WESTINGHOUSE EXPERIENCE ON AGEING MANAGEMENT IN THE NORDIC REGION AND A GENERAL OVERVIEW OF THE METHODOLOGY

M. STENLUND, J. ERIKSSON, P. LARSSON, J. GÖTBERG, G. STÅHL, M. OLSSON, J. FINNE

Westinghouse Electric Sweden AB

Fredholmsgatan 22, 72163 Västerås - Sweden

ABSTRACT

Westinghouse together with the Nordic utilities developed a methodology for AM within the Nordic Owners Group in early 2000. This methodology was later adapted for the Forsmark NPPs in Sweden in order to provide input to the AMP and to perform an AMR. The methodology was used to identify new preventive maintenance package and mitigation activities. More recently the experience from Forsmark and the NOG projects were used at the Olkiluoto NPPs in Finland. This paper provides a general overview of the methodology and approach chosen to be able to efficiently perform AM activities.

1. Introduction

Efficient Ageing Management (AM) is becoming an increasingly essential activity for nuclear operators in order to maintain nuclear safety and disturbance-free and profitable operation as Nuclear Power Plants (NPP) are getting older, and in many cases nearing or reaching the original design life and entering Long Term Operation (LTO). Ageing NPPs also causes AM to obtain increasing focus from regulatory bodies, leading to new requirements forcing utilities to increase their AM activities.

AM is the management process, preferably deployed during all stages of plant life, in which a set of different measures and actions are taken to detect, monitor, prevent and/or mitigate ageing in order to maintain plant safety and availability throughout plant life. The activities and measures are often organized in different ageing management programs (AMPs) for certain components or issues. Examples of some generic AM activities are Ageing Management Reviews (AMRs) and ageing assessments, proactive and preventive design work, Preventive Maintenance (PM), Equipment Qualification (EQ) programs, etc..

Physical ageing of components can be regarded as the process by which the physical characteristics of components changes over time, or through use, due to different ageing mechanisms caused by certain combinations of component materials, design and different physical and environmental conditions. The effects of component ageing are often degradation or loss of component function which for certain components might affect plant safety or operability and thereby be unacceptable. Obsolete components are not a physical ageing effect but obsolescence has to be managed in a similar way since it might impact plant safety or operability. The IAEA preferred AM process is based on coordinating, integrating and modifying existing programs/activities related to AM (maintenance, inspections, EQ etc.) and if needed to develop new programs/activities, in order to achieve effective AM. Since the topic of AM is a very broad and vast area, this paper will focus mainly on the experience with AMRs within the Nordic region.

2. Ageing Management within the Nordic Owners Group

Nine different projects were conducted within the NOG during the years of 2003 and 2015, which had some relation to AM:

1. Framework for ageing management (2003-2005)
2. Temperature transients in the reactor pressure vessel (2004)
3. Dynamics of measurement systems (2005-2006)
4. Reliability of safety related equipment in stand-by mode (2006-2009)
5. Primary containment design (2009-2011)
6. Ageing of organic material in mechanical components (2010-2015)
7. Life time extension for Nordic BWRs (2010-2015)
8. Flow assisted corrosion in BWRs (2011-2012)
9. From analogue to numerical electrical equipment (2014-2015)

The most significant project for the overall methodology was done within the “Framework for ageing management” project which sets up the framework for the AMR methodology.
Another important project is the “Ageing of organic material in mechanical components” for which the purpose was to improve the management of organic material in the Nordic BWR fleet for sustainable safety and accessibility. The end goal was to develop an organic materials handbook that provides guidance towards the use of polymeric materials and lubricants in mechanical components within NPP. The handbook had the objective to describe important material behaviours and had the aim to become useful when for example considering component replacement and modernization. In the end, two different handbooks were developed, one for polymeric materials and one for lubricants. These handbooks have since then been periodically updated in order to keep them up-to-date with experience and new research and have also lately been translated into English.

3. The AMR process

The AMR process is divided into eight different steps as listed below. The methodology is based on [1] and the NOG project “Framework for ageing management”.

1. Screening – Systematic review of system and component information,
2. Grouping – Definition of component groups,
3. Evaluating – Evaluation of material, environment and function,
4. Selecting – Key component selection for each group,
5. Analysing – Analysis of ageing mechanisms,
6. Comparing – Gap-analysis of the maintenance program,
7. Documenting – Documentation of findings, recommendations and actions,
8. Implementing – Implementation of changes in the maintenance program and instructions.

