Report.
- Design basis document.
- Systems description manuals.
- Component design and manufacturing documentation.

The reactor vessel components that perform the reactor coolant pressure boundary function, included in the aging management programme, are those shown below in table 05.1.

Vessel (PWR; W)	Vessel (PWR; KWU)	Vessel (BWR; GE)
CRD stroke housing	CRD stroke housing	CRD housings
Pawls housing	Pawls housing	Stub tubes
Closure head to vessel flange	Closure head to vessel flange	Nuclear instrumentation housings
CRD housing adapters flange	CRD housing adapters flange	Vessel shell
Intermediate/upper shell	Intermediate/upper shell	Bottom head
Vessel closure head (only Ascó I NPP and Almaraz NPP have weld)	Vessel closure head and weld	Vessel upper head
Bottom head	Bottom head	Closure head and vessel flange
Lower vessel in-core instrumentation penetrations	Vessel head vent line penetration	Nozzle-vessel welds
Vessel head vent line and RVLIS penetrations	Nozzle-vessel welds (inlet and outlet)	Nozzle-safe end welds
Nozzle-vessel welds (inlet and outlet)	Nozzle-safe end welds	Sealing ring leakage monitoring tube
Nozzle-safe end welds	Sealing ring leakage monitoring tube	Pressure boundary welds
Sealing ring leakage monitoring tube	Toroidal sealing gaskets	Nuts, bolts and washers
CRD housing and standby adapter tubes	Control rod nozzle bolts	
Thermocouple housing adapter tube	Vessel head instrumentation tube and control rod penetrations	
In-core instrumentation guide-tubes and seal table	Flux Thimble guide tubes	
Flux Thimble guide tubes	Nuts, bolts and washers	
Nuts, bolts and washers	Pressure boundary welds	
Pressure boundary welds		

Some of these components are shown in the simplified diagrams included in annex 1 of this report

Table 05.1

After the vessel components are determined within the scope of the AMP, the Spanish nuclear power plants follow the process established in IS-22 [21] to identify in each case the significant ageing effects and mechanisms that might affect compliance with their intended "pressure boundary integrity" function, for which they use different documentary sources including the existing industry and research experience. The main document used is NUREG-1801, along with all the references included in it and relating to the ageing management programmes applicable to the vessel. Other documents published by EPRI and the IAEA are also used, or the document "Material Degradation Matrix", drawn up by NEI for the components of the reactor coolant system of LWR plants.

05.1.2. Ageing assessment of RPVs

Identification of the ageing effects and mechanisms that need to be managed in the case of vessel components is accomplished within the Ageing Management Review (AMR) process, in accordance with the methodology described in chapter 02 of this report. According to that methodology, the materials from which the vessel components included within the scope are made are identified, along with the environments to which they are typically subjected, from both the inner and outer surfaces.

The materials most characteristically used in the vessel are as follows:

- Carbon steel.
- Alloy steel with stainless steel cladding.
- Stainless steel.
- Nickel-based alloys.

As regards environments, consideration is given, among other things, to the fluid in contact with the surface (e.g., reactor coolant, leaks of borated water), temperature, radiation and operating conditions.

In developing the reactor vessel AMR process, the Spanish nuclear power plants have used information taken from the plant Final Safety Analysis Report and from documentation relating to the manufacturing and placing in service of the vessel, and in addition have taken into account the experience of the industry and the applicable results of the R&D programme. Furthermore, as part of this process the Spanish plants have carried out an analysis of their plant-specific operating experience in comparison to the experience of the US industry in order to ensure that there are no specific ageing mechanisms that were not initially considered.

In conclusion, the process adhered to by the Spanish plants identifies for each of the AMR groups (material-environment combination) those potential ageing effects and mechanisms that are considered to be "significant"; i.e., those for which the consequences of their development without an effective control or mitigation programme might compromise the capability of the component to perform its intended function.

The result of this process for the (PWR, W) and (BWR, GE) type reactor vessels taken as an example, in accordance with the provisions of the TPR [1] specification, is shown in the tables below. The KWU vessel is not included since its results are considered to be very similar to those of Westinghouse vessels.

a. Reactor vessel, including base metal, cladding and welds

Shown below are tables 05.2 and 05.3, applicable to PWR-W and BWR-GE plants respectively.

Element	Material	Environment	Ageing effect	Mechanism
Vessel flange	Steel with stainless steel cladding	Air with leakage of borated water	Loss of material	Boric acid corrosion
		Reactor coolant	Cracking	SCC/IGA/IASCC
			Loss of material	Pitting and crevice corrosion
Vessel shell (shell plates or forgings; shell welds)	Steel with stainless steel cladding	Air with leakage of reactor coolant	Loss of material	Boric acid corrosion
		Reactor coolant and neutron flux	Cracking	SCC/IGA/IASCC/ Fatigue
			Loss of material	Pitting and crevice corrosion
			Loss of fracture toughness	Neutron Irradiation embrittlement

Table 05.2 PWR, W

Element	Material	Environment	Ageing effect	Mechanism
Vessel flange	Low alloy steel	Reactor coolant	Cracking	Fatigue
			Loss of material	Pitting and crevice corrosion
Vessel shell (shell plate)	Carbon steel with stainless steel cladding	Reactor coolant and neutron flux	Cracking	Fatigue
			Loss of fracture toughness	Neutron irradiation embrittlement
			Loss of material	Pitting and crevice corrosion

Table 05.3 BWR, GE

b. Vessel closure head and lower head, including penetrations

Shown below are tables 05.4 and 05.5, applicable to PWR-W and BWR-GE plants respectively

Element	Material	Environment	Ageing effect	Mechanism
Closure head and lower head	Steel alloy clad with stainless steel	Interior environmental air	Loss of material	Boric acid corrosion
		Reactor coolant	Cracking	SCC/IGA/IASCC/ Fatigue
			Loss of material	Pitting and crevice corrosion
Penetrations: Head vent pipe, RVLIS, in-core instrumentation and control rod guide tubes	Nickel-based alloy (Inconel, Incoloy)	Air with reactor coolant leakage	Loss of material	Boric acid corrosion
		Reactor coolant	Cracking	SCC/IGA/IASCC/ Fatigue
			Loss of material	Pitting and crevice corrosion
Flux thimble guide tubes	Stainless steel	Reactor coolant	Cracking	SCC/IGA/IASCC
			Loss of material	Pitting and crevice corrosion
Closure bolts	High strength alloy steel	Air with reactor coolant leakage	Cracking	Stress corrosion cracking, fatigue

Table 05.4 PWR, W

Element	Material	Environment	Ageing effect	Mechanism
Bottom head	Steel alloy with stainless steel cladding	Reactor coolant	Cracking	Fatigue
Closure head	Low alloy steel	Reactor coolant	Cracking	Fatigue
Penetrations: In-core instrumentation; control rod drive (CRD) housing; stub-tube	Stainless steel; nickel alloy (housings)	Reactor coolant	Cracking	Stress corrosion, fatigue

Element	Material	Environment	Ageing effect	Mechanism
Closure bolts	High strength alloy steel	Air with reactor water leakage	Cracking	Stress corrosion, cracking and fatigue

Table 05.5 BWR, GE

c. Inlet and outlet nozzles

Shown below are tables 05.6 and 05.7, applicable to PWR-W and BWR-GE plants respectively.

Element	Material	Environment	Ageing effect	Mechanism
Inlet and outlet nozzles	Steel alloy with stainless steel cladding	Air with reactor coolant leakage	Loss of material	Boric acid corrosion
		Reactor coolant and neutron flux	Cracking	SCC/IGA/IASCC/ Fatigue
			Loss of material	Pitting and crevice corrosion
			Reduction of fracture toughness	Neutron Irradiation embrittlement

Table 05.6 PWR,W

Element	Material	Environment	Ageing effect	Mechanism
Inlet and outlet nozzles	Low alloy steel without cladding; stainless steel, nickel alloy	Reactor coolant and neutron flux	Cracking	SCC/IGSCC/Fatigue
			Loss of material	Pitting and crevice corrosion
			Reduction of fracture toughness	Neutron Irradiation embrittlement

Table 05.7 BWR, GE

Once the significant ageing mechanisms and effects for the components of the vessel have been identified, it is needed to assign to them ageing management activities appropriate for their mitigation and management.

In this respect, the maintenance practices included in the plant programmes (ISI, water chemistry, etc.) and applicable to the management of the aforementioned ageing effects and mechanisms are assessed and then incorporated in ageing management programmes (AMP's). These AMP's are subsequently compared to the model programmes (AMP) of NUREG-1801 [25] for the incorporation, where appropriate, of the improvements required for correct management of the indicated effects and mechanisms.

The acceptance criteria for the different ageing mechanism detection activities are defined on the basis of the standards or recommendations established in the AMP's.

At the Spanish nuclear power plants, the aforementioned vessel components are managed using the following AMP's, based on the provisions of NUREG-1801 [25]:

- **"In-service inspection of Class 1, 2 and 3 components",** based on the XI.M1 model programme included in NUREG-1801 "ASME Section XI In-service Inspection, Subsections IWB, IWC and IWD.
- **"Water chemistry control",** based on the XI.M2 model programme included in NUREG-1801 "Water Chemistry".
- **"Inspection of vessel head closure bolts",** based on XI.M3 model programme included in the NUREG-1801 "Reactor Head Closure Studs".
- **"Boric acid corrosion programme",** based on the XI.M10 model programme included in NUREG-1801 "Boric Acid Corrosion".
- **"Inspection of nickel-alloy components and nearby carbon steel surfaces in the primary circuit",** based on the XI.M11B model programme included in NUREG-1801 "Cracking of Nickel-Alloy Components and Loss of Material due to Boric Acid-Induced Corrosion in Reactor Coolant Pressure Boundary Components".
- **"Reactor vessel surveillance",** based on the XI.M31 model programme included in NUREG-1801 "Reactor Vessel Surveillance".
- **"Inspection of thimbles",** based on the XI.M37 model programme included in NUREG-1801 "Flux Thimble Tube Inspection".
- **"Fatigue management programme",** based on the X.M1 model programme included in NUREG-1801 "Fatigue Monitoring".
- **"Inspection of feedwater nozzles",** based on the XI.M05 model programme included in NUREG-1801 "BWR Feedwater Nozzle". Applicable to BWR plants.
- "Inspection of CRD return line nozzles", based on the model XI.M06 programme included in NUREG-1801 "BWR Control Rod Drive Return Line Nozzle". Applicable to BWR plants.
- **"Control and mitigation of stress corrosion (NUREG 0313/BWRVIP-75)",** based on the XI.M07 model programme included in NUREG-1801 "BWR Stress Corrosion Cracking". Applicable only to BWR plants.
- **"Inspection of vessel penetrations (BWRVIP)",** based on XI.M08 model programme included in NUREG-1801 "BWR Penetrations". Applicable only to BWR plants.

Both the plant-specific and industry operating experience applicable to each AMP are analysed periodically in accordance with the methodology described in chapter 02 of the present report.

In fact, the process adhered to for the development of the Spanish nuclear power plant AMP's applicable to the vessel proceed from the industry operating experience included in NUREG-1801 and is completed with the applicable improvement actions deriving from other industry operating experience not referenced in the said document, such as the events, recommendations or experiences received from WANO, Significant Operating Experience Reports (SOER) and Significant Event Reports (SER), letters from the designers and/or suppliers of equipment (technical bulletins, NSAL, 10CFR21) and the action plans defined by the regulatory authorities, in particular the NRC. In the specific case of Trillo NPP, and due to its German design, the information issued by GRS and AREVA is also contemplated.

In this respect, it should be pointed out that, the Spanish nuclear power plants have improved their AMP's, incorporating specific surveillance, mitigation and control activities, along with others aimed at prevention, as a result of the leakage, cracking and corrosion identified in areas of the reactor vessel head, as well as in other cases of cracking detected in components containing nickel alloy materials, located in vessel nozzles and penetrations.

The following are especially significant among the aforementioned events:

- leakage from a vessel head CRDM penetration detected during hydrostatic testing at the Bugey 3 plant in France,
- degradation of a large number of vessel head penetrations at the Spanish José Cabrera (Zorita) plant,
- corrosion of the vessel head at a US plant (Davis-Besse), or
- PWSCC of a nozzle-safe end interface at a US plant (VC Summer) and another in Sweden (Ringhals).
- More recently, quasi-laminar indications due to hydrogen formation, detected in the base material of two Belgian vessels, Döel 2 and Tihange 3, and one in Switzerland, Beznau 2.

The following may be pointed out from among the improvements implemented as a result of the aforementioned experience:

- Inspection programmes additional to those required by ASME XI on vessel heads and CRDM penetrations.
- Replacement of the vessel head at four out of the five PWR-W plants to other vessel head fabricated with other materials less susceptible to degradation mechanisms.
- Planned inspection of the base material of the Trillo NPP vessel shell rings as a result of the applicability of the Incident Reporting System (IRS) "Flaw Indications in the Reactor Pressure Vessel".

Finally, among the R&D activities relating to the performance of vessel materials, special mention may be made to the CSN's participation in and promotion of the macro project led by EPRI on the performance of Inconel 690 materials under reactor primary water conditions. The work carried out within the framework of this project, "EPRI Alloy 690/52/152 Primary Water Stress Corrosion Cracking Research Collaborative Project", in which a large number of international organisations have taken part, has been completed recently and has served for the drawing up of two EPRI documents: MRP-368 and MRP-420.

05.1.3. Monitoring, testing, sampling and inspection activities for RPVs

Activities relating to the inspection and monitoring of the aforementioned vessel components are performed in accordance with the requirements of the ageing management programmes in which they are included. Described below are the different AMP's established, indicating in each case the type of vessel to which they apply.

In-service inspection of class 1, 2 and 3 components

The Spanish plants develop their in-service inspection programmes in accordance with the requirements of section XI of the ASME Code, as established in CSN Instruction IS-23 [43]. These programmes define the periodic visual, surface and volumetric examinations, as well as the pressure tests for all the pressure-retaining components, which are to be carried out every 10 years in compliance with the requirements of the code mentioned. Table 05.8 includes a summary of the areas to be examined in each ten-year period, the scope and ASME denomination and the examination method.

Component	ASME XI Inspection	ASME Category	ASME item	Examination method
Shell-welds (circumferential-longitudinal)	100%	B-A	B1.10	Volumetric
Head welds (circumferential-meridional)	100%	B-A	B1.20	Volumetric
Shell-to-flange weld	100%	B-A	B1.30	Volumetric
Head-to flange weld	100%	B-A	B1.40	Volumetric & surface
Inner radius of the vessel nozzles	100%	B-D	B3.100	Volumetric or Visual*
Nozzle-vessel welds	100%	B-D	B3.90	Volumetric
Accessible vessel interior areas	Accessible areas every 3 years	B-N-1	B13.10	Visual
CRD housing welds (dissimilar weld)	10% peripheral CRDs	B-O	B14.10/B14.20	Volumetric or surface

* All the plants have accepted the use of the ASME N-648-1 Code case, which allows the volumetric examination to be replaced with a visual VT-1 examination of the inner surface. Cofrentes NPP maintains UT inspection.

Table 05.8 Vessel inspection programme (ASME XI)

Regarding to the vessel cladding, although it does not perform any intended function and is not, therefore, included in the AMR groups, it is visually inspected within the framework of the activities associated with category B-N-1 of the in-service inspection programme, as well as within the activities performed in the AMP for monitoring of the reactor vessel internals in accordance with the applicable EPRI guidelines, for example MRP-227-1, BWRVIP-49, etc.

Likewise, the plants have established a mitigation process that makes it possible to reduce the susceptibility of stainless steel to degradation, by controlling the chemistry of the reactor coolant.

As regards pressure testing, all the Spanish plants perform VT-2 visual examinations on class 1 components, including therefore the reactor vessel, under the pressure and temperature conditions corresponding to normal operation, at the end of each refuelling outage in accordance with the requirements of ASME XI, with the exception of Trillo plant, which performs this test at the pressure and temperature defined in the RSK guidelines and the KTA-3201.4 standard.

