Long Term Operation of Nuclear Power Plants in Spain: Preparing for the Future

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Abstract

The Spanish nuclear industry is preparing for the Long Term Operation (LTO) of its complete fleet. Therefore, an important number of activities are being currently developed in order to achieve the safe and economical life extension of the operational life of the Spanish nuclear power plants. This paper describes the main activities that will be performed to meet the licensing requirements, in order to be granted an operating license for LTO, such as the development of Ageing Management Plans (AMP), Time Limited Ageing Analysis (TLAA) as well as databases and software tools to support LTO. In addition to this, this paper will describe the implementation of the NDE activities included in the AMPs and some of the R&D programs that the Spanish nuclear industry research is working on related to LTO (e.g. cable ageing, concrete degradation, etc.).

1. INTRODUCTION

Since the eighties, Spain nuclear industry has been working on Ageing Management (AM), preparing the Long Term Operation (LTO) of the nuclear power plants. In July, 2009, the Spanish regulatory body (CSN) published the Safety Instruction IS-22 1, for the development of lifetime management in the Nuclear Power Plants (NPP) within Spain. These new regulations apply during the period of normal operation based on equipment design life, and also for the long term operation period as well as for the application to justify their LTO. On October last year 2016, the CSN published the memo to the revision 1 draft of the IS-22 2. The mentioned IS-22 is mainly based on the USA regulations 10CFR54 3, NUREG-1800 4, NUREG-1801 5 and the technical guide NEI 95-10 6.

As a result of this issue, the nuclear power plants in Spain have performed a convergence process, adjusting their previously existing Lifetime Management Plans (LMP) to the new requirements, taking into account specificities of each plant 99. The documents generated and the work performed has been readapted following the publication of revision 2 of GALL, NUREG-1801 and IAEA IGALL 7 report and attachments.

This paper provides an overview of the current status of this process. It also describes the on-going and future activities needed to achieve the goal of guarantying the safety LTO of the plants

2. FRAMEWORK

2.1. Nuclear Power Plants in Spain

There are seven operating plants in Spain. The majority of the Spanish fleet is more than30 years old (Figure 1) and there are no plans for new constructions. These plants generate more than 20% of the electricity consumed in Spain 11. Therefore, there is a need for the nuclear industry to accomplish the requirements for the safe Long Term Operation of the existing plants.

All the Spanish NPP are preparing the life extension, including Sta Mª de Garoña, which has operated more than 40 years and is performing work to meet post-Fukushima requirements.

Figure 1. Spanish nuclear power plants: age and design

2.2. Previous Activities

Spanish NPPs launched their ageing management programs at the beginning of their operation. The plants formally developed an ageing methodology in the 90's. This methodology was well considered by the Spanish regulatory body (CSN) and applied in all Spanish plants from 2000 on. This former methodology included economical and availability aspects jointly with safety requirements.

This methodology has never converted in a legal framework. After publication of the 10CFR54 3 and the Spanish IS-22 1 based mainly on that American code, the plant's programs were adapted to the new rules. Subsequent modifications in the methodology applied by the plants were following publication of new revisions of NUREG-1801 5 and IAEA documents, particularly IGALL 7. In that latter case, Spanish nuclear industry has had and has an active involvement in the development of IGALL.

2.3. Legal Framework

The Spanish Nuclear Safety Council (CSN) regulates the operation of nuclear and radioactive facilities in Spain to ensure that they uphold safety criteria. The CSN proposes rules and regulations to the government and adjusts domestic legislation to comply with international one. Legislation usually comes from the origin country of the technology used in the nuclear power plant 10.

At present, in Spain there is no legal limitation in the operational live of the nuclear power plants. However, in the case of NPP of a western design, like the Spanish ones, 40 years is usually considered the plant design lifetime due to the analyses supporting the plant safety assessment were carried out using that hypothesis. Spanish nuclear power plants are obliged to undertake a Periodic Safety Review (PSR), at least once every 10 years according to the CSN Safety Guide 1.10 8 in order to renew its license.