The following subsections discuss these eight steps in more detail.

3.1 Screening – Systematic review of system and component information

The first step in the AMR is a systematic review of systems and components with safety related functions, usually referred to as “screening and scoping”. This is done by using the Safety Analysis Report (SAR), the Technical Specification (Tech Spec) and similar documentation as a foundation which is then complemented with process knowledge about the specific components functions at an event. The end result of the step is a list of components selected for further evaluation.

3.2 Grouping – Definition of component groups

The list from the previous step consist of a multitude of different components, however, many are of similar design and have similar functions (e.g. pumps, valves, etc). This allows to significantly reduce the overall amount of components selected for further analysis by grouping the components in preliminary groups, where the components in the same group has the same or similar ageing characteristics and/or can be managed within the same AMP. This requires significant amount of component knowledge. The end result of this step consists of an organisation of the selected components in the previous step (see section 3.1) into groups of similar components which all can be represented by one single representative component.

3.3 Evaluating – Evaluation of material, environment and function

Each component in every group from the previous step (see section 3.2) is then evaluated with respect to material, environment and function. This allows a fine-tuning of the previous step and is aimed at verifying that the components are in fact attributed to a relevant group. This step may increase or decrease the preliminary amount of groups.

3.4 Selecting – Key component selection for each group

Once the material, environment and function of each group are established (see section 3.3), a representative component (key component) is selected. A key component from each group is chosen in such way that the key component is corresponding to the component which is experiencing the most conservative ageing environment. Since none of the remaining components in each group will experience a more severe ageing it is possible to assume that the key component is a conservative representative of the group it belongs to. The result from this step is to have an identified key component for each group.

3.5 Analysing – Analysis of ageing mechanisms

Each key component (see section 3.4) is analysed with respect to its ageing mechanisms. This includes analysis of ageing parameters such as temperature, oxidation, humidity, irradiation, load & stress, contamination, lack of maintenance, function, etc. on the materials included in the key component. This step does also take into account the operating experience. Furthermore, maintenance actions for the component are identified and recommended actions are listed in order to detect or mitigate identified ageing mechanisms. This step might result in a largely over-conservative maintenance program for a certain amount of the components in the investigated group. If this is the case, then the concerned components are used to create a new group with a new key component being identified. The result from this step consists of a deck of aging mechanisms and recommended maintenance actions related to each key component, based on the materials they consist of and their function, which has been balanced with operating experience.

3.6 Comparing – Gap-analysis of the ageing management program

Once the ageing analysis is completed for the key component (see section 3.5), a gap-analysis is undertaken in order to verify if the ageing analysis results with respect to recommended maintenance actions are covered by the current AMP or not. The result from this step is a listing of where the current AMP is covering the needs identified in the ageing mechanism analysis results and a listing of recommended additional maintenance actions that are not covered.

3.7 Documenting – Documentation of findings, recommendations and actions

A final documentation for each group is developed and recommendations and actions are listed. The listed recommendations may take the form of modifications of current maintenance programs or even totally new maintenance actions to be inserted into the maintenance program. Examples of recommendations can be that an instruction for the replacement of a component is missing and should be developed or that the maintenance interval should be modified (usually to a shorter periodic interval). The document does not only list potential recommendations to the maintenance program from the gap-analysis, but also how the current maintenance program is covering the aging mechanisms for each key component. Furthermore, a check-list is provided as a “blueprint” of an adequate AMP.

3.8 Implementing – Implementation of changes in the maintenance program and instructions

The last step in this AMR process is to implement the changes in the maintenance program and instructions. This is best done by the maintenance services at the utility. It requires insight and knowhow in how the maintenance program is maintained and utilized at the utility.

4. The Nordic Experience

Apart from the experience within the NOG, as described in section 2, Westinghouse has been involved to varying degree in AM projects performed at Forsmark and Olkiluoto between 2007 and 2016. The following subsections provide a general overview.

4.1 The Forsmark Ageing Project

Forsmark has three units of ASEA-Atom BWR design. The Forsmark AM project was initiated in 2007, with the Westinghouse part of the project finalized in 2011. The project performed a systematic AMR, as described in section 3, of structures, systems and components (SSC) related to safety. It included some 32 000 components and resulted in 147 reports for type components. The project resulted also in the insertion of almost 700 maintenance actions into the plants maintenance programs. These maintenance actions affect areas such as training, instructions, procedures, PM schedule, PM actions, operation, etc. The Forsmark ageing program methodology was approved by the Swedish regulator in 2014.