The acceptance criteria applicable are specific to each inspection or test performed and in accordance with the requirements established by the ASME XI code or other standards used.

Inspection of vessel closure head bolting

The programme for the surveillance of the sealing elements of the vessel closure head is based on the in-service inspection activities defined for these areas in the ASME XI code and on the preventive measures for the mitigation of cracking.

The programme consists of performing visual examinations on closing nuts measuring more than 2” in diameter and their washers, and volumetric examinations of closure bolts and threaded areas measuring more than 2” in diameter.

The programme also follows the recommendations established in NUREG-1339 and NRC Regulatory Guide 1.65, for the management of reactor vessel closure bolts.

Inspections shall be carried out on all sealing items every 10 years.

The applicable acceptance criteria are those established in article IWB-3000 of ASME XI.

Boric acid corrosion programme

This programme is specific to PWR plants and is based on the recommendations of NRC generic letter 88-05, drawn up for the management of corrosion caused by leakage of boric acid across the reactor coolant pressure boundary.

The programme contains periodic inspection activities performed during each refuelling outage to visually locate and identify leakage points and their propagation paths, which may cause the degradation of carbon or low alloy steel items and components at the source of the leakage or in structures and components close to the point of leakage due to boric acid-induced corrosion.

In the area applicable to the vessel, these activities focus on the analysis of any indication of leakage in the closure head or lower head and their penetrations. If any remains of boric acid are detected, the origin of the leak causing this is determined and the corrective actions needed to confirm or restore the intended functions of the affected structures and components are carried out.

As regards frequency, and as has been pointed out above, a VT-1 visual examination is to be carried out every refuelling outage.

In relation to acceptance criteria, components whose visual examination confirms the absence of relevant conditions are considered acceptable for continued service. Relevant conditions are considered to be the existence of areas of corrosion, boric acid deposits, colouring, decolouring or other indication of leakage.

Inspection of nickel alloy components and nearby carbon steel surfaces in the primary circuit

Through this additional programme, included among in-service inspection activities, the PWR plants manage the effects of Primary water stress corrosion cracking (PWSCC) in all susceptible nickel-based alloy components involved in the reactor coolant pressure boundary, including welds. The activities consist of periodic examinations (visual, surface and/or volumetric) of components susceptible to PWSCC in accordance with the requirements of the ASME Code cases N-729-1, N-722-1 and N-770-1.

In addition to the inspection activities, the reactor coolant leakage detection system provides the capability to detect the presence of significant leakage from the reactor coolant circuits to the containment during normal operation.

Table 05.9, shown below, indicates the inspection activities and their frequency, while table 05.10 shows the acceptance criteria applied to the different nickel-based components.

Component	Code Case	Examination method	Frequency
Vessel head penetrations	N-729-1	Visual examination (VE) of 100% bare metal on the outer surface	Every three (3) refuelling outages or every five (5) years
		Ultrasonic test (UT) and eddy current (EC) inspection from the inside of each penetration	At least once during the ten-year (10) interval
Vessel bottom instrumentation penetrations	N-722-1	Visual examination (VE) of bare metal	Every two (2) refuelling outages
Hot and cold leg nozzle welds	N-722-1 and N-770-1	Visual examination (VE) of bare metal	Hot legs: every refuelling outage Cold legs: every 10-year interval
		Ultrasonic test (UT)	Hot legs: every five (5) years Cold legs: every two (2) periods without exceeding seven (7) years

Table 05.9 Activities and frequencies in nickel-based areas

The acceptance criteria for each activity are as follows:

Component	Examination	Acceptance criteria	Corrective actions
Vessel head penetrations	Visual examination (VE)	Confirmation of absence of relevant conditions (presence of leakage or leak deposits at the intersection between the penetration and the surface of the head) unacceptable	Extension of scope, determining the source of the leakage and the extent of degradation Additional NDT examinations Repair/replacement activities
	Ultrasonic test (UT)	UT inspection confirms the absence of defects	
Vessel bottom instrumentation penetrations	Visual examination (VE)	Acceptance criteria established in article IWB-3522 of ASME Code XI, as required in Table 1 of Code Case N-722-1	
Hot and cold leg nozzle welds	Visual examination (VE)	Acceptance criteria established in article IBW-3522, as required in Code Case N-722-1 and article 3140 of Code Case N-770-1	
	Ultrasonic test (UT)	In accordance with Table 1 of Code Case N-770-1, the acceptance criteria are established in section -3130 of the said Code Case.	

Table 05.10 Acceptance criteria for nickel-based areas

Any leakage of boric acid detected within the scope of this programme shall be managed using the specific AMP for surveillance the boric acid corrosion.

Inspection of thimbles

This programme is specific to PWR plants and is aimed at verifying the thimbles integrity, detecting any reductions in thickness due to vibrations induced by internal currents of water in the reactor at locations where there are structural discontinuities, such as the support plates. This programme is implemented in compliance with the recommendations of *Bulletin* Nº 88-09. Inspection of the thimble for detecting loss of thickness is performed examining each one with the eddy current technique..

In general, the frequency of inspection of the thimbles is set at three years (2 operating cycles). This frequency is obtained by forecasting fretting wear (expected depths of wear) in future thimble inspections, which is calculated using an exponential curve based on the values of wear of the current inspection and the accumulated time that will elapse up to the date for which the forecast is made.

As an acceptance criterion it is established that values of wear of less than eighty per cent (80%) loss of thickness are acceptable.

Nozzle-vessel inspection (BWR)

As a result of the operating experience relating to the vessel nozzles in BWR type plants, and in accordance with the recommendations of the NUREG-1801 model programmes, the only BWR plant currently in operation in Spain has developed two specific programmes, one relating to the feedwater nozzles and the other to the nozzle of the CRD return line.

The scope of inspection of both nozzles includes the nozzle-vessel weld and the inner radius, by means of volumetric examination, in accordance with ASME category B-D. As regards surveillance of the potential effect of intergranular stress corrosion cracking (IGSCC) in the nozzle-safe-end welds and closure cap, this is accomplished in accordance with the provisions of EPRI guideline BWRVIP-75A. This nozzle is examined every 10 years using UT techniques in accordance with ASME XI, which also includes the applicable acceptance criteria.

Vessel penetrations

This programme manages the effects of crack initiation and growth in the vessel instrumentation penetrations, the vessel drainage penetration and the core differential pressure penetrations due to cyclic loads, stress corrosion or intergranular stress corrosion.

The type of inspection performed comprises from the ultrasonic examination of certain of the nozzles to VT-2 visual examination (for leak detection) during pressure testing. This methods is conducted to detect evidence of leakage from pressure retaining components.

The inspection is performed once every 10 years and the acceptance criteria applied are those applicable to nuclear class 1 components in ASME Code XI (IWB-3000).

Control and mitigation of stress corrosion (NUREG-0313 / BWRVIP-75)

This programme is applied specifically at Cofrentes NPP. The objective of the programme is the monitoring of the appearance and evolution of cracking due to IGSCC in stainless steel welds susceptible to this phenomenon, in both items of equipment and piping and without any distinction regarding nuclear class. In the case of the components included within the scope of the present chapter, this AMP is applicable only to the nozzle welds in recirculation loops, two (2) loop suction nozzles and ten (10) loop discharge nozzles.

The programme consists of the periodic performance of nozzle inspections by volumetric examination, as well as pressure testing. The nozzles are inspected and tested in accordance with the examination and inspection requirements specified in NUREG-0313. This document describes the scope and frequency requirements for this type of welds depending on their susceptibility to IGSCC, as in the case of document BWRVIP-75A. As regards the acceptance criteria of the programme, these are the same as for ASME XI category B-F.

Reactor vessel surveillance (irradiation embrittlement)

The objective of the programme is to monitor the evolution of the properties of the materials making up the reactor vessel on the basis of the neutron flux received throughout the service lifetime of the component, by means of tests performed on the surveillance capsules located inside the vessel and made of the same materials as this component, both prior to irradiation and following increasingly prolonged periods of exposure. The standards used for this purpose are ASTM E-185 and ASTM E-482.

The methods used to assess the degree of embrittlement of the vessels are those set out in appendices G and H of 10 CFR 50.

The ageing mechanism controlled by the programme is embrittlement due to irradiation of the vessel. In this respect, as the results of testing of the different surveillance capsules are analysed, the values of the critical parameters used to assess the integrity of the vessel are reviewed in accordance with the methodology described in RG 1.99. The objective of this methodology is to estimate the evolution of the RT_{NDT} (reference temperature for nil ductility transition) and USE (upper shelf energy, Charpy test) parameters with irradiation, in order to allow the future embrittlement status of the vessel to be predicted. Determination, in accordance with these tests, of the change in the adjusted reference temperature (ART) makes it possible to obtain the safe operating ranges of the reactor (P-T curves).

The analyses and tests carried out on the specimens tested to date indicate that the mechanical properties of the vessel materials at the operating plants have undergone variations included within the limits established by the standards, the materials consequently maintaining adequate levels of toughness.

Following removal of all the surveillance capsules, the plants have setup an ex-vessel neutron dosimetry programme (EVND) that allows for the monitoring of neutron exposure up to the end of lifetime, by installing dosimeters outside the vessel. The EVND programme is designed to provide verification of the distributions of exposure to fast neutrons inside the vessel beltline zone and to establish a mechanism allowing for the long-term surveillance of this part of the vessel regarding the evolution of the RT_{NDT} due to the effects of significant exposure to neutron radiation during reactor operation. The dosimeters are checked every 3 refuelling cycles.

As has been pointed out above, the acceptance criteria of these programmes are established on the basis of the requirements indicated in 10CFR50.61 and appendix G of 10CFR50.

According to CSN Instruction IS-22 [21], the calculations relating to neutron embrittlement of the vessel fulfil the definition of “Time-limited Ageing Analysis” (TLAA), for which reason they must be reviewed in the event of long-term operation (LTO). At the date of editing this chapter, the calculations depending on an estimation of creep over time have been solved for the Vandellós II and Almaraz plants, the fundamental conclusions being as follows:

- The new materials of the vessel beltline have been identified, including the upper shell, the nozzles and the associated welds.
- Compliance with the limits established in the reference standards has been verified for all the beltline materials (traditional and extended) up to the end of the LTO (54 EFPY).

For the rest of the plants the analysis is currently on-going, since it is associated with LTO.

Fatigue management programme

Fatigue is an ageing mechanism that affects nuclear reactor vessels and is taken into account in the ASME Section III construction code used in the manufacturing of these components.

This programme includes a preventive activity against the effect of thermal fatigue in the components making up the vessel pressure boundary. This activity consists of monitoring the conditions (pressure, temperature and flow) of the reactor coolant system in all plant operating situations; i.e., stable operating conditions and transients, and comparing these to those foreseen in the design in order to assess consumption of the fatigue usage factor, which in accordance with design requirements is determined for Class 1 components.

The Spanish plants have developed a programme that fulfils the requirements indicated in the X.M1 model programme included in NUREG-1801 [5], this being used for the monitoring of transients in preselected Class 1 components. Transient monitoring is performed on two levels:

- Monitoring of operating transients in accordance with the requirements established in the technical specifications (TS). The plant establishes a control of the transient situations that happen under different operating conditions and that affect the reactor coolant system and verifies that these do not occur on a greater number of occasions than those that are foreseen by design and controlled by the mentioned technical specifications.
- Monitoring of consumption of usage factor by certain Class 1 components. In relation to the components identified in design with high usage factors; i.e., with a lower margin or greater susceptibility to cracking as a result of fatigue, the plant performs accurate monitoring of the operational parameters of the reactor coolant system and associated systems in order to calculate usage factor consumptions. In the case of Cofrentes plant, for example, the components subject to monitoring of the usage factor are the reactor vessel feedwater nozzles. This monitoring is performed by means of a code known as FatONE.

As has been pointed out above, in relation to neutron irradiation embrittlement, the fatigue calculations and analyses meet the conditions needed for them to be defined as being TLAA, for which reason the wear due to fatigue must be determined for a foreseeable LTO and the needed forecasts to the end of the new period considered must be performed.

The PWR plant components that have been determined to have the greatest accumulated usage factor with respect to fatigue are as follows:

- Vessel bottom and transition zone.
- Inlet nozzles.
- Outlet nozzles.
- Core support.
- Instrumentation tubes.

The experience of the inspections performed in the different AMP's is recorded in the reports describing the results of the different activities. This information is used to schedule future inspections taking into account previously detected defects. Likewise, the results history is analysed for each AMP by means of the corresponding monitoring process, for which a specific periodic report is issued.

If the AMP applied to manage the effects of ageing requires the formal tracking of trends, this shall be performed in accordance with the requirements of the specific programme.

As has been commented in chapter 02, the periodically performed process of AMP monitoring and the assignment of indicators make it possible to detect trends in the occurrence of degradations, these being used to assess whether the programme is being effective or whether, on the contrary, it requires improvement. If during the inspections any type of degradation is detected, it shall be reported. If the degradation detected has not previously been identified in the AMR process, it shall be evaluated in order to determine whether it is a new ageing effect and, if this is the case, shall be included in the corresponding AMP for management.

The inspection, surveillance and monitoring activities included in the AMP's applicable to the reactor vessel components, as well as other plant activities, are subject to the plant Quality Assurance Manual and, as a part of the OAMP, to internal audits and inspection by the technical staff of the regulatory authority. The participation of other certification organisations is not required, except in those cases in which this is established by other licensing requirements associated with the activities (e.g., certification of inspectors in accordance with ASME levels).

05.1.4. Preventive and remedial actions for RPVs

The water chemistry control programme in place at the plants is particularly outstanding among the preventive and mitigating measures, against ageing effects on the components of the vessel pressure boundary, is.

The objective of this programme is to minimise the loss of material due to corrosion and stress corrosion cracking and to maintain levels of contaminants below the thresholds accepted by the industry. The programmes are based on the recommendations included in EPRI guideline 1014986, as established in the model programme XI.M2 NUREG-1801 [5], “Water Chemistry”. Other types of documents are also taken as references, such as the technical specifications, other EPRI guidelines applicable to BWR plants, the Siemens guidelines applicable to German design plants and the plant-specific experience.

Chemistry control is carried out using plant-specific procedures to periodically monitor and control physical-chemical and radiochemical parameters and impurities, in order to ensure that their concentration in water remains below those thresholds that might cause any of the aforementioned ageing effects in the primary circuit, both during normal operation and outages and reactor scrams. The acceptance criteria are established depending on the established water chemistry, but in all cases in accordance with the indications of the applicable EPRI guidelines, the technical specifications and the plant operating conditions.

As regards the applicable acceptance criteria, it may be pointed out that when a parameter is outside the limits accepted by the industry the corresponding corrective actions are applied to return it to its acceptable range.

Other preventive actions undertaken at the Spanish nuclear have been the replacement of the vessel head at both units of Almaraz, unit 2 of Ascó and at Vandellós II. The new vessel heads are designed and fabricated with materials that reduce the susceptibility to stress corrosion in the environment of the primary water that characterised the previous model, made of Inconel 600/82/182. This material has been replaced with Inconel 690/52/152, which according to industry experience is more resistant to IGSCC. In certain cases other modifications have also been introduced, such as reduction of the number of penetrations, elimination of the thermal housings, elimination of the head-flange weld or a new design for the seals of the thermocouple columns penetrations to reduce the risk of leakage across the cannoseal gaskets and canopy welds.

Particularly significant among the processes of mitigation of ageing effects performed on the BWR type reactor vessel, Cofrentes plant, has been the injection of hydrogen in the feedwater, since 1997, in order to mitigate intergranular stress corrosion cracking in stainless steel components in contact with the reactor coolant. Furthermore, Cofrentes NPP has been applying a more advanced mitigation method, since 2010, based on the addition of noble metals with the injection of low concentrations of hydrogen in the feedwater.

Another process carried out at this plant has been the application of the MSIP (Mechanical Stress Improvement Process) technique on vessel nozzles with dissimilar welds. This technique is a process of improving stresses recommended by NUREG-0313, for preventing or mitigating the stress corrosion cracking in pipe weldments.The process works by removing tensile residual stress and generating a favorable compressive stress pattern in its place. This process was performed during the 6th refuelling outage on a total 42 dissimilar nozzle-safe end and safe end-extension welds.