The scope of the PSR includes the assessment of programs under way to improve safety in the facility or the establishment of new programs. After assessing the results of the PSR carried out by the facilities, the CSN sets additional safety requirements for the licensees if it considers needed. CSN Instruction number IS-22, revision 0 and revision 1 (draft) 1, 2 summarize the process to be followed by the licensees of Spanish NPP to implement a process for management of ageing of the components including LTO beyond the design lifetime defined for each plant. This instruction includes the reference contained in standard 10CFR54 3 and its enacting documents and other from the nuclear industry, such as NUREG-1800 4, NUREG-1801 5 and NEI 95-10 6 of the American Nuclear Energy Institute. The requirements laid down in the instruction IS-22 are applicable to all plant operating conditions.

3. IMPLEMENTATION OF AGEING MANAGEMENT PROGRAMS

3.1. Nuclear Power Plants in Spain

Based on IS-22 1 rule the licensee shall perform ageing management (AM) activities to cover the facility design lifetime and beyond it:

- Within the design lifetime: The licensee shall carry out the necessary plant *Systems, Structures and Components* (SSC) ageing management activities, such that these include measures for the surveillance, control and mitigation of the ageing mechanisms to identify the proposals for improvements incorporated to detect these mechanisms and control their effects. The conclusions of this periodic review shall be included in the lifetime management plan (LMP);
- LTO period;
- Within the LTO period.

The licensees of the NPP shall draw up periodic reports based on the activities mentioned above. The scope and content of the LMP shall be based on the methodology of the standard 10 CFR 54 “Requirements for renewal of the operating permit”, articles 54.3, 54.4 and 54.21, until the end of its design lifetime, with the exception of the requirements of articles 54.3a and 54.21c on specific time limited analysis (TLAA) of components. The scope of the life management plan is provided in Table I.

Table I. Scope of Lifetime Management Plan

Period	Reports	Timeframe
Design lifetime	Lifetime Management Plan	First six months of each calendar year.
LTO	a) Integrated Ageing Assessment b) TLAA c) Final Safety Analysis report supplement d) Technical Specification revision	Three years prior to the date for renewal. Updating shall be submitted a year before the date of renewal.
During LTO	Long term AM Plan	First six months of each calendar year.

3.2. Scope Setting and Screening

Safety-related systems, structures and components (SCC) 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 capacity to shut down the reactor and maintain it in safe shutdown conditions; or

- The capacity to prevent or mitigate the consequences of accidents, such that off-site radioactive exposures are kept below the established limits.

SSC within the scope shall be:

- Passive components since the application of the Maintenance Rule (regulated in CSN Instruction IS-15 12) to active components guarantees that the critical functions of components are within the acceptance levels.
- Not included in any replacement program based on qualified lifetime maintenance or any other replacement program.

As a reference, check-list type documents for each SSC are developed in order to support and compile this process. The SSC scope check list is presented in Figure 2.

TABLA 1.1:

	SI		NO
1. Función relacionada con la seguridad (RS):			
1.1 Integridad de la barrera de presión del refrigerante del reactor.	☑	1_1	☐
1.2 Parada y mantenimiento de condición segura	☑	1_2	☐
1.3 Prevenir o mitigar accidentes con fugas al exterior	☐	1_3	☑
2. Función esencial No Relacionada con la Seguridad y/o función implicada en el cumplimiento de otros sucesos regulados			
2.1 El fallo impide una de las funciones de seguridad anteriores (No contestar si es función RS).	☐	2_1	☐
2.2 Protección contra incendios (10 CFR 50.48)	☐	2_2	☑
2.3 Calificación ambiental (10 CFR 50.49)	☑	2_3	☐
2.4 Choque térmico a presión (PTS) (10 CFR 50.61)	☑	2_4	☐
2.5 Transitorio anticipado con fallo de disparo (ATWS) (10 CFR 50.62). (No se produce el disparo auto.)	☐	2_5	☑
2.6 Station blackout (SBO) (10 CFR 50.63). Pérdida completa de suministro de corriente alterna.	☐	2_6	☑
2.7 Sistema sujeto a requisitos de operabilidad en las especificaciones técnicas, limitando condiciones de operación	☑	2_7	☐
2.8 Análisis Probabilístico de Seguridad (APS)	☑	2_8	☐
2.9 Contemplado en los procedimientos de emergencia (No contestar si es función RS).	☐	2_9	☐
2.10 El fallo puede provocar el disparo del reactor o la actuación de un sistema relacionado con la seguridad (No contestar si es función RS)	☐	2_10	☐
2.11 El fallo puede causar un transitorio de la planta o requerir una actuación operacional inesperada (contingencia)	☑	2_11	☐
2.12 Necesario para solventar un transitorio operacional o accidente (No contestar si es función RS).	☐	2_12	☐
2.13 Aplica Calificación Sísmica.	☑	2_13	☐
3. Generación Eléctrica y Fiabilidad			
3.1 Transporta energía térmica del núcleo del reactor a la turbina	☐	3_1	☑
3.2 Conversión de energía térmica a eléctrica	☐	3_2	☑
3.3 Transporte de energía eléctrica del generador a la red	☐	3_3	☑
3.4 El fallo podría provocar el fallo de una de las 3 funciones anteriores	☐	3_4	☑
3.5 Afecta al camino crítico durante recargas	☑	3_5	☐
3.6 Puede parar la planta	☑	3_6	☐

Figure 2. SCC scope check list

3.3. Safety Identification of Relevant Ageing Mechanisms

For each component included within the scope defined, the potential ageing mechanisms and their possible causes and consequences should be analyzed. Then, they may be analyzed individually or as families, considering their design and/or functional similarity.

As a result, the ageing effects and mechanisms considered to be significant and requiring surveillance, control or mitigation activities to ensure that the functionality of the structure is not limited during its service lifetime, will be determined.

3.4. Mitigation and Prevention of Ageing Effects

The causes and consequences of significant ageing effects and mechanisms shall be duly 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, control of operating parameters, surveillance, etc. Maintenance, inspection and testing activities required by the current licensing basis will be valid for the AM of the affected SSC, 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 or 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 AM and, where required, the implementation of new maintenance practices.

3.5. Review of Ageing Management Process

Within the scope, content and period for submittal of the documentation relating to the periodic safety review (PSR) of the facilities, a revision of the LMP shall be included:

- The ageing and degradation mechanisms of safety-related and safety relevant elements;
- Unexpected ageing mechanisms and effects;
- New relevant information;
- The most adequate methods and tools available for AM;
- The effectiveness of maintenance management, in accordance with the results of the practices implemented.

4. LONG TERM OPERATION APPLICATIONS IN SPAIN

In the case of LTO, all the analyses and calculations performed by the licensee shall fulfill the following conditions to classify as a Time Limited Ageing Analysis (TLAA):

1. SSC considered within the scope of AM;
2. Take into account the effects of time and LTO;
3. Adhere to hypotheses of limited design lifetime;

4. Conclude with the capacity or not of the stress corrosion cracking (SCC) 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 relevant in a safety assessment;
6. The calculation or analysis is part of the current licensing basis of the facility.