4.2 The Olkiluoto Ageing Project

TVO operates two units of ASEA-Atom BWR design at their Olkiluoto site and these are sister units to the Forsmark units 1 and 2. The Olkiluoto AM project is currently work in progress. Westinghouse became involved in the Olkiluoto units 1 and 2 AM project in late 2014. It was early recognized that the results from the Forsmark project are highly relevant for the two

Olkiluoto units. Hence, the results from the Forsmark project was re-used in order to review around 20 000 components at Olkiluoto 1 and 2.

4.3 Aging management and equipment qualification

With AM of an NPP SSC follows a need to be able to requalify aged equipment or introduce and qualify new equipment. The Westinghouse Equipment Qualification (EQ) laboratory in Sweden has qualified/re-qualified over 300 components during the last 10 years. These services has utilized the EQ laboratory resources of e.g. thermal chambers, climate cycling chambers, electric loading, LOCA and post-LOCA testing, etc.. The objective of EQ programs is to demonstrate that SSCs can perform their required function, at both normal and abnormal operating conditions, during a specified and limited qualified life. This means that EQ verifies that certain ageing mechanisms will not cause unacceptable SSC degradation during the qualified life, given a specified set of operating conditions and, if necessary, requiring specific installation, inspection, monitoring, or periodic maintenance actions to maintain component ageing effects within the bounds of the qualification basis. EQ may be accomplished in several ways, such as type testing, by operating experience, analysis etc. or by combinations of these methods, depending upon the complexity and nature of the SSC, functional requirements and significant ageing mechanisms.

Westinghouse has EQ laboratories and test facilities in Sweden and the US for servicing NPPs around the globe. The EQ laboratory in Sweden complies with requirements in SS-EN ISO/IEC 17025:2005 and has been accredited by the Swedish board for accreditation, SWEDAC, for a total of six methods since late 2015. Further methods will be accredited as continuous improvement, since Westinghouse believes that requirements for certified methods and resources will become more common in the future within this domain [2].

4.4 Generic ageing experience

For Passive Mechanical Components (PMC) the most dominant ageing mechanisms are corrosion and fatigue. IGSCC are relevant only for SSCs in austenitic steel for which this is the major ageing mechanism. PMCs showing degradation are typically pipe works in Reactor Coolant Pressure Boundary (RCPB), steel vessels, heat exchanger tubes and flanges (particularly tubes of closed cooling water heat exchangers) and core internals.

For Active Mechanical Components (AMC) wear (moving parts), fatigue, corrosion, and thermal degradation of organic seals are the dominating ageing mechanisms. Failing AMCs due to ageing are commonly Motor Operated Valves (MOVs), Pressure Operated Valves (POVs), pumps and emergency diesel engines (and auxiliaries).

For Electrical and I&C components (EIC) it is usually the active SSCs that are susceptible for ageing. Failures of passive SSCs (cables etc) are few, although it has in some cases due to aging been necessary to replace in-containment cables. Typical ageing mechanisms are loss of insulation resistance, loss of capacitance, set point drift, wear (relays), etc. or unidentified causes (especially for electronic cards). Electronic cards, relays, electrolytic capacitors, batteries, small power units, and switches seem to be the most ageing susceptible EICs based on experience.

5. Conclusion

Efficient AM is becoming an increasingly essential activity for nuclear operators in order to maintain nuclear safety and disturbance-free and profitable operation as NPP are getting older, and in many cases nearing or reaching the original design life and entering LTO. Ageing NPPs

also causes AM to obtain increasing focus from regulatory bodies, leading to new requirements forcing utilities to increase their AM activities.
Since the topic of AM is a very broad and a vast area, this paper focused mainly on the experience with AMRs within the Nordic region. The methodology used at Forsmark NPP and Olkiluoto NPP is based on IAEA Safety Guides and different NOG projects on AM related issues.

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6. References

[1] IAEA Safety Guide NS-G-2.12

[2] E. Wretsäter et al. “The journey to a certified equipment qualification laboratory – Westinghouse approach and lessons learned” TopSafe 2017, 12-16 February 2017 in Vienna, Austria.