05.2. Licensee’s experience of the application of AMP’s for RPVs

As has been pointed out in chapter 02 of this report, the analysis of the operating experience of vessel components is included in the tracking reports of each of the applicable AMP's. These reports assess whether the ageing effects detected correspond to those postulated during the AMR process.

From the analysis performed by the Spanish plants on the tracking reports of the AMP's applicable to the reactor vessel components identified in the TPR specification it may be concluded that no ageing effects not identified during the ageing management review process have been detected. Significant operating experiences have, however, been detected, some of which are dealt with below.

Almaraz NPP

- In 2010, indications associated with a loss of thickness due to wear were detected on the outer surface of a thimble. These indications exceeded the wear limit established in the thimbles surveillance programme (80%), as a result of which the Almaraz plant decided to leave the affected item out of service as a corrective measure.
- During the 2010 refuelling outage at unit 2 of the Almaraz plant, accumulations of boric acid were detected on the thermal insulation of the vessel head, resulting from leakage across the cono-seals. Following the removal of these traces and the cleaning of the surfaces for the performance of inspections and the removal of the thermal insulation to facilitate examination of the outer surface of the head, Almaraz found no degradations due to boric acid.

Vandellós II NPP

- The in-service inspection programme applicable to the vessel according to the requirements of ASME Code XI, along with the alternative requirements based on the code cases applicable to Inconel areas, are considered to be effective for the management of ageing effects in vessel pressure-retaining components.

  These programmes have allowed for the following:

  - Prompt detection of boric acid leakage and sediments, which are assessed and managed in accordance with the plant corrective actions programme, with the implementation of appropriate corrective actions when needed. In no case the leaks have been considered unacceptable.
  - Confirmation of the absence of relevant indications associated with PWSCC in dissimilar welds. In certain cases indications have been detected in the area between the weld and the buttering – in no case open to the surface – these being considered as being due to the process of welding and depositing of the buttering during the construction phase.
- As regards the thimbles surveillance programme, this has proven to be effective for the prompt detection and management of wear of the instrumentation tubes, through activities relating to the replacement and withdrawal of the affected thimbles. The experience of the application of this programme underlines certain of the preventive actions performed:
  - During refuelling outage R11 a thimbles replacement campaign was carried out, this consisting of replacing 15 of the 50 thimbles as a preventive measure. A historic analysis of thimble wear at this plant shows that the evolution of the

indications is gradual, since neither the surrounding flow conditions nor the configuration of the core are excessively aggressive for them.

  - During refuelling outage 21 (October 2016), and despite the rejection criterion not having been exceeded, thimble N-12 was plugged as a preventive measure.

Ascó NPP

- The in-service inspection programme applicable to the vessel in accordance with the requirements of ASME Code XI, along with the alternative requirements based on the code cases applicable to Inconel areas, is considered to be effective for the management of ageing effects in vessel pressure-retaining components.

  These programmes have allowed for the following:

  - The detection of boron deposits on the vessel head, which have required inclusion in the corrective actions programme, for example:
    - Traces of boron in vessel head penetrations following visual inspection.
    - Leakage across a CRDM vent plug.

  All the boric acid deposits and leakage identified at the plant have been assessed and subsequently appropriate corrective actions and prompt measures have been applied where necessary.

  - Surveillance of the phenomenon of PWSCC in vessel head and bottom penetrations, which has determined the absence of relevant indications in the material.
  - The performance of dissimilar welds of nozzle-to safe end connections has provided satisfactory results, no type of degradation having been encountered.

- As regards the preventive controls associated with the chemistry of the primary circuit, it should be pointed out that in addition to the habitual treatments of chemistry control programmes, this plant also includes the injection of zinc. According to the experience of the plant, this treatment has proven to be beneficial in reducing the appearance of stress corrosion in vessel materials susceptible to this mechanism, in particular Inconel 600.
- The thimbles surveillance programme has proven to be effective for the prompt detection and management of instrumentation tube wear, through replacement and withdrawal of the affected thimbles. The tracking of trends and the predictive calculations have proven to be effective in preventing the loss of component functions.

  Historically, tubes whose forecast wear indicates that they are close to exceeding the rejection criteria are plugged and withdrawn, until a significant number of them are in a condition to be replaced. In this way, Ascó plant optimises thimble replacement interventions.

Trillo NPP

A significant experience worthy of mention is the fact that in 1992 Trillo plant detected a corrosion-induced loss of material in the grooves that hold the inner and outer O-rings of the vessel closure head flange, as a result of which the following corrective actions were established:

- Ultrasonic measurement of pore depth.
- Creation of metallographic replicas and putty-based plastic impressions.
- Sketch of the vessel head sealing surface showing the approximate location of the existing indications, with a view to controlling the evolution of the process of corrosion in subsequent refuelling outages. No significant changes have been detected till current date.
- In-depth cleaning of the seals and sealing surface.

Cofrentes NPP

The inspection programmes for surveillance of the pressure retaining part of the reactor vessel are based on compliance with the applicable requirements of ASME Code XI, in accordance with the in-service inspection programmes, and in other specific standards such as NUREG 313, and have been in place since the beginning of operation of the plant. To date no degradation effects that might affect the integrity of the vessel have been detected.

From the analysis of the industry operating experience performed in each AMP applicable to the components of the vessel pressure boundary it may be concluded that it has not been necessary to include any modifications as a result of the appearance of ageing effects other than those contemplated in these programmes.

Particularly significant among the industry operating experience assessments performed has been the issuing in July 2012 of report IRS-8244 by the Belgian Döel 3 plant via the IAEA’s events reporting system. This document reports on the finding of laminar indications in the base material of one of the three forged rings that go to make up the reactor vessel. These laminar defects are parallel to the inner and outer surfaces of the vessel and have initially been attributed to a possible defect in manufacturing.

As a result of the above, Cofrentes NPP reviewed the documentation associated with the manufacturing of the rings of its reactor vessel, paying special attention to those processes that might have generated manufacturing defects in the base material, and to the inspections that might have detected these defects prior to the placing in service of the vessel.

The result of the aforementioned review suggests that it is highly unlikely that the cause of the manufacturing defects in the vessels of Döel 3/Tihange2 has existed during the process of manufacturing the vessel for Cofrentes NPP.

05.3. Regulator’s assessment and conclusion on ageing management of RPVs

In relation to the process of managing the ageing of reactor vessel components considered in the specification, the CSN considers the ageing management programmes applied by the Spanish nuclear power plants to be adequate. The scope and main activities of these programmes have been presented in this chapter.

It should be pointed out that all the surveillance, control and mitigation activities have been defined and implemented since the beginning of commercial operation, since these are required by the applicable licensing bases. In this respect, the following may be underlined:

- The programme for the inspection of the areas of the reactor vessel head, closure bolts, vessel shell, nozzles and penetrations is developed in accordance with the requirements of ASME Code XI, and is include in the In-Service Inspection Manuals (ISIM) of each facility. Performance of the programme is completed every 10 years.
- The reactor vessel material irradiation surveillance programme is defined in the technical specifications and described in the final safety analysis report. In compliance with the technical specifications, the surveillance capsules must be removed and examined in order to determine changes in the properties of the materials in accordance with intervals defined therein.
- The chemistry programme is monitored and controlled by the technical specifications.

Furthermore, and as a result of international operating experience, the Spanish plants have incorporated additional vessel inspection programmes, such as the application of ASME code cases N-729-1, N-722-1 and N-770-1 and, in other cases deriving from experiences such as the inspection of the in-core instrumentation tubes (thimbles). All of these programmes are also included in the In-service Inspection Manual (ISIM) of each plant, in accordance with the requirement of CSN Instruction IS-23 [43], which states: "*inclusion of those deriving from the temporary application of any standard, from the conditions for the operating authorisation in force, licensee commitments or other requirements defined through instructions or requirements issued by the CSN as a result of in-house or nuclear industry operating experience, requiring systematic performance.*"

Consequently, in view of the far-reaching regulations applicable, on the one hand Instruction IS-22 [21], applicable to lifetime management and long-term operation, and, on the other, the aforementioned IS-23 [43], applicable to in-service inspection activities, the CSN considers that the regulations guarantee that the AMP's maintain homogeneity as regards scope, inspections and acceptance criteria and that they are performed in accordance with established conditions.

As regards the tracking of these programmes, the CSN carries out two-yearly inspections of the lifetime management plans of all the plants in accordance with the basic inspection plan established. These inspections, performed on site and in accordance with CSN internal procedure PT.IV.223 [41], include supervision of the ageing management programmes applicable to the reactor vessel at both documentary and implementation level. This supervision is complemented with the information submitted annually by the Spanish nuclear power plants to the CSN in compliance with the requirements of Instruction IS-22 [21].

On the other hand, and as has been pointed out above, most of the AMP's applied to the vessel are included within the scope of Instruction IS-23 [43], for which reason they have also been reviewed by the CSN by way of the basic inspection plan in place. In this respect, CSN internal procedure PT.IV.207 [44] has been adhered to, this being used to ensure that the scheduling and performance aspects of the in-service inspection programme meet the requirements of the applicable standards, that the requirements of new standards or recommendations based on operating experience are applied and that they provide a capacity adequate for the surveillance of any degradation phenomenon that might jeopardise the structural integrity of the component.

The verifications performed by the CSN on the ageing management processes applied to the components of the reactor vessel confirm the conclusions reached by the licensees regarding the effectiveness of these processes.

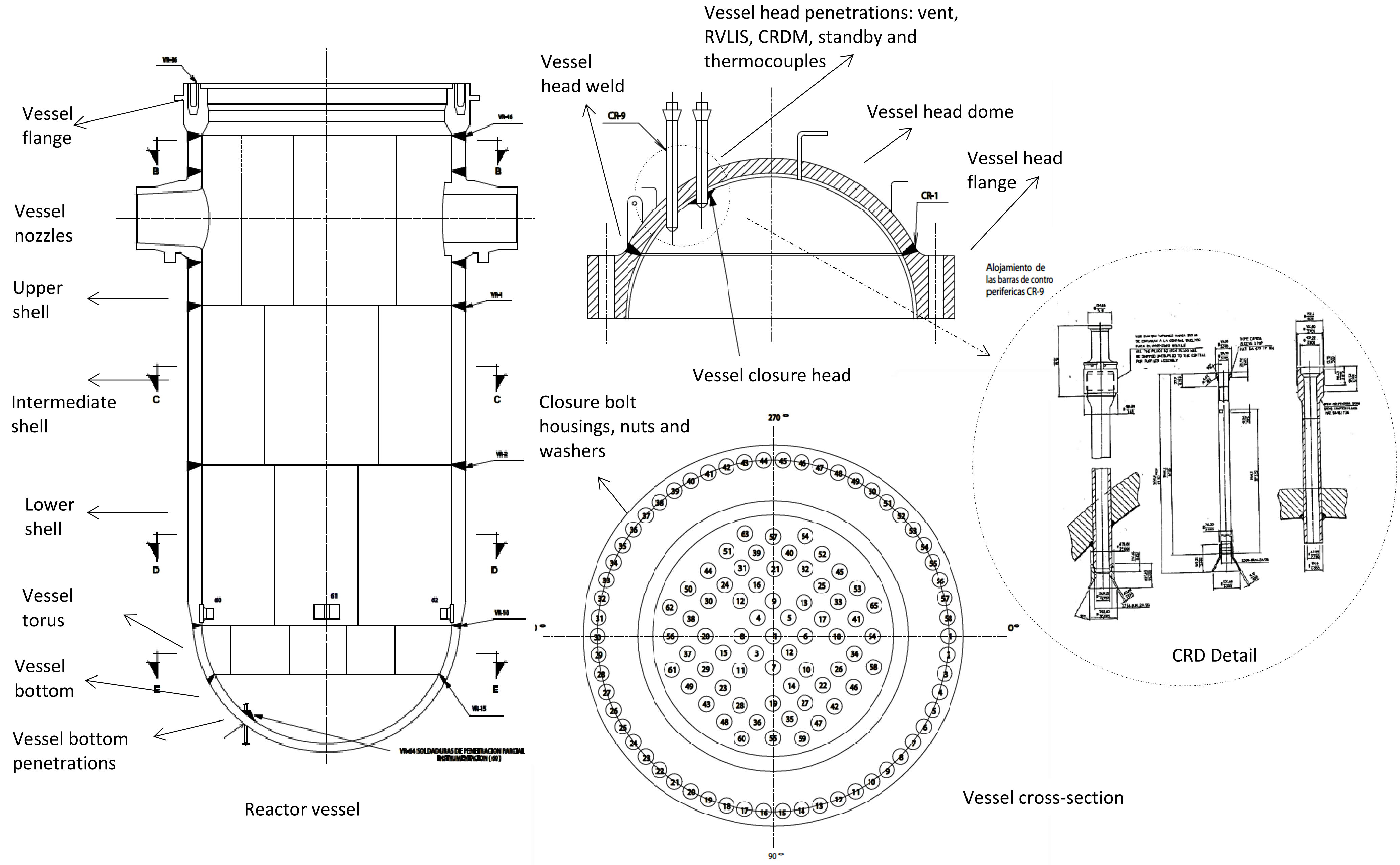
Likewise, it may be pointed out that the AMP's indicated make it possible to detect the expected degradations and act accordingly, maintaining the intended functions of the equipment, components and systems. The experience available as of the date of this report is that all the AMP's have been fully implemented and that the results show that no expected or not previously identified degradations that might compromise the integrity of the structures included within the scope of the AMP have been observed.

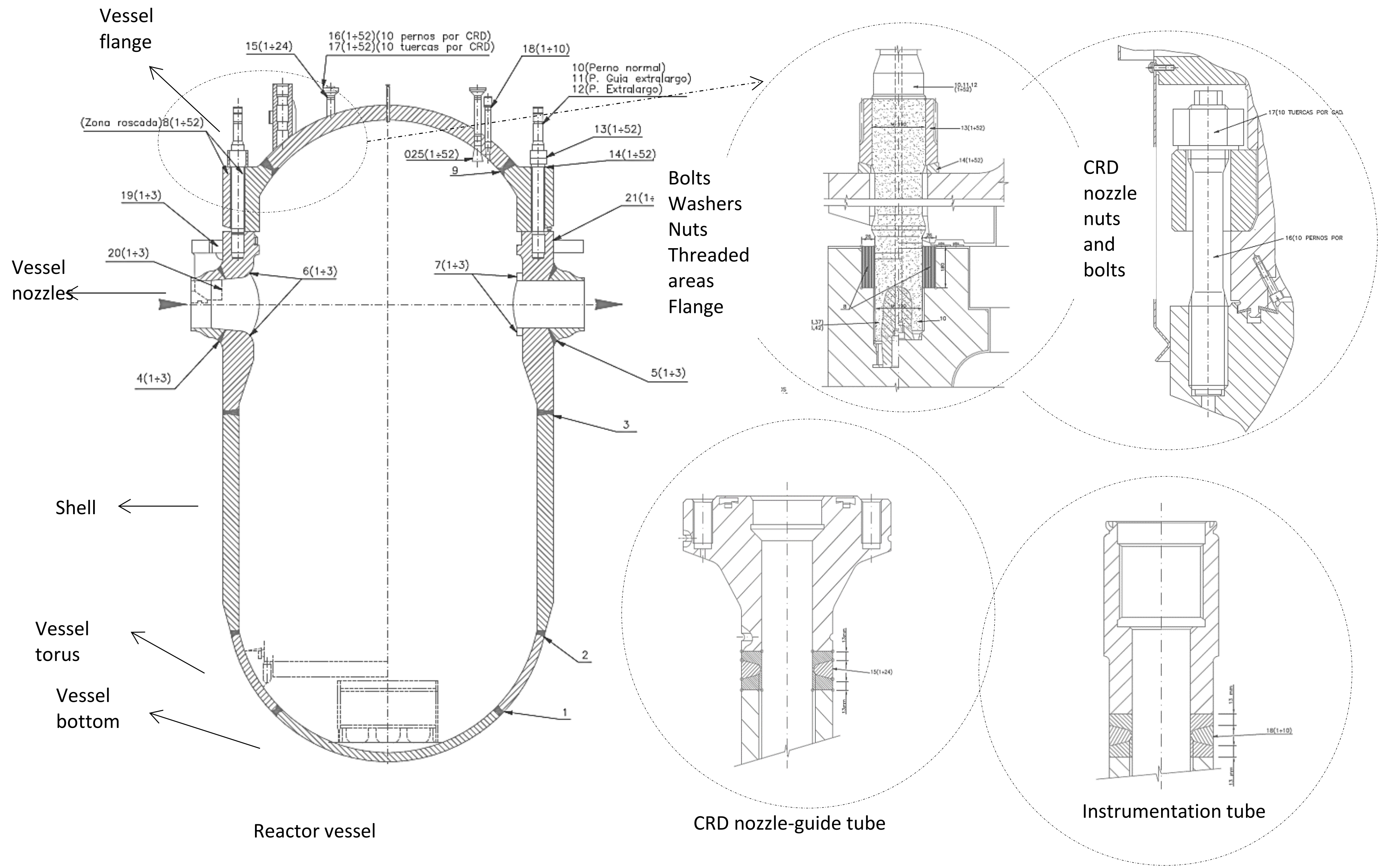
Regarding to the volumetric examinations performed according to the RPV inspections programme, it should be pointed out that all of them have been performed with qualified procedures according to the UNESA-CEX-120 methodology, and have also taken into account the methodology based on the harmonisation process within the "European Network for Inspection Qualification" (ENIQ) and the Nuclear Regulators Working Group (NRWG).