4.1. Plant Program Status

All the Spanish NPP are developing the LTO programs according to IS-22 1, 2 requirements and all of them has ageing management programs running based on Plant Program Status GS.1.0 requirements 8. Table II show the relevant dates for each plant,

Table II. Spanish Nuclear Power Plants PSR

NPP	Type	Electric Power (MWe)	Commissioning year	Next RPS	40 years	60 years
Garoña	BWR	466	1971	--	2011	2031
Almaraz I	PWR	1049,5	1981	2017	2021	2041
Almaraz II	PWR	1044,5	1983	2017	2023	2043
Ascó I	PWR	1032,5	1983	2018	2023	2043
Ascó II	PWR	1027,21	1985	2018	2025	2045
Cofrentes	BWR	1092	1984	2018	2024	2044
Vandellós II	PWR	1087,14	1988	2017	2027	2047
Trillo	PWR	1066	1988	2021	2028	2048

4.2. Approach

As previously described Spanish NPP LTO processes are performed mainly in agreement with USA 10CFR54 3 (see Figure 3). A typical PWR plant has an average of 50 to 60 ageing management plans most of them identical to GALL AMP and more than 120 possible TLAA are analyzed of which around 40 needs to be solved. Only one or two are usually plant specific.

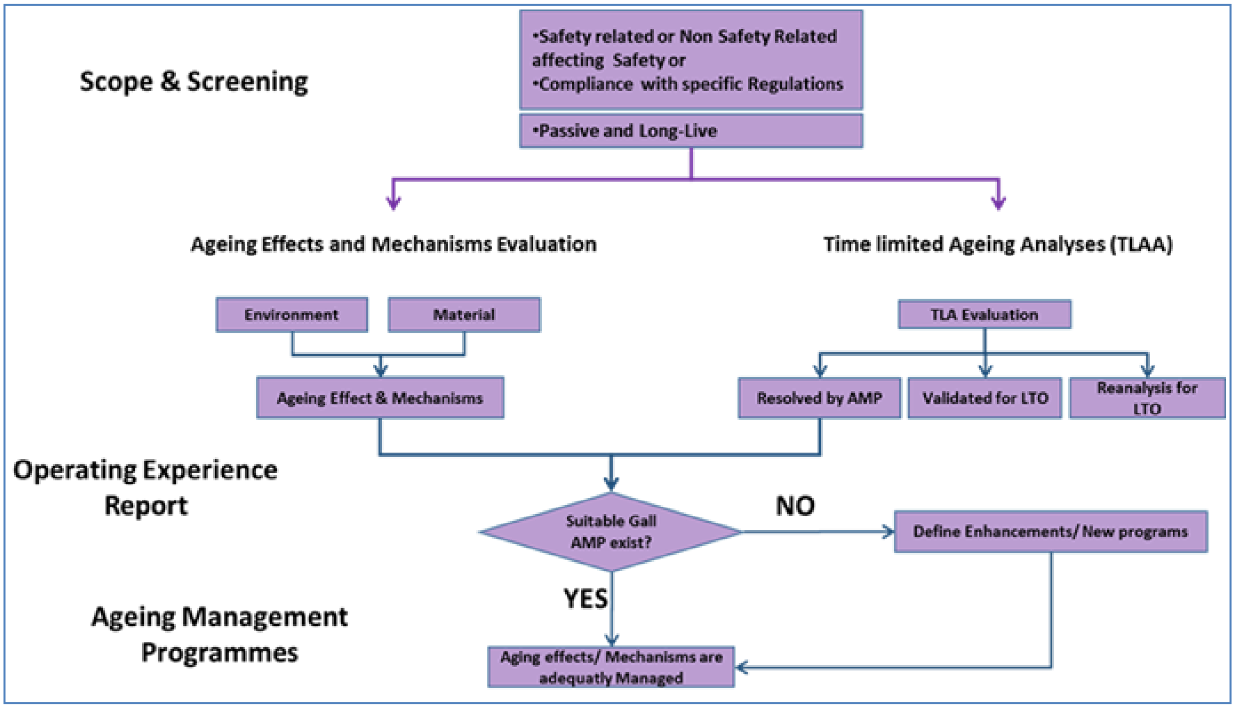

Figure 3. Long term operation process

4.3. Review of Long Term Operation Processes

The Spanish NPP, to verify the effectiveness of the AMP, for each program, perform every three years the following activities:

- Analysis of results;
- Compliance with the requirements of the program;
- Identification of activities performed and their results;
- Acceptance criteria compliance;
- Corrective actions performed, if needed;
- Monitoring and trending analysis;
- Verification of qualification of inspectors.