As has been indicated in the first section of this chapter, the reactor vessel is a basic component of a lifetime management programme. Indeed, the applicable regulations specifically indicate that the ageing management of the reactor vessel and its welds shall take into account all relevant factors, including at least embrittlement, thermal ageing and fatigue, in order to compare their performance with respect to the analytical predictions made throughout the lifetime of the component. The CSN considers the assessment of these aspects to be crucial for requests for license extension from 40 to 60 years of operation, especially when for certain of these aspects, for example fatigue, no methodology is initially available to assess the impact of environmental fatigue.

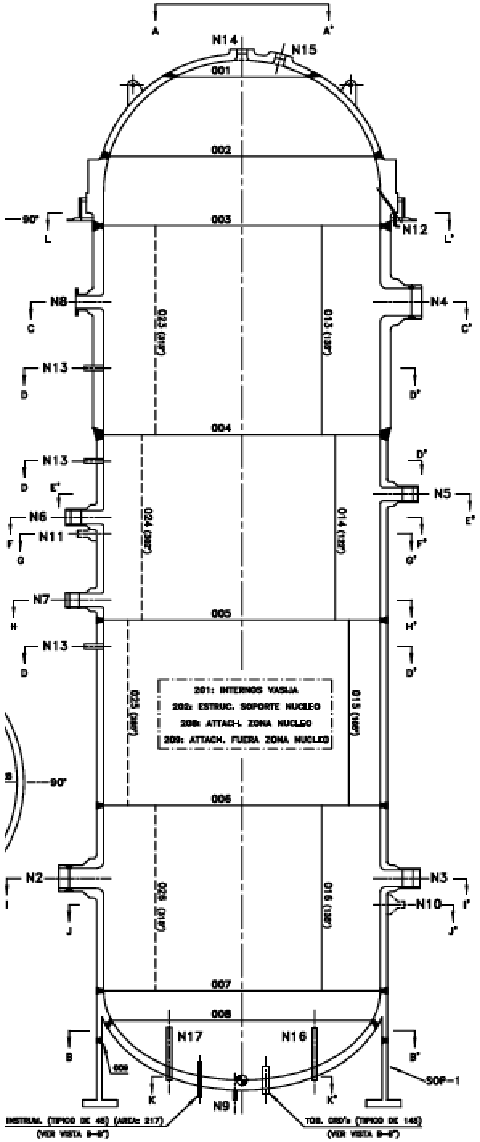
ANNEX TO CHAPTER 05

PWR-W TYPE VESSEL

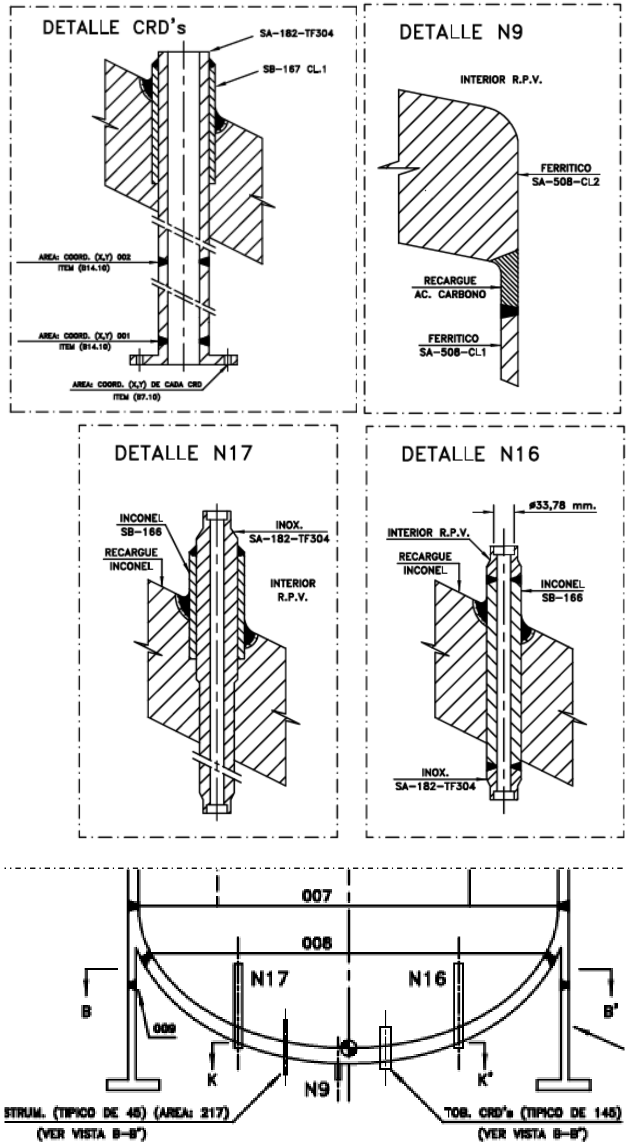



Vessel flange
15(1÷24)
16(1÷52)(10 pernos por CRD)
17(1÷52)(10 tuercas por CRD)
18(1÷10)
10(Perno normal)
11(P. Guia extralargo)
12(P. Extralargo)
(Zona roscada)8(1÷52)
13(1÷52)
025(1÷52)
14(1÷52)
9
19(1÷3)
21(1÷
20(1÷3)
6(1÷3)
7(1÷3)
Vessel nozzles
4(1÷3)
5(1÷3)
3
Shell
Vessel torus
2
Vessel bottom
1
Reactor vessel
Bolts
Washers
Nuts
Threaded areas
Flange
CRD nozzle nuts and bolts
17(10 TUERCAS POR CAD.
16(10 PERNOS POR
CRD nozzle-guide tube
15(1÷24)
Instrumentation tube
18(1÷10)

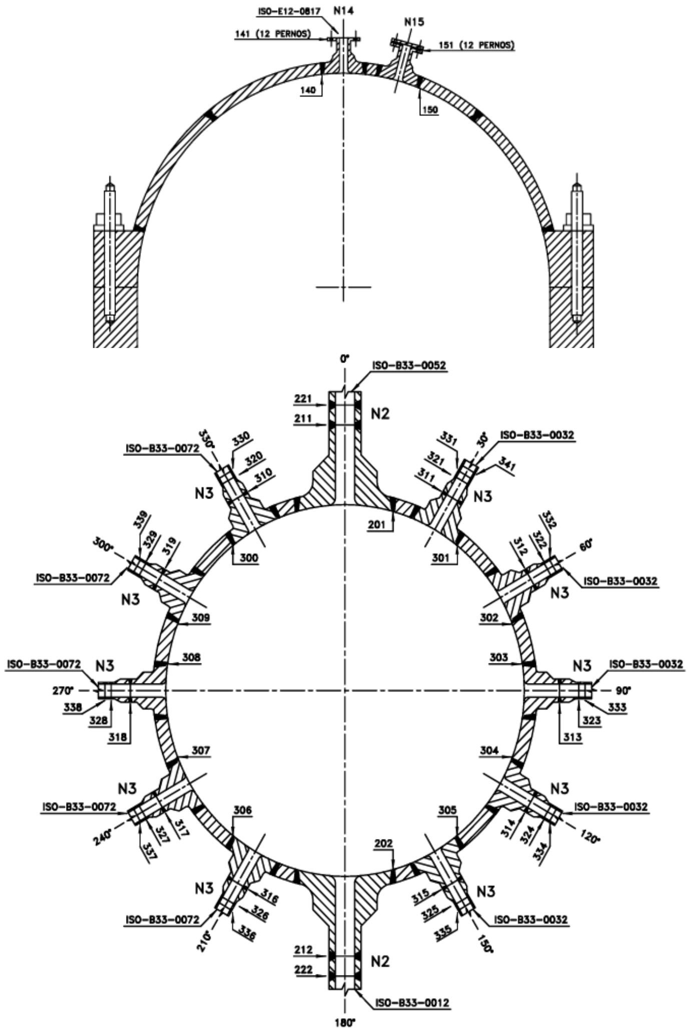
BWR-GE TYPE VESSEL



Reactor vessel



Detail of vessel bottom and CRD's N9, N16, N17



Vessel head and cross-section

06. Calandria/pressure tubes (CANDU)

As it has been explained in chapter 01.2 of this report, in the Spanish nuclear power fleet, there is not this type of technology, therefore this chapter is not applicable to the present report.

07. Concrete containment structures

07.1. Description of ageing management programmes for concrete structures

07.1.1. Scope of ageing management for concrete structures

The structures included within the scope of the present report and the description of their functions are sub-divided in this chapter on the basis of the design technology of the plant.

Westinghouse PWR type technology

A differentiation may be made in this category between pre-stressed concrete structures with post-tensioning reinforcement and reinforced concrete containments.

<u>Pre-stressed concrete containment with post-tensioning reinforcement</u>

This category includes the reactors of the Ascó plant, with two units, and the Vandellós II plant. The reactor containment buildings consist of pre-stressed concrete structures with post-tensioned tendons, designed by the companies Bechtel and Initec.

The containment buildings were designed as vertical-straight cylindrical structures of pre-stressed concrete, with an essentially flat base foundation slab, conventional reinforcement and closed at the upper part by means of a torispherical dome, in the case of Ascó, and a hemispherical dome in the case of Vandellós II.

Three buttresses are arranged symmetrically every 120° on the cylindrical wall and are used to anchor the horizontal tendons of the pre-stressing system. In the case of Ascó plant, there is a stiffening ring at the upper end of the cylindrical wall, used for the anchoring of the tendons of the dome.

The thicknesses of the cylindrical wall and the dome are 1.15 m and 1 m respectively at Ascó and 1.15 m and 0.95-1.15m in the case of Vandellós II.

Below the base slab there is a continuous accessible gallery for the installation, tensioning and inspection of the vertical tendons.

Pre-stressing induces compressive stresses in the concrete, such that when a load such as the design accident pressure is applied, the tensile stresses in the concrete are minimised.

In pre-stressed containments, compressive stresses are induced in both the vertical and horizontal directions, in the cylinder and the dome. The level of pre-stressing is adjusted such that when tensile stresses are activated there are no tensions in the concrete for the majority of load combinations.

Compression is induced in the concrete by installing and then tensioning high strength steel tendons in internal ducts in the cross-section of the concrete. In order to protect the tendons against corrosion, the tubes are filled with corrosion-inhibiting grease. In order to determine the number and location of the tendons, consideration is given in the design of the containment to losses of tension in the tendons as a result of friction forces during tensioning, the penetration of wedges, elastic shrinking of the concrete, the retraction and creep of the concrete and the relaxing of the steel.

In the case of the Ascó plant, the post-tensioning system is made up of three families of tendons (horizontal, vertical and dome) with a fixed number of 37 strands per tendon. At the Vandellós II plant the post-tensioning system includes two families of tendons (horizontal and vertical in the shape of an inverted “U”) with a variable number of strands per tendon, to a maximum 53. Each strand is made up in turn of seven high strength steel wires.

The tendons are housed inside ducts measuring 14 cm. in diameter, formed by galvanised bands measuring 0.60 mm in thickness, which are left embedded in the concrete during construction. The tendons are tensioned from both ends by means of hydraulic jacks, their cables being anchored by means of wedges in an anchoring header. This header transmits loads to a distribution plate embedded in the concrete, which in turn transmits them to the structure.

Reinforced concrete containment

Almaraz plant comprises two twin units. The containment buildings are reinforced concrete structures, designed by Gibbs & Hill Inc. These reinforced concrete containment buildings were designed as continuous, vertical and cylindrical structures with hemispherical domes, supported on an almost flat slab. The wall and dome measure 1.40 and 0.75m in thickness, respectively.

In order to guarantee leak tightness, the containments are fitted internally with a steel liner made up of welded carbon steel plates of different thicknesses, these depending on the plants (6.5 mm constant at Ascó and Vandellós II, 6 mm for the cylinder and dome at the Almaraz plant and 10 mm for the base plate). These liner plates are anchored to the inner face of the concrete by means of connectors.

The floor liner is installed over the base slab and then covered with a protective slab of concrete.

The safety functions of the outer containment structures are in all cases the following: provide the containment of steam and limit out-leakage following an accident inside containment, isolate the reactor coolant system and other safety-related systems from extreme environmental conditions and provide biological shielding.

The method for the selection of concrete containment structures has been developed on the basis of the criteria of the IS-22 [21], which are based on the 10 CFR 54 [23], in accordance with the methodology described in Chapter 02 of the present report.

The following table 07.1 indicates the components included within the scope and the significant ageing mechanisms that require the management of concrete containment structure components, and has been drawn up on the basis of the Ageing Management Review (AMR), in accordance with the methodology described in chapter 02 of this report.

Structure	Ageing mechanism
Concrete components	▪ **Cracking due to:** • **settling or movement of the land** • **icing-deicing cycles** ▪ **Changes in properties due to:** • **Leaching Ca(OH)2** • **Chemical attack** ▪ **Loss of material due to:** • **corrosion of embedded items** • **chemical attack** • **icing-deicing cycles** ▪ **Reduction of anchoring capacity due to concrete degradation (concrete).**
Containment liner	**Loss of material due to corrosion**
Post-tensioned tendons	▪ **Loss of tension due to:** • **High temperature** • **Creep** • **Retraction** ▪ **Loss of material due to corrosion**
Anchor plates and wedges	▪ **Loss of tension due to:** • **High temperature** • **Creep** • **Retraction** ▪ **Loss of material due to corrosion**
Containment perimeter sealing (liner-concrete interface and others)	▪ **Cracking due to:** • **Thermal exposure** • **Irradiation** ▪ **Loss of flexibility and strength due to degradation (elastomers).**
Leak chase channel	**Loss of material due to corrosion**

Table 07.1

Finally, after having identified the significant effects and mechanisms requiring management, the ageing management programmes are assigned on the basis of the model programmes of NUREG-1801 [25] and the LR-ISGs, for the management of the said ageing effects.

KWU type PWR technology

The reactor building of Trillo plant, which is of KWU design, consists basically of an enveloping reinforced concrete structure with a circular foundation slab measuring 59.20 m in diameter and a hemispherical upper dome. A metallic sphere measuring 53 m in diameter located inside the building divides the overall assembly into two areas: the containment building itself, which is the part located inside the metallic sphere, and the annulus, which is located between the metallic containment sphere and the outer reinforced concrete envelope. The containment structure is designed to retain whatever radioactive materials might be released from the reactor core during a loss of coolant design basis accident.

The concrete structures selection method has been drawn up in accordance with the criteria of 10 CFR 54 [23], in keeping with the methodology described in chapter 02 of the present report.

The components included within the scope of this report are the concrete structure surrounding the metallic containment sphere, the concrete calotte shell and the sphere-calotte shell transition area.

The identification of the ageing effects and mechanisms that require the management of the components of the concrete structures has been accomplished by way of the Ageing Management Review (AMR), in accordance with the methodology described in chapter 02 of this report. This process has served to identify the effects for the elements coinciding with those shown in Table 07.1 (those which are applicable).

As in the previous cases, the assignment of the corresponding AMP's from the Trillo plant catalogue was accomplished in accordance with the provisions of NUREG-1801 [25] and the LR-ISG documents.

General Electric BWR technology

Cofrentes plant has a Mark III type primary containment designed by General Electric. This is a self-supporting cylindrical steel vessel with an ellipsoid dome, supported by a reinforced concrete containment resting on a flat foundation slab of reinforced concrete and lined with steel. The steel containment vessel is completely surrounded by a cylindrical reinforced concrete shielding building with a flattened dome cover. Between the two there is a space known as the annulus, which extends at the upper part, maintaining also the separation between the containment vessel and the dome of the shielding building.

The concrete containment is a cylindrical pressure-retaining structure lined with a steel sheet and constitutes the lower part of the building. The concrete containment surrounds the suppression pool and rises above the water level in order to minimise the effect of the dynamic loads produced by the actuation of the relief and safety valves in the suppression pool. The cylindrical containment wall is anchored to the concrete foundation slab. The shielding building and steel containment are supported by the concrete containment and anchored to it, at an elevation of approximately -80 m. The liner sheet continues above the concrete containment and constitutes part of the metallic containment above elevation -0,80 m. The foundation slab covering sheet is joined by a leaktight weld to the containment liner.

The shielding building is a cylindrical reinforced concrete structure measuring 37.8 m in inner diameter fitted with a flattened dome cover. It is supported on a foundation slab shared with the concrete and steel containment and the internal structures of the containment. The shielding building completely surrounds the steel containment and operates as a secondary containment boundary to reduce leakage during and after a loss of coolant accident. It also provides biological shielding when the containment contains fission products and structural shielding against external missiles.

The ageing of the concrete containment structures and shielding building at Cofrentes plant is monitored within the framework of the Ageing Management Programmes (AMP's), one based on Sub-section IWL of ASME XI "ISI Concrete containment" and other based on MR "Surveillance of structures" (metallic structures anchored to the shielding building and expansion joints between the shielding building and annexes).

For this plant, the identification of the significant ageing effects and mechanisms requiring management of the components of concrete structures has been accomplished by way of the Ageing Management Review (AMR), in accordance with the methodology described in chapter 02 of this report. As a result of this process, the ageing effects and mechanisms identified by the licensee are analogous to those included in **Table 07.1**.

07.1.2. Ageing assessment of concreate structures

The AMP's that manage the significant ageing effects and mechanisms identified in table 07.1 for the different containment structures and components are as follows:

- "In-service inspection of containment (liner)", based on AMP XI.S1 "ASME Section XI, Sub-section IWE", the objective of which is the visual inspection of all MC-class components. In the case of plants equipped with programmes for the management of liner, anti-humidity barrier and leak chase channels effects, visual inspections are performed depending on the examination category shown in Table IWE-2500-1 to which each component belongs:
  - Category E-A, for accessible surfaces of containment, requiring VT-3 visual examinations.
  - Category E-C, for containment surfaces subject to augmented inspection, requiring VT-1 visual inspections in the case of visible surfaces and, otherwise, the monitoring of thickness by means of ultrasonic techniques.

  This programme is applicable to PWR type plants of Westinghouse design.

  In the case of the KWU design plant, the German standard KTA 3401.4 is also used. For the specific case of KWU, this programme also manages the effects of the sphere-calotte shell transition elastomeric elements.
- "Surveillance of structures", based on AMP XI.S6 "Structures Monitoring". The scope of this programme includes all those structures that are to be inspected and maintained in order to comply with the provisions of the Maintenance Rule (in accordance with CSN Instruction IS-15), the requirements of which fulfil the directives of NRC RG 1.160, NUMARC 93-01 and CSN Safety Guide 1.18. For the case covered by this study, containment structures, this programme manages the effects of the concrete components. As a result, the containment structures of the reactor building are monitored by means of inspection walkdowns.
- "Containment leak test", based on AMP XI.S4. This is a primary containment leakage control programme applied at Westinghouse design PWR plants to verify integrity and leak tightness. The programme is based on option B of Appendix J of 10 CFR Part 50 and on NRC Regulatory Guide 1.163.

- "In-service inspection of containment (concrete)", based in turn on AMP XI.S2 "ASME Section, Sub-section IWL", which responds to section XI of ASME Sub-section IWL. In this way, visual inspections are performed for the management of significant ageing effects and mechanisms in concrete elements. This programme is applied to all the plants except the one of KWU design.
- "Containment tendon management programme", based on TLAA X.S1, by means of which periodic lift-off tests are performed on a representative sample of containment tendons and the results obtained are compared to certain previously defined acceptance criteria fulfilling the provisions of NRC R.G. 1.35.1 "Determining pre-stressing forces for inspection of pre-stressed concrete containments". Visual inspections are also performed on the anchors and the protective grease is chemically analysed. This programme is applicable only to plants with pre-stressed reinforced concrete containments.

The documentation used for the performance of the programmes is that defined in NUREG-1801 [25], as well as that indicated in chapter 02 of this report. In addition, the following has been used specifically for the concrete structures dealt with in this study:

- **NUREG-1801 Rev. 2**, Generic Aging Lessons Learned (GALL) Report, December 2010 [25].
- **10 CFR 54**, Requirements for Renewal of Operating Licenses for Nuclear Power Plants [23].
- **10 CFR 50 Appendix J**, Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors, Office of the Federal Register, National Archives and Records Administration, 2009.
- **KTA 3401.4**, Steel Containment Vessels. Part.4: In-service Inspections. June 1991.
- **CSN Instruction IS-15**, Instruction IS-15 (Rev. 1) on requirements for monitoring of the effectiveness of maintenance at nuclear power plants [45].
- **ASME Section XI Sub-section IWE**, Requirements for Class MC and Metallic Liners of Class CC Components of Light-Water Cooled Plants. The ASME Boiler and Pressure Vessel Code, 2004. The American Society of Mechanical Engineers, New York.
- **ASME Section XI Sub-section IWL,** Requirements for Class CC Concrete Components of Light-Water Cooled Power Plants. The ASME Boiler and Pressure Vessel Code, 2004. The American Society of Mechanical Engineers, New York.
- **ACI Standard 201.1R**, Guide for Making a Condition Survey of Concrete in Service, American Concrete Institute.
- **ACI Standard 349-3R**, Evaluation of Existing Nuclear Safety-Related Concrete Structures, American Concrete Institute.
- **NRC Regulatory Guide 1.163**, Performance-Based Containment Leak-Test Program, Rev. 0, US Nuclear Regulatory Commission, September 1995.
- **NRC Regulatory Guide 1.160**, Monitoring the Effectiveness of Maintenance at Nuclear Power Plants. US Nuclear Regulatory Commission Rev. 2. March 1997.
- **CSN Safety Guide 1.18**. Measurement of the effectiveness of maintenance at nuclear power plants [46].
- **ANSI/ANS 56.8**, American National Standard for Containment System Leakage Testing Requirements, 1994.
- **NEI 94-01**, Industry Guideline for Implementing Performance-Based Option 10 CFR Part 50 Appendix J, Rev.2.

- **10 CFR 50 Appendix B**, Quality Assurance Criteria for Nuclear Power Plants, Office of the Federal Register, National Archives and Records Administration, 2009.
- NPP's Technical Specifications.
- NPP's Quality Assurance Manual.

The plant-specific and industry operating experience applicable to each programme is periodically assessed in accordance with the methodology described in chapter 02 of the present report, and its specific applicability to each plant is dealt with in section 07.2 of the present chapter.

Finally, in the framework of R&D activities relating to the structural performance of concrete, mention might be made of the CSN's participation in and promotion of the so-called "Zorita Concretes" project. This project came about as the result of a collaboration agreement between the CSN, different Spanish nuclear power plant licensees and other organisations, this arising due to the opportunity provided by the on-going process of dismantling the José Cabrera plant, which will allow samples of material removed from different structural elements of the plant containment to be used for testing. The results will allow for the in-depth experimental and theoretical study of the performance of concrete structures under the in-service conditions of the material (temperature, radiation and others) existing during nuclear power plant operation.

Another noteworthy R&D activity is the CSN's participation, along with ANAV and the Polytechnic University of Catalonia, in the Vercors project, sponsored by the NEA. This consists of the manufacturing of a 1/3-scale model of a PWR containment by EDF (France) to assess the ageing effect and for the modelling of leak rate during pressure testing. The project includes a benchmark and a later workshop in 2018.

07.1.3. Monitoring, testing, sampling and inspection activities for concrete structures

For each programme identified under the previous heading, the activities and inspection frequencies defined at the Spanish plants will be described. Likewise, all the programmes will be identified, along with the acceptance criteria applied and the methods used to assess trends.

Inspection activities and frequencies

- In-service inspection of containment (liner): The inspection activities included in the programme "In-service inspection of containment (metallic)" are performed by means of the "Containment Inspection Programme" and are generally as follows for the aforementioned examination categories and for Westinghouse PWR design plants:
    - Visual inspection VT-3 of containment surfaces (in accordance with Cat. E-A, item E1.11 of IWE ASME XI) / 100% each ISI period.
    - Visual inspection VT-3 of containment anti-humidity barriers (in accordance with Cat. E-A, item E1.30 of IWE ASME XI) / 100% each ISI period.
    - Augmented inspection by means of VT-1 of visible surfaces (in accordance with Cat. E-A, item E4.11 of IWE ASME XI) / 100% each ISI period.

- Augmented inspection by means of UT of surfaces not visible by VT-1(in accordance with Cat. E-C, item E4.12 of IWE ASME XI) / 100% each ISI period.

At the KWU design plant, the entire transition area between the metallic containment and the concrete calotte shell is checked visually. Checks are performed for possible changes in construction status due to mechanical influences, corrosion, damage to protective paint, cracking and layers, as well as a lack of leak tightness in areas subjected to stress. This inspection is carried out every other refuelling outage.

- Surveillance of structures: The visual inspections performed in concrete containment buildings and included in the "Surveillance of structures" programme are defined in the guidelines or procedures drawn up by each licensee within his Maintenance Rule programme for structures and on the basis of CSN Safety Guide 1.18 [46]. All of these inspections are identified below:
  - A visual inspection of the accessible outer surfaces of the containment is performed at a frequency of two such inspections every ten years, the aim being to detect signs of external degradations such as: abnormal cracking of the structure, the presence of flaking, changes in volume/porosity, evidence of reduced strength, signs of excessive deformations or settling, the presence of alkali-silica reactions, chemical attack, seepage of water and signs of corrosion of reinforcements.
  - The following inspections are carried out on the protective concrete slab during each refuelling outage:
    - Embedded tubes, in order to check for the presence of water in them.
    - Containment sumps, in order to assess possible leakage to the protective concrete, including joints between channels inside containment and the sumps.
    - Leak testing of sump water inlet channels in order to assess the condition of their joints.

    In addition, the seals of joints located in the containment building concrete foundation slab are inspected, specifically the following:

    - the sealing of slab concrete-laying joints,
    - the sealing between the slab and walls,
    - the sealing between the slab and the sheet liner of the outer wall,
    - the sealing of joints in the water collection channel area.

    These visual inspections are aimed at detecting possible anomalies, such as cases of lift-off, cracking, lack of sealing, the presence of foreign materials or drying-out.
  - By means of a number of different procedures included in the Overal Ageing Management Programme at certain plants, and in the Maintenance Rule at others, an inspection is performed on the condition of exposed surfaces of buried concrete, whenever excavations are performed providing access to normally

inaccessible areas. These inspections are carried out with a view to detecting the signs of degradation mentioned in the previous section for accessible surfaces.

- Containment tendon management programme: The tests performed on the post-tensioning tendons of concrete containment buildings, included in the "Containment Tendons" programme at the Ascó and Vandellós II plants, cover the application of item L2.10 (tendons) of inspection category L-B (unbonded post-tensioning tendons system) of sub-section IWL of ASME XI.

  As part of the containment tendons management programme a measurement is made of the lift-off force of a representative random sample of at least 13 tendons (5 horizontal, 4 vertical and 4 in the dome, in the case of Ascó, and 4 inverted U-shaped and 9 horizontal tendons, in the case of Vandellós II), this being compared to the limits mapped out for each. A series of inspections and analyses, defined in the section on in-service inspection, are also performed. On completion of the surveillance, a technical assessment is performed on the results obtained with a view to analysing the evolution of the characteristics of the pre-stressing system in relation to those expected and the results obtained from previous monitoring exercises, and the evolution for the next surveillance period is mapped out, as requested in the Technical Specification Surveillance Requirements.

  The frequency of the testing, in accordance with ASME XI IWL-2420 (a), is five years, as long as traces of abnormal degradation of the structural integrity of the containment making a shorter period between tests advisable have not been detected in the three previous surveillance exercises.

  The calculations associated with the loss of containment tendon tension fulfil the requirements of the definition of time-dependant ageing analysis (TLAA), for which reason resolution should be performed before applying for long-term operation. As of the date of issuing of this report, the licensee of Vandellós II NPP had had carried out a new 60-year calculation for loss of containment tendon tension on the basis of a finite elements model corrected with the results of the surveillance programme. This calculation shows that the tension values of the tendons will not drop below the minimum values specified during the 60 years of plant lifetime. These same calculations are currently being performed for Ascó 1 and 2 units.

- Containment leak test: The "Containment A, B and C test programme" and the procedure "Containment integrated leak testing" define the containment integrated leak test (Type A). Before performing type A leak tests, a visual inspection is carried out on all accessible internal and external surfaces in order to detect any possible deterioration that might affect structural integrity or leak tightness. This inspection includes the sheet liner and is carried out during the refuelling outage in which the type A tests are performed, as well as during at least a further two refuelling outages during the 10-year period of this test. When this visual inspection coincides with a type A test, it will be performed prior to, during and after the said test on concrete surfaces and prior to and after this test on the surfaces of the liner. This inspection is made to coincide with the general visual inspection of the containment building performed during each inspection period. This visual inspection is included in the programme mentioned above: "In-service inspection of containment (liner)".

- In-service inspection of containment (concrete): Through the ageing management of concrete items within the framework of the "In-service inspection of containment" programme, periodic inspections identified in the In-Service Inspection Manual (ISIM are performed for items corresponding to Category L-A and Category L-B (for plants with pre-stressed containments) of ASME XI. In particular:
  - General visual inspection of the surface of accessible areas of the containment concrete and monitoring of grease stains (in accordance with category L-A, item L1.11 of ASME XI).
  - Detailed visual inspection of the surface of areas in which degradation of the containment concrete is suspected (in accordance with category L-A, item L1.12 of ASME XI).
  - Inspection of containment tendons in accordance with category L-B, item L2.10 of ASME XI: Lift-off tests in accordance with surveillance procedure PV-58A and the ISIM, in the case of Ascó NPPO, and PMV-749 and the ISIM in the case of Vandellós II NPP.
  - Inspection of containment tendon strands / rods (in accordance with category L-B, item L2.20 of ASME XI): Visual inspection, elastic limit testing, tensile strength testing, elongation measurement, in accordance with surveillance procedure PV-58A and the ISIM in the case of Ascó NPP, and PMV-749 and the ISIM in the case of Vandellós II NPP.
  - Inspection of anchoring devices, hoods and concrete surfaces adjacent to the containment tendons (in accordance with category L-B, item L2.30 of ASME XI): Detailed visual inspection, acoustic inspection, in accordance with surveillance procedure PV-58A and the ISIM, in the case of Ascó NPP, and PMV-749 and the ISIM in the case of Vandellós II NPP.
  - Inspection and analysis of containment tendon protective grease (in accordance with category L-B, item L2.40 of ASME XI): analysis of alkalinity, analysis of water content, analysis of concentration of chlorides, nitrates and sulphides and differences in grease removed/injected, in accordance with surveillance procedure PV-58A and the ISIM in the case of Ascó NPP, and PMV-749 and the ISIM in the case of Vandellós II.
  - Measurement and analysis of free water in the containment tendons (in accordance with category L-B, item L2.50 of ASME XI): volume and pH of free water in hoods, in accordance with surveillance procedure PV-58A and the ISIM in the case of Ascó NPP, and PMV-749 and the ISIM in the case of Vandellós II.
- Ground Movement Surveillance Manual (GMSM): In view of the effect of rising of the land, Ascó plant has had a Ground Movement Surveillance Manual (GMSM) since the beginning of its commercial operation. The different tomes contained in this manual have served as a basis for the development of the systematic approach to be adhered to for control of the plant structures, hydrology and geotechnical aspects, defining a series of parameters to be monitored and assessed against those expected and assessed in the structural calculations of the SSC's affected by this phenomenon. In the specific case of the containment building, topographic

movement is controlled, along with the deformation of the lower slab of the building and its degree and direction of tipping.