The results of these activities contribute to the identification of gaps, including: activities not performed as scheduled and real frequency compliance, incomplete, no adequate or inexistent inspection records and AMP results not evaluated or treated properly. Remedial actions are proposed to avoid these gaps.

Continuous improvement of programs is implemented based on operating experience review and analyze as well as international organizations recommendations:

- Cause evaluations and extent of condition are performed;
- Inspection frequencies are adjusted when needed;
- Sample size is expanded when required;

- Review of operating experience related with the program, internal and external (EPRI, INPO/WANO, NEI, US NRC…). Changes to activities if applied. Detailed analysis and identification of recurring failures (example: leakage in containment penetration valves testing).

The goal is to identify opportunities for improvement, if needed, and included them in the corrective action program of the plant. The correct resolution of previous improvements is studied as part of this continuous improvement process.

4.4. Other Work Performed

In addition to the required analysis and studies, an important support work has been performed. This work includes the development of databases and other software tools linked with plant existing applications. The new tools are providing support in the different processes described but also for future revision of the components (Figure 4).

The Spanish fleet is still in the process of refining the scope of the aging management programs. Some of the inspections related to the implementation of the AMP have already been performed to address specific operating experiences of the plants (e.g. a plant performed Guide Card Wear measurements and inspections, most plants have performed extended cables testing programs) or to accomplish with regulatory requirements. Other inspections are expected during 2017 and 2018, starting with the first reactor vessel internals inspections based on EPRI MRP-227/228 guidance 13, 14 for LTO.

Figure 4. Inspection support tool: WebISI

5. RESEARCH ACTIVITIES

The Spanish nuclear sector is developing some specific research projects but also contributing in a wide number of international research projects in order to acquire and disseminate Nuclear Knowledge from LTO. The most relevant are:

- National project: Cable ageing management, ongoing set of projects to determine main degradations, monitoring and surveillance techniques and influence of different stresses on cable long term performance.
- National project: Irradiation concrete characterization, taking advantage of Zorita NPP, a decommissioned PWR plant with high irradiated concrete.
- International project: Cut and remove part of the Zorita NPP internal reactor vessel, for laboratory testing, and evaluating the extracted materials degradation and aging properties.
- Euratom/H2020 projects: ***Soteria***, Safe Long Term operation of light water reactors based on improved understanding of radiation effects in nuclear structural materials; ***Adfam***. ADvanced FAtigue Methodologies to optimize fatigue assessment of critical components, ***ATLAS plus***, Advanced Structural Integrity Assessment Tools for Safe Long Term Operation, etc.

6. CONCLUSIONS

In summary, the process for preparing for long term operation of nuclear power plants in Spain is well established and the regulations are fully developed. The requirements are in agreement with the international (IAEA) recommendations and the process follows the state-of-art and international best practices.

All the Spanish NPP are developing their long-term operation programs in accordance with the regulator requirements and all of them have ageing management programs in place.

ACRONYMS

AMP - Ageing Management Program
CSN – Nuclear Safety Council (Spanish Regulatory Body)
EPRI – Electric Power Research Institute
IAEA – International Atomic Energy Agency
INPO - Institute of Nuclear Power Operations
LMP – Life Management Plan
LTO - Long Term Operation
NDE - Non Destructive Examination
NDT - Non Destructive Test
NEI - Nuclear Energy Institute
PSR – Periodic Safety Review
PWR - Pressure Water Reactor
R&D - Research and Development
SCC – Stress Corrosion Cracking

SSC – Systems, Structures and Components
TLAA - Time Limited Ageing Assessment
US NRC- United States Nuclear Regulatory Commission
WANO - World Association of Nuclear Operators
ZIRP – Zorita Internals Research Project

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