As regards the containment of Ascó 1 unit, the GMSM manages the topographic control of the building, analysing the data obtained from levelling points.

The calculations associated with ground movement at Ascó plant also fulfil the definition of Time Limited Ageing Analysis (TLAA), for which reason, and as in the case of the tendons, they should be resolved prior to the request for long-term operation. The periodic reviews of the calculations and analyses associated with prediction of the movement ensure that the safety limits established are not reached during the next operating period requested.

Acceptance Criteria

- In-service inspection of containment (metallic): The areas and items examined that make up the primary containment and that are managed using the programme "In-Service Inspection of Containment (metallic)" are assessed in accordance with the criteria set out in Article IWE-3000 of ASME XI, that is by comparing the results of the examinations performed with the registers of the corresponding basic reference inspection and applying the criteria set out in IWE-3510 for category E-A and IWE-3511 for category E-C.

  Furthermore, the minimum permissible thickness used to analyse the results of ultrasonic inspections are determined by the plant engineering department, if there is no nominal reference thickness for the liner sheeting.

  In addition, the acceptability of inaccessible areas is assessed whenever conditions are detected in accessible areas that might indicate the presence of or cause degradation in the said inaccessible areas.

  In the specific case of the visual inspection of the sphere-calotte shell transition zone at Trillo plant, the acceptance criteria are perfect leak tightness conditions and the complete absence of damage.

- Surveillance of structures and in-service inspection of the containment (concrete): In the specific case of concrete structures, the acceptance criteria of both programmes (Surveillance of structures" and "In-service inspection of containment (concrete)") coincide and are based on the criteria of the responsible personnel, as established in Guideline ACI 201.1R. Consequently, 3 acceptance levels are established, in accordance with the criteria of ACI 349-3R:

  - Acceptable: The concrete surfaces inspected are considered to be acceptable if they fulfil the following criteria: absence of washing or chemical attack phenomena, absence of signs of abrasion, erosion and cavitation, absence of laminated or segregated areas, spalling of less than 10mm in depth and 100mm in any dimension, absence of signs of corrosion in reinforcing elements or component anchoring devices, passive fissures of less than 0.4 mm in maximum width, absence of deformations, settling or excessive movements and absence of alkali-silica reactions, chemical attack or other active degradation mechanisms.

- Acceptable following assessment: This category includes structures requiring review in order to judge their acceptability; i.e., structures showing signs of degradation and considered to be acceptable following analysis of these indications.

  The degree of degradation may be judged as being acceptable following assessment, which may consist of a more detailed inspection, testing, analysis or repair.

- Unacceptable: Concrete surface conditions exceeding the limits indicated in the previous section on the category of acceptable following assessment are considered unacceptable and require a detailed technical review.

  This review may include tests, additional inspections or analytical means, and the assessment of the acceptability of the structure must be carried out by the Responsible Engineer.

- <u>Containment tendons management programme:</u> The acceptance criteria for the tests relating to the containment tendons are included in the technical specifications and are as follows:
  - Traction force observed for each of the 13 randomly selected tendons (distributed as indicated previously in the section of this report on "Inspection activities and frequencies") within the limits mapped out for each and in accordance with what has been indicated above.
  - In each inspection, one tendon from each family is kept unchanged in order to set up a history and correlate the data observed. If the lift-off force observed in any tendon in the original sample is between 95% of the lower limit established and 90% of the said lower limit, the lift-off force of the two adjacent tendons shall be checked. If both these adjacent tendons are above 95% of their lower established limit, then in those that are below the minimum required by design, the stress expected by calculation for the age group shall be re-established, and the group of tendons shall be considered acceptable when there is a single anomaly. Unless abnormal degradation of the pre-stressing system is identified during the last three consecutive inspections, the sample population for subsequent inspections shall include at least nine tendons (3 in each family).
  - De-tensioned tendons (1 per family) shall be used to identify the possible presence of broken or damaged strands. Following their removal, a check is performed to determine whether there is any corrosion, cracking or damage and whether they present a series of minimum conventional yield strength, tensile strength and elongation values.
  - Maximum permissible elongation during the re-tensioning of previously de-tensioned tendons.
  - Lift-off forces equal to or greater than the limits established for each type, dome, vertical or horizontal.
  - Determination of operability, in relation to the water content of the covering grease (in accordance with ASTM D95), alkalinity (in accordance with ASTM D974), concentrations of chlorides soluble in water (in accordance with ASTM

D512), determination of nitrates (in accordance with ASTM D3867), sulphides (in accordance with APHA 427, edition 14 or APHA 4500), absence of free water and comparison of the amounts of grease removed and injected, in order to assess losses of grease from the structure and verify that these do not exceed 10% of the net volume of grease in the tendon.

- Containment leak test: The acceptance criterion for the different "type A tests" is included in the design technical specifications (TS) of each plant, where:

  The overall integrated leak rate of the containment in the as-found condition must be less than or equal to the acceptance criterion of 1.0 La, at a pressure of between 0.96 Pa and Pd, where:

  La: 0.20% by weight of air in containment every 24 hours.

  Pa: accident pressure.

  Pd: design pressure.

  When performing the Type A test and before entering an operating mode in which containment integrity is required, a check shall be made to verify that the integrated containment leak rate in the as-left condition does not exceed 0.75 La. If the value of 0.75 La is exceeded, the established repairs or modifications shall be performed, followed by an additional test giving acceptable results. The as-left and as-found values are calculated in accordance with the methodology described in ANSI/ANS 56.8.

Assessment of trends

As regards inspections associated with the metallic containment programmes, and as established in the ISIM's, the inspection areas in which relevant indications or degradations have been detected, requiring assessment in accordance with the ASME Code, and being acceptable for continued service, are included in examination category E-C (areas requiring augmented inspection) and are re-examined during the next inspection period. These inspections are performed regardless of whether the method for acceptance of the component for continued service has been by engineering assessment or repair. If the inspections demonstrate that the defects or degradations remain unchanged, a return may be made to the inspection programme initially foreseen for the area or areas in question. It is likewise established that when accessible areas are detected with conditions suggesting the possibility of degraded conditions in inaccessible areas, such inaccessible areas must be assessed.

In those plants in which the leak tests are included within the scope, the containment leakage value is kept updated by means of the containment leak test (ILRT) procedures.

During the performance of the inspections associated with the concrete containment and structures surveillance programmes, inspection sheets are filled in in order to accurately define the areas inspected and the results of assessment, such that they serve as a reference for future inspections and checklists, which will allow for the systematic inspection of essential aspects to be assessed.

Likewise, in compliance with the procedures of the Maintenance Rule, it is established that in those areas in which the degradation detected is such that the structure or component inspected may cease to perform its intended function if allowed to continue until the next normal scheduled inspection without corrective actions being taken, augmented monitoring should be performed, whenever possible, with visual inspections carried out at a greater frequency than those initially performed.

As regards the evolution of tension in the tendons (in pre-stressed containments), the estimated and measured pre-stressing forces are plotted against time and the Predicted Lower Limit (PLL), Minimum Required Value (MRV) and trend curves for the Long Term Operation are developed. Regulatory Guide RG 1.35.1 provides guidance on PLL and MRV calculation. The trend curve represents the tendency of the pre-stressing force on the basis of the currently measured forces. IN 99-10 provides guidance for the plotting of the trend curve. According to IWL-2420 (a) of ASME XI, the test frequency is every 5 years but may be altered in view of the trends.

07.1.4. Preventive and remedial actions for concrete structures

Preventive actions

In view of the eminently inspection or monitoring-related nature of these programmes, the licensees of the Spanish nuclear power plants do not consider preventive actions for concrete structures within the scope of this report (other plant structures do have actions of this type). This is reinforced by the results of the inspections performed throughout the lifetime of the plant, which have not revealed any significant ageing problems. An exception to this, however, are plants with pre-stressed containments, due to the particular condition caused by the presence of tendons in the structure. Described below are the preventive actions for the Ascó and Vandellós II plants.

The structural integrity surveillance programme for outer concrete surfaces and the post-tensioning tendons system is a condition monitoring programme; however, preventive actions are performed to prevent corrosion, verifying the condition of the grease covering all the tendons inspected, in accordance with the technical specifications.

Before the cap is removed from the tendons, the condition of the grease (solid or fluid) is observed; it is then removed and the outer part is inspected for the possible presence of water. A grease sample is taken for testing purposes.

In addition, Ascó plant performs the following, in accordance with the surveillance procedures and the CSN letter ASCAS1-IMES-94-48:

- Containment inspection to detect possible grease leakage from the pre-stressing system.
- Inspection of grease level inside the upper hoods of all vertical tendons.
- The quantity of grease injected in each tendon of the dome is recorded for the purpose of identifying any leakage.

For its part, Vandellós II plant controls grease stains in the containment building every 18 months, additionally to what is required by the code.

The pre-stressing forces of each of the families of tendons are monitored within the framework of the "Containment Tendons" programme by means of lift-off testing, actions being taken to keep them above the minimum required value, in accordance with the acceptance criteria described in the surveillance procedures, where necessary.

Corrective actions

In describing the associated corrective actions, these will be classified on the basis of the programmes dealt with in the previous sections.

- In-service inspection of containment (liner). If an inspection gives an unacceptable result, the licensees adopt a series of corrective measures depending on whether the affected areas are accessible or not.
    - Accessible areas:
        - Repair or replacement: When an area or component does not meet the acceptance criteria, it shall be declared unacceptable for continued service, and shall be repaired or replaced. The acceptability of the area or component is determined by acceptable examination following repair or replacement.
        - Engineering assessment: When an area or component does not meet the acceptance criteria, it may be declared as acceptable for continued service without repair if an engineering assessment determines that the indication or degradation is non-structural in nature or has no unacceptable effect on the structural integrity of the containment.
        - Supplemental examinations: The examinations used to detect indications or degradations may be supplemented with other examination methods or techniques allowing for characterisation of the flaw (for example, size, depth and orientation).
    - Inaccessible areas: Whenever there are conditions of degradation in areas accessible for inspection in the metallic containment that may indicate the presence or result of degradation in inaccessible areas, an acceptability assessment shall be performed.
- In-service inspection of containment (concrete). If an inspection gives an unacceptable result, the licensees adopt a series of corrective measures, included in the applicable ISI procedures, based on ASME XI sub-section IWL.
    - Concrete surface conditions exceeding the limits indicated in the previous section on the category of acceptable following assessment shall be considered unacceptable and require a detailed technical review.
    - In the event of items or areas of the structure showing signs of unacceptable degradation being detected, an assessment shall be performed in order to determine the possible presence of flaws in areas that are not accessible, and have not, therefore, been inspected. Furthermore, alternative inspection methods are proposed, or analyses justifying the impossibility of the presence of effects in these areas due to the absence of the root cause or their not being potentially significant.
    - In the event of repair/replacement being required, these activities shall be carried out in accordance with the provisions of ASME XI article IWL-4000.

Furthermore, whenever acceptable indications or degradations are found in examination category L-A areas (concrete surface), an assessment of the inaccessible areas of the concrete containment is required if in the accessible areas there are conditions that might indicate degradation in inaccessible areas.

Subsequently, the licensee shall draw up a final assessment report including, among other things, a description of the justifying analyses and corrective measures planned, for conditions exceeding the limits indicated above.

- Containment leak test. The corrective actions included in this programme are taken from Appendix J of 10 CFR 50 and NEI 94-01. In accordance with the leakage programme, if, in compliance with the technical specifications, a type A test does not satisfy the limit of 0.75·La, the cause should be identified and the necessary corrective actions taken. Once the problem has been corrected, the operating criterion should once again be established through the performance of an additional type A test, with acceptable results, within 48 months, but not before 24 months. If this test is acceptable, the 10-year extended period may be restored.
- Surveillance of structures. The licensees apply the general criteria of the MR to this programme. The term for the corrective actions depends on the specific procedures of each plant and the length of their refuelling cycles. Although the processes may vary slightly from one plant to another, if indications or signs of degradation are identified classifying the structure in the category “unacceptable” or “acceptable following assessment or with deficiencies”, the assessment and definition of corrective actions for these indications shall be required:
  - Acceptable following assessment or acceptable with deficiencies. SSC’s giving unacceptable results in the second assessment shall be analysed by an engineering report. An in-depth shall be made of characteristics of the degradations, such as scope, degree, causes and propagation. The impact of the degradations on the capacity and function of the structure shall be analysed. The inspections shall be extended and whatever tests and analyses are considered necessary shall be performed. A third assessment shall be carried out and documented in a report, its results possibly being:
    - Acceptable.
    - Acceptable with deficiencies. Minor deficiencies not implying non-compliance with any of the structure’s design functions. The resulting actions must be performed up until the next inspection and may be any of the following:
      - Normal surveillance.
      - Surveillance at a greater frequency.
      - Repair.
      - Replacement.
  - Unacceptable. Non-compliance with grade 2 acceptance criteria and the condition of the SSC does not guarantee compliance with one of the functions or fulfils the design requirements but with non-compliance with one of them prior to the next inspection. The required characteristics of strength, durability and

performance of structures requiring repair following assessment shall be restored.

- Containment tendons. The corrective actions included within the scope of the "Containment Tendons" programme are set out in the corresponding surveillance procedures. In this documentation a distinction is made between actions relating to structural integrity and actions relating to the performance of the tendons themselves.
  - Relating to structural integrity
    - If the average stresses are lower than the minimum required for each family, they shall be restored in 72 hours or the plant shall be taken to hot standby in 6 hours and to cold shutdown in 30 hours.
    - If the trend of the loss traction in a tendon or group of tendons is such that the minimum value required may be reached prior to the next surveillance, the lift-off forces of additional tendons shall be increased and the cause of the event determined.
    - If the lift-off force of one or more tendons is between 90% and 95% of the lower limit of the tolerance band, and at least one of the adjacent tendons is below 95%, the lift-off force of additional tendons shall be measured in order to determine the cause.
    - If the lift-off force of one or more selected tendons is below 90% of the lower limit of the tolerance band, the lift-off force of the adjacent tendons shall be measured, the affected tendon or tendons shall be de-tensioned and inspected to identify possible broken strand and a strand shall be removed for visual inspection and testing.
  - Relating to correct performance of tendons
    - If the lift-off force observed in any of the tendons of the original sample is between 95% of the lower limit expected and 90% of the said limit, the lift-off force of the adjacent tendons shall be checked. If these two adjacent tendons are both above 95% of the lower limit expected, then in those below the minimum required by design the stress expected by calculation for the age group in question shall be re-established and the group of tendons shall be considered acceptable, when this is the only anomaly.
    - The acceptance criterion for the tendons removed shall be the absence of corrosion, cracking or damage. Minimum values of yield strength, minimum tensile strength and elongation are also required.
    - If the specified limits are not met, an investigation shall be performed in order to ensure that the as-found values do not jeopardize the integrity of the pre-stressing system or, where appropriate, the system shall be returned to the design conditions.

In any case, the actions associated with the application of the programmes shall be performed in accordance with the requirements established in the plant quality assurance programme, which fulfils the requirements of Appendix B of 10 CFR 50 and is considered to be adequate for the analysis and implementation of corrective actions.

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

This section includes all the experiences that the licensees of the Spanish nuclear power plants have included in their reports.

ASCÓ NUCLEAR POWER PLANT

During refuelling outage R21 in unit 1, within the framework of the "In-service inspection of containment (metallic)" programme, the perimeter joint of the containment building was found to be degraded and with discontinuities, allowing water to enter to the lower elevations of the liner, an inaccessible area. In addition to repairing the perimeter joint, liner thickness measurements were performed every 20 centimetres using ultrasonic techniques at the liner-concrete interface in the area of the joint and below it, with penetrant liquid surface inspections being performed in the seven areas to be repaired. Of the total 651 thickness measurements performed in the area of the joint, 4 of less than 4.5 mm were discovered (the nominal thickness of the liner is 6.5 mm). Of the total 415 thickness measurements performed in the area below the joint, 3 areas were found with thicknesses of less than 4.75 mm, which were also repaired. No indication was detected by means of penetrant liquid surface inspection.

During the leak tests performed on the leak chase channel of the containment building liner during refuelling outage R21 in unit 1 of Ascó plant, and outage R20 in unit 2, two leak chase channel circuits per group were identified with indications of leakage, and were repaired and leak tested with acceptable results.

In view of the different activities carried out on the containment liner, the integrity of the liner is acceptable and that it fulfils its intended function.

The "In-service inspection of containment (concrete)" programme has proven to be effective for the detection and correction of degradation effects on the concrete surface of the containment of Ascó plant.

Following evaluation of the latest results obtained from inspections of the structural integrity of the containment, for both units 1 and 2 of Ascó plant, it is concluded that both the new and previously existing cracks are of little importance and normal for concrete structures. The new cracks reported measure 0.2 mm and those with increasing thickness grow from 0.2 to 0.3 mm, creating a very gradual trend regarding the appearance of new cracks and the widening of those previously in existence. Most of the cracks are located in the area close to the dome tendon anchor boxes. From the very first inspections a horizontal crack was detected at the elevation of the lower dome tendon anchor boxes. No significant variations have been detected with respect to previous inspections of this crack. These cracks are attributed to the nearby concentration of stresses due to the tendon anchoring devices and the geometry of the concrete (numerous edges and low thickness). It is also concluded that the quantity of grease emerging via the cracks is minor, and furthermore does not indicate any significant increase in the number of points from which the grease is exuding, as has been documented in several reports issued between 2011 and 2014.

Inn 2013 free water was detected in tendons H41, H-125 and H-102 in unit 2 of Ascó plant. As a result of this event, 100% of the horizontal tendon caps were inspected and the condition of the tendons was checked. Traces of corrosion were detected in certain tendons, these being replaced as a precautionary measure.

In view of the history of the results obtained at Ascó plant from the "Containment leak testing" programme, it may be concluded that the application of this programme has been effective in preventing inacceptable leakage in components belonging to the containment pressure boundary. The operating experience gained in applying this programme underlines the appearance of periodic failures, mainly affecting the containment isolation valves and relating to leakage across the valve seats, beyond the scope of this programme.

As regards the "Containment Tendons" programme, the results indicate that at Ascó plant the containment tendons management programme has been effective in identifying ageing effects and has allowed appropriate corrective measures to be taken before the occurrence of loss of function.

In particular, at Ascó 1 NPP:

During the 4th surveillance it was determined that selective horizontal tendon re-tensioning would be performed in order to place the safety margin for the next surveillance period in a safe zone, since the safety margin calculated for the 5th surveillance was very tight.

For Ascó 2 NPP:

During the 6th surveillance, tendon H-32 in the horizontal family gave a tension value lower than expected, but still higher than 95% of the lower limit. It was de-tensioned and then re-tensioned to the value existing during the construction phase.

In view of all the above, the licensee maintains that the effectiveness of the programme for the correct management of the ageing of containment buildings included within the scope has been demonstrated. It should be pointed out that although the conditions to which these items are subjected are susceptible, according to NUREG-1801 [25], to the mechanisms mentioned in section 07.1.1, the operating experience included therein indicates that the programme requires extension if other ageing mechanisms are detected during the performance of inspections.

VANDELLÓS II NUCLEAR POWER PLANT

As regards the condition of the inaccessible part of the containment liner, beneath the protective concrete, the inspections tests carried out through the "In-service inspection of containment (metallic)" programme during refuelling outage R14 in 2005 showed that as a result of deterioration of the sealing of the joints of the protective slab at containment elevation 100 (mainly in the sections located inside the water collection channels), water had been detected in the tubes embedded therein, which might pose a serious threat of corrosion of the liner below the slab, which would be difficult to detect visually.

During the 2005 refuelling outage, containment liner thickness measurements were also performed. In this respect a campaign of corrosion rate and potential measurements was carried out. The point with the highest value of corrosion potentials and corrosion rates was selected for sampling in the concrete at elevation 100 and in order to assess the condition of the liner. A superficial layer of oxide was observed but no loss of thickness. Repairs were carried out in all the areas that might allow water to get through to the protective concrete (liner protection slab joints, embedded drains pipes and containment sumps) and all the water present in the embedded tubes was drained off.

Following the assessment performed it was concluded that the loss of material due to corrosion in the area identified as having the highest corrosion rate was insignificant. This was due to the fact that, despite having high corrosion rates, this process took place over short time periods, for which reason there had been practically no loss of liner thickness and, consequently, no traces indicating the possibility of its undergoing a process of corrosion that might jeopardise its integrity.

Since the year 2000, inspections have been carried out on the tubes embedded in the protective slab at elevation 100, including control of the water level detected, analysis and removal of this water and repair of deteriorated sections of joints following visual inspection.

The "In-service inspection of containment (concrete)" programme has led to the detection of grease stains on the outer surface of the containment building, due to leakage across the outer walls arising from a loss of sheath leak tightness. This phenomenon has been observed at various nuclear power plants. It is a documented event, being included in the available standards, such as ACI and SEI/ASCE, and is monitored by means of periodic inspections performed throughout the lifetime of the plant. A study was performed at Vandellós II plant on the possible origin and influence of the grease stains observed and tests were carried out on the suitability of materials in their long-term performance.

The leakage of grease through the outer walls of the containment building is considered to be an acceptable anomaly, inasmuch as it does not affect the integrity and safety of the external structure of the containment, although it should be tracked and monitored in case signs of more significant degradation appear. The surveillance procedure includes the tracking of grease stains every cycle. In addition, and as a result of the analyses performed, the control of grease stains is performed every 18 months.

In view of the results obtained at Vandellós II plant from the "Containment leak test" programme, application of the programme may be considered to have been effective in preventing unacceptable leakage in components belonging to the containment pressure boundary.

The operating experience gleaned from the application of this programme underlines the appearance of periodic failures, mainly affecting the containment isolation valves and relating to leakage across the valve seats, such failures being beyond the scope of this programme.

As regards the "Containment tendons" programme at Vandellós II, the necessary corrective measures have been taken in relation to tendon lift-off tests, such as cleaning of the anchoring devices, the injection of grease, the replacement of tendon wires, etc., in compliance with the acceptance criteria of the surveillance procedures, as set out in different work orders.

Taking all the above into account, the licensee assures that the effectiveness of the programme for the correct management of the ageing of containment buildings included within the scope has been checked. It should be pointed out that although the conditions to which these items are subjected are susceptible, according to NUREG-1801 [25], to the mechanisms mentioned in section 07.1.1, the operating experience included therein indicates that the programme requires extension if other ageing mechanisms are detected during the performance of inspections.

ALMARAZ NUCLEAR POWER PLANT

The activities carried out in 1996 in the containment buildings for the removal of the steam generators and the installation of replacement units required the opening of gaps measuring approximately 7x8 metres in the side walls, at the elevation of the operating floors in each group. The leakage (integrated leak test) and structural integrity tests performed following the closure of the gaps verified the correct performance of the containment in response to the test pressure and confirmed that the opening and closing of the gaps in the containment walls did not affect its structural integrity, the structure being restored to its original condition.

Furthermore, as regards the components included within the scope of this assessment at Almaraz plant, no relevant operating experiences that might degrade or hinder the intended function of such components have been registered. Only minor and occasional degradations have been detected, corresponding to the ageing effects and mechanisms managed by the AMP's assigned for these components, in accordance with the Ageing Management Review explained in the first section of this document, following which the appropriate corrective actions were performed:

- In 1998, loss of material due to generalised corrosion was detected on the pillars, girders, ceilings, inner walls and liner of the containment building. The corrective action applied was the repair of the coating of the inner surfaces of the containment (liner).
- In 2003, during inspection of the anti-humidity barrier, corrosion was identified in the slab-wall contact area at elevation -7.85 m. Following the measurement of thicknesses in the area and checking that the values were acceptable, it was proposed that the existing footing block be modified, this consisting of chamfering in order to prevent the accumulation of water as a result of condensation in the area.
- In 2015, minor indications of oxides were also detected in the liner, following which the occasional cases of flaking were repaired.

Taking into account all the above, the inspections considered may be seen to be effective for adequate management of the ageing of the buildings included within the scope, making it possible to detect degradations and act accordingly, maintaining the intended functions of the equipment, components and systems.

TRILLO NUCLEAR POWER PLANT

As regards the components included within the scope of this assessment at Trillo NPP, no relevant operating experiences that might degrade or hinder the intended function of such components have been registered. Only minor and occasional degradations have been detected, corresponding to the ageing effects and mechanisms managed by the

AMP's assigned for these components, in accordance with the Ageing Management Review explained in the first section of this document, following which the appropriate corrective actions were performed:

- In 1992 and 2002 certain sphere-head transition areas were identified with traces of oxide due to generalised corrosion. The corrective action performed consisted of cleaning all the points of contact between the metallic sphere and the concrete of the head where the corrosion was detected and the original liner was replaced.
- In 2006 flaking was detected on the outer concrete walls, following which the deteriorated surfaces were cleaned.
- In 2008 concrete flaking was detected beneath the personnel lock, caused by corrosion of the surface reinforcement. The fissured area was repaired and cleaned up.

Taking all the above into account, the inspections considered for adequate ageing management of the part of the reactor building that is included within the scope of this TPR may be seen to be effective, as a result of which it is possible to detect degradations and act accordingly, maintaining the intended functions of the equipment, components and systems.

COFRENTES NUCLEAR POWER PLANT

The analysis of the operating experience associated with concrete containment components dealt with in this chapter is included in the tracking reports for each of the programmes covering their management. These reports assess whether the ageing effects detected correspond to those postulated during the aging management review.

As regards the relevant operating experience, the following may be underlined:

- From the experience of the inspections required by the ISIM it may be seen that in 2003, during inspection of the annulus side of the concrete containment, an accumulation of water was observed in the lower part, along with a clogged sump and oxide stains in the interface between the metallic containment and the concrete footing block, the most probable cause being determined to be the condensation of water vapour coming from leakage in the E32 system (MSIV leakage control) and obstruction of the sump drains siphon line. The sump was unblocked during that refuelling outage and both the oxidation detected and the concrete-metal sealing area were repaired.
- As regards tracking of the industry operating experience, NRC Information Notice IN-2011-20, dated 18/11/2011, was analysed in 2011. This Information Notice deals with the degradation of concrete due to an "alkali-silica" reaction (ASR).

  As a result, during an inspection performed at the plant in 2012 by a certified company, leading to the detection of traces of alkali-silica reactions (ASR) in the concrete. Samples (specimens) of concrete were taken from various structures for analysis. These observations led to the conclusion that there were indications of ASR reactivity in the early stages of development; however, as there was no conclusive diagnosis, new monitoring and assessment activities are foreseen in relation to this ageing mechanism.

7.3 Regulator's assessment and conclusions on ageing management of concrete structures

Not all the programmes that have been included in the scope of the TPR for the management of concrete containment structures have been applied since the beginning of commercial operation of the plants.

Inspection of the visible surfaces of the concrete containment and of the liner has been performed coinciding with type A leak testing (ILRT) from the beginning of the operating phase, the basic reference considered being the inspection carried out during pre-nuclear testing of the structural integrity of the containment (SIT).

In the case of pre-stressed containments, surveillance of the pre-stressing system has been accomplished through the application of the USNRC's RG. 1.35 and was included in the Technical Specifications.

Following the publication of sub-sections IWE and IWL of ASME XI (1994), the CSN required the licensees to include the corresponding chapter for application in the In-Service Inspection Manual (ISIM) of each plant, and that the containment surveillance requirements included in the Technical Specifications be adapted in accordance with the said sub-sections. This adaptation did not require any significant changes since the requirements of section IWL coincide to a large extent with the provisions of RG. 1.35 Rev. 3.

As has been pointed out throughout this report, the in-service inspection programmes (metallic containment-liner, concrete and tendons surveillance programmes), which constitute the vast majority of the inspections included within the selected scope, are set up in accordance with the ASME standard. Consequently, the homogeneity of the scope, inspections and acceptance criteria may be highlighted. These programmes are included in the ISIM of each plant, which is submitted by the licensee to the regulatory authority before each refuelling outage. In addition, in accordance with the Technical Specifications, if any significant deviation is detected, such that any of the acceptance criteria are not met in the surveillance of both the concrete surfaces and the pre-stressing system, the licensee shall submit a special report to the CSN reporting the anomaly and indicating the actions implemented and foreseen.

From the regulatory point of view, a particularly significant improvement in the tracking of the performance of safety-related structures has been the one achieved through the structures surveillance programmes applied with the current scope since the implementation of the Maintenance Rule (MR) at the Spanish plants, as from the beginning of the decade of the year 2000.

All the programmes identified by the licensees in this chapter are inspected by the CSN within the framework of the basic inspection plan for tracking of the effectiveness of the Maintenance Rule applied to structures. In Spain the MR is developed via revision 1 (2016) of CSN Instruction IS-15 [45] on requirements for surveillance of the effectiveness of maintenance at nuclear power plants, and in CSN Safety Guide 1.18 [46] "Measurement of the effectiveness of maintenance at nuclear power plants". Every two years an inspection is performed by the technical staff of the CSN in accordance with CSN procedure PT.IV.210_02.

The checks carried out by the CSN with respect to the ageing management processes for concrete containment structures at the Spanish plants make it possible to confirm the conclusions reached by the licensees regarding their effectiveness.

Mention may be made of certain aspects relating to the containment AMP's described in the previous sections in which the CSN has intervened, requiring additional actions.

- As has been pointed out above, in the early days of commercial operation of unit 2 of Ascó NPP, a process of rising of the land affecting different structures was detected. As a result, it was necessary to draw up a Ground Movement Surveillance Manual (GMSM) establishing the systematic control approach to be adopted in relation to the plant's structures, hydrology and geotechnical aspects. Among the affected structures are the containment building, and this led to the requirement that, in drawing up the tendons surveillance programme in accordance with RG 1.35, the licensee of Ascó could not consider the containments of the plant's two units as being twin structures, due to the differential factor of the movements of the ground, this meaning that independent surveillance programmes had to be established for each.
- The results of the first three pre-stressing system surveillances exercise at unit 1 of Ascó plant pointed to a generalised trend towards a greater deferred loss of tension in the horizontal tendons than that contemplated in the design, as a result of which a horizontal tendon re-tensioning campaign was performed following the fourth surveillance of the system.
- Also relating to the surveillance exercises performed at Ascó NPP, in response to the detection in certain cases during the first surveillances of a significant loss of protective grease from the tendons, the performance of a study was required in order to analyse the impact of the grease filtering via the fissures on the structural performance of the concrete. This study was performed by the Polytechnic University of Catalonia in 1993. Subsequently, in the year 2000, a non-destructive testing campaign was performed using georadar techniques on the outer containment wall at Ascó 1 NPP to detect and locate possible grease accumulation from the pre-stressing system.

The programmes implemented make it possible to detect degradations and act accordingly, maintaining the intended functions of the equipment, components and systems. No degradations have ever been observed at levels that might compromise the integrity of the structures within the scope of this study.

Notwithstanding the above, certain areas are observed in which there are items for improvement or special monitoring, these being dealt with in collaboration with the licensee within the framework of the CSN's regulatory activity. These are set out below.

- Although screening of the SSC's and acceptance criteria in the programmes are homogeneous between the different Spanish nuclear power plants, a certain heterogeneity has been observed in the prioritisation of the corrective actions and the number of minor maintenance actions pending. The two-yearly tracking inspections performed by the CSN are focussing on the treatment of the corrective actions provided by the different licensees, with a view to homogenising prioritisation on the basis of operating experience.

- In the programmes relating to the containment ISIM (IWE-IWL) or in the case of Ascó NPP with the Ground Movement Surveillance Manual (GMSM), despite their feedback to the structures MR, as they are performed by staff other than those belonging to the department in charge of the Maintenance Rule (MR), their corrective actions are not always prioritised using the same criteria as those established by the said department. Something similar may happen in the case of the "Structures surveillance" programme, based on AMP XI.S6 "Structures Monitoring Programme", which basically coincides with application of the MR, with certain minor differences in scope.
- This led to the need, within the framework of the CSN's regulatory activity and during the programme implementation phase, to focus on checking that the responsibilities for the application of the AMP's corresponding to each of the structures were correctly defined by the licensees and on the tracking of corrective actions and assessment of the results.

08. Pre-stressed concrete pressure vessels (AGR)

As it has been explained in chapter 01.2 of this report, in the Spanish nuclear power fleet, there is not this type of technology, therefore this chapter is not applicable to the present report.

09. Overall assessment and general conclusions

Since the nineties, ageing management has implied a series of recurring activities at the Spanish nuclear power plants, resulting from the plant operation and from the need to respond to the regulatory requirements established in the early years as a result of the specific conditions set out in the operating permits.

Likewise, the Spanish plants are subject to a process of continuous assessment and a Periodic Safety Review every 10 years, in which, among other aspects, the control and mitigation of the ageing of structures, systems and components (SSC) are analysed in accordance with the provisions of Safety Guide GS-1.10 [22], the first edition of which was published in 1995. This guide has recently been revised and adapted to the IAEA guideline [47].

CSN Instruction IS-22 on safety requirements for the management of ageing and long-term operation of nuclear power plants was published in 2009 and establishes the requirements and methodology for the development of the Overall Ageing Management Plan (OAMP). The methodology of this instruction is based on the American regulations, specifically 10 CFR 54 [23], which is further developed in documents NUREG-1800 [24] and NUREG-1801 [25], as well as in the guideline developed by the industry NEI 95-10 [26].

In addition to this regulation, the CSN has issued other standards applicable to certain SSC's included within the scope of the OAMP. This is the case of CSN Instruction IS-15 [45], requirements for monitoring of the effectiveness of nuclear power plant maintenance, applicable for monitoring of the condition of structures and components, including the containment structures, and CSN Instruction IS-23 [43], on in-service inspection at nuclear power plants, applicable to monitoring of the class 1, 2 and 3 systems inspection and testing programme, including the reactor pressure vessel and the containment.

The regulatory requirements established by the CSN require the Spanish nuclear power plants to draw up and implement an OAMP, defined as the ageing management actions programme, with the aim of reaching the original design lifetime of the plant without any deterioration of safety and of maintaining compliance with the current licensing bases.

As has been pointed out above in relation to ageing management, mention may be made of the existence of a national standard, with the force of law: Instruction IS-22 [21], on safety requirements for the management of ageing and the long-term operation of nuclear power plants.

The essential characteristics of Instruction IS-22 are as follows:

- It is applicable to the management of "physical" ageing during the design lifetime and long-term operation (LTO).

- The scope of the Instruction refers to “passive” and “long-lived” nuclear power plant components, since the ageing of “active” components is managed by way of the CSN Maintenance Rule (Instruction IS-15 [45]) and other plant maintenance and inspection programmes.
- The technical aspects and analytical methodology are based on Rule 10 CFR 54 [23] and on the aforementioned documents through which it is developed, while the administrative aspects (types of reports, content and the application formats, etc.) are covered by the Spanish regulations.
- As regards specific contents, the Instruction establishes requirements and criteria for the following:
  - Definition of the “scoping and screening” activities, in order to identify those structures and components that will require ageing management, performance of the process of ageing management review (AMR) of such structures and components including in turn the identification of significant ageing mechanisms and effects the assessment of the existing plant maintenance practices and the definition of applicable ageing management programmes for the management of those effects and mechanisms.
  - Identification and assessment of time limited ageing analyses (TLAA’s).
  - Determination of the ageing management activities to be performed during the design lifetime, by means of the Overall Ageing Management Plan.
  - Drawing up of the application for authorisation for LTO by means of the Integrated Plan Assessment (IPA).
  - Determination of the activities to be performed during LTO, in accordance with a Long-Term Overall Ageing Management Plan, LTO-OAMP.
  - Preparation of the documentation on ageing management, defining the reports to be issued during the design lifetime (annual ageing management reports), the contents of the IPA and the annual reports to be issued throughout LTO period.

Recently, throughout the period during which the present report has been drawn up, the CSN has revised Instruction IS-22 [48]. The new revision does not introduce any significant changes to the content. Basically, it clarifies certain concepts and terms with respect to the previous revision and imposes the requirement for updating the OAMP (establishing also the maximum period for this updating) as a result of physical modifications in the plant, the results of the operating experience review or changes to the legal framework. This revision of IS-22 does not imply any major change to the working method applied by the Spanish plants or the CSN, since although the previous revision did not impose these updating requirements, the plants had in fact been applying them and submitting documentation in response to CSN requests.

In view of the current age of the Spanish nuclear fleet, which in the case of certain plants now stands at almost 40 years, as may be appreciated from the figure shown in chapter 01.2, in June and July 2017 respectively the Almaraz and Vandellós II plants drew up their Integrated Plant Assessments (IPA) and submitted them to the CSN. These documents are required by IS-22 to apply for an authorisation for long-term operation.

Chapter 02 of the present report describes the process applied by the licensees of the Spanish nuclear power plants for the development of their OAMP's. The conclusions of the assessment performed by the CSN as well as the good practices performed by the licensees are identified at the end of this chapter.

Subsequently, chapters 03, 04, 05 and 07 of the present report describe the process developed by the licensees, for the management of the significant aging effects and mechanisms identified, as a result of the AMR process applied, to electrical cables, buried and restricted access piping, the reactor pressure vessel and concrete containment structures, respectively. Analogously to chapter 02, included at the end of each chapter are the results of the assessment of each of these processes performed by the CSN, with a description of the most significant results of application of the corresponding AMP's and special attention to the strengths and improvements of these AMP´s.

Chapters 06 and 08, applicable to calandria/pressure tubes and pre-stressed concrete pressure vessels are not included in the present report, since this type of technology is not present in the Spanish nuclear fleet.

The following is highlighted from the assessment by the CSN of the contents of chapter 02 of this report, which describes the process of ageing management:

- The first general conclusion is that the OAMP's currently implemented by the licensees of the Spanish plants fulfil the WENRA reference levels corresponding to ageing management and referred to in WENRA specification [1].
- The CSN considers that the methodology applied by the licensees for activities relating to the scoping and screening of structures and components, the identification of significant ageing mechanisms and effects on them and the development of the AMP's needed for their mitigation and control, meets the requirements of IS-22 [21] and also that, this process is also correctly documented, for which reason it is considered to be suitable.
- As the regulatory authority, the CSN reviews the OAMP's of the Spanish plants by means of assessments and as part of the two-yearly inspections performed as a result of its basic inspection plan.

o Among the documentation used by the CSN for this supervision is the "annual report on ageing management activities", submitted yearly by the licensees in compliance with Instruction IS-22 [21], which among other information includes the AMP activities performed during the previous year and their results.

o The CSN has drawn up specific procedures for the performance of inspection and assessment activities regarding the ageing management of nuclear power plant components and structures, specifically the following:

- PT.IV.223 “Ageing management of nuclear power plant components and structures (inspection activities)” [41].
- PT.IV.105 “Ageing management of nuclear power plant components and structures (assessment activities)” [42] respectively.
- PT.IV.207 “In-service inspection” [44].
- PT.IV.210 “Effectiveness of maintenance (two-yearly)” [49].

- In addition to these CSN inspections, the licensees OAMP’s are subjected to internal audits resulting from their plant-specific processes.
- The findings, potential improvements and commitments acquired as a result of the CSN inspections and internal audits, are included by the Spanish plants in their corrective action programmes for management and implementation, and are documented in the aforementioned annual reports. This allows for the tracking of their management and resolution in the manner and term scheduled or of possible deviations in such resolution.

As regards the ageing management of the elements referred to in the WENRA specification: cables, concealed piping, reactor pressure vessels and concrete containments, the following conclusions are reached:

- The AMP activities are currently under way, although their degree of implementation varies from one plant to another. From analysis of their results it may be concluded that, in no case have been detected unforeseen degradations or degradations of a level such that they might compromise compliance with the intended functions of the affected structure or components.
- On certain occasions it has been observed that the performance of actions designed to correct the degradations detected was not prioritised in such a way as to guarantee its adequate management, although in no case has this degradations compromised the corresponding safety function.
- Regarding buried piping, the operating experience drove certain Spanish plants to modify activities included in their AMP’s associated with the surveillance of the fire-system, in accordance with NEI 09-14. This methodology, developed by EPRI, classifies buried piping on the basis of risk, and uses BPWorks software. Although this methodology has been widely used at US nuclear power plants with good results, its effectiveness has not yet been demonstrated at the Spanish nuclear power plants that have opted for it.
- The licensees have occasionally encountered difficulties in obtaining information relating to the construction period of the plants, such as for example, information on buried piping runs, their covering or the refill material used, or on the original design cable runs.

The following are considered to be among the positive aspects (strengths) of the AMP development process carried out by the Spanish plants:

- Special mention may be made of the organisational structure stablished place by the licensees for the performance of plant lifetime management activities. The key element on which this organisation is based is the multidisciplinary "Lifetime Management Committee", that allows fluid communications among the different departments involved in ageing management and is important for the correct implementation and tracking of the numerous activities covered by the more than forty AMP's included in each of the Spanish plants' OAMP.
- Another important figure is the "Ageing management coordinator", responsible for the general coordination of ageing management activities at each plant, facilitating synergies allowing for a more efficient development of the programmes.
- The CSN values positively the development by the licensees of specific databases managing the entire process of development of the lifetime management plan and supporting documentation.
- The CSN also values the development of technical guidelines in which the Spanish nuclear power plants define the methodology to be adhered to for the performance of the different tasks involved in ageing management: scoping and screening, AMR process, review of operating experience, development of AMP's and corresponding manuals, drawing up of AMP tracking reports, identification of TLAA, etc.
- Value is also attached to the following:
    - The process of updating and on-going improvement of the AMP's applied by all the plants, on the basis of analysis of the results of applying these plans, the impact of design modifications or the appearance of new standards, the results of plant-specific and industry operating experience reviews and the results of specific national and international R&D programmes (IGALL [40]).
    - The AMP effectiveness indicators, used for the periodic quantitative and qualitative assessment of the effectiveness of each AMP and, therefore, the overall set of AMP's.
        - It should be pointed out, however, that there is no homogeneity in the definition of the indicators for all the plants. The only plant that has numerical indicators is Cofrentes NPP, the remainder having qualitative indicators.
        - During the inspections performed by the CSN it has also been observed that there is diversity among the plants regarding the degree of objectiveness and self-assessment when assessing effectiveness by means of these indicators.

The following are considered to be positive aspects (strengths) of the AMP's for cables, buried and restricted access piping, vessel and concrete containment structures drawn up by the Spanish nuclear power plants:

- The response of the plants to the CSN recommendation that the scope of their AMP's include cables with environmental qualification requirements not included within the scope of the model programmes of NUREG-1801 [25], this allowing for the monitoring of the actual condition of these cables throughout their design lifetime.

- As regards the cable-related AMP's, the inclusion therein of activities additional to those specifically required in the NUREG-1801 [25] model AMP's, such as the performance of walkdowns for the identification of hot spots and the application of mechanical and electrical tests additional to the visual inspections required for cables.
- In relation to vessel inspections, the CSN considers that the variety of regulations applicable guarantee that the activities included in the corresponding AMP's allow for the surveillance of degradation mechanisms in accordance with the most up-to-date inspection programmes, which in all cases take into account the latest international operating experience.
- Regarding the concrete containment structures, it should be highlighted that in addition to the application of sub-section IWE and IWL of ASME XI Code, that guarantee that all plants have an homogenous response, the plant-specific operating experience as well as the fulfilment with the maintenance rule have improved the AMP´s.

Nevertheless, certain aspects are observed in which there is a margin for improvement or special surveillance, these being dealt with in collaboration with the licensee as part of the regulatory activity. These aspects are set out below:

- With regard to the potential impact on the AMP of design modifications, certain plants analyse this impact during the modification design process, prior to its implementation. The CSN considers that a possible improvement might consist of establishing similar processes at those plants that analyse the impact on the AMP of design modifications only after implementation.
- As regards the ageing management of cables, the surveillance activities of cables located inside metallic ducts or trays and inaccessible for visual inspection must be improved. . Although the plants perform electrical tests on these cables, such as reflectometry or other analogous tests, their effectiveness is questionable for quantifying ageing-induced degradation in such locations. These aspects might be the subject of future research activities to determine effective ageing surveillance techniques for this type of cables.
- In relation to pipes embedded in concrete or passing through walls, which are not considered by the Spanish nuclear power plants as requiring ageing management review, the CSN considers that a more in-depth analysis of this issue should be performed with a view to long-term operation.
- The regulations applicable to the reactor vessel specifically indicate that the ageing management of the vessel and its welds shall take into account all relevant factors, including at least embrittlement, thermal ageing and fatigue, for comparison of their performance with respect to the predictions of analyses carried out throughout the lifetime of the component. The CSN considers the assessment of these aspects to be

crucial for requests for license extension from 40 to 60 years of operation, especially when for certain of these aspects – for example fatigue – the industry is collecting new experimental data that could lead to re-consider the methodology to assess the impact of environmental fatigue.

- Regarding concrete pre-stressed containment structures, the analyses performed by ANAV (Ascó and Vandellós 2 NPPs owner) and Polytechnic University of Catalonia about the pre-stress long-term evolution and the collaboration in NEA and EDF project Vercors, will allow to confirm the resolution of the post-stress surveillance TLAA.

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Abbreviations used in this report

Abbreviations	Definition
AMP	Ageing Management Programme
AMR	Ageing Management Review
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATWS	Anticipated transient without scram
BWR	Boiling Water Reactor
BWRVIP	Boiling Water Reactor Vessel and Internals Project
CHUG	Checkworks Users Group
CSN	Spanish Nuclear Safety Council
DBD	Design Basis Document
EQ	Environmental Qualification
EPRI	Electric Power Research Institute
FP	Fire Protection
GS	CSN Safety Guide
IAEA	International Atomic Energy Agency
IASCC	Irradiation-Assisted Stress Corrosion Cracking
IGA	Intergranular Attack
IGSCC	Intergranular Stress Corrosion Cracking
INPO	Institute of Nuclear Power Operations
IPA	Integrated Plant Assessment
IS	CSN Instruction
ISIM	In-Service Inspection Manual
LR-ISG	License Renewal Interim Staff Guidance
LTO	Long-Term Operation
LT-OAMP	Long-Term Overall Ageing Management Programme
MR	Maintenance Rule
MRP	Pressurized Water Reactor Materials Reliability Program
NDE	Nondestructive evaluation
NEI	Nuclear Energy Institute
NMAC	Nuclear Maintenance Application Center
NRC	Nuclear Regulatory Commission
OAMP	Overall Ageing Management Programme
PSR	Periodic Safety Review
PTS	Pressure Thermal Shock
PWR	Pressurized Water Reactor
PWSCC	Primary Water Stress Corrosion Cracking
R&D	Research and development
R&D&i	Research and development and innovation
SBO	Station Blackout
SCC	Stress Corrosion Cracking
SGMP	Steam Generator Management Programme
S&C	Structures and Components
SSC	Structures, Systems and Components
TLAA	Time-limited Ageing Analysis

UNESA	Spanish electrical companies association
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association