Beyond Design Life Expectations for Structures Systems and Components Important to Safety - Phase 2

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Contact Details:	[redacted]

Head of Regulatory Support Directorate
Jacobs
305 Bridgewater Place
Birchwood Park
Warrington
Cheshire
WA3 6XG
United Kingdom

T [redacted]
E [redacted]
W www.jacobs.com

Contents

Executive Summary iv
1. Introduction 1
2. Phase 2 Methodology 2
3. Review of IAEA RGP 5
3.1 IAEA SSG-48 5
3.2 Other IAEA RGP 8
3.3 Summary of IAEA RGP Themes 12
4. Review of Nuclear Industry Codes and Standards and Other RGP 13
4.1 2019 ASME Boiler and Pressure Vessel Code 13
4.2 ENSREG Topical Peer Review 2017 – Ageing Management 14
4.3 Organisation for Economic Co-Operation and Development (OECD) – Nuclear Energy Agency (NEA) 14
4.4 Other Nuclear Industry RGP 15
4.5 Summary of Nuclear Industry RGP Themes 17
5. Summary of Nuclear Industry Key Themes, Considerations and BDL Expectations 18
5.1 Key Themes and Considerations 18
5.2 BDL Grouped Themes 22
5.2.1 Plan 22
5.2.2 Do 24
5.2.3 Check 26
5.2.4 Act 27
5.2.5 Understanding 28
5.2.6 Other 29
5.2.7 Summary of BDL Themes 30
5.3 BDL Expectations 33
6. Review of Other High-Hazard Industries RGP 36
6.1 Summary of HSE RGP 36
6.1.1 Beyond lifetime criteria for offshore cranes 36
6.1.2 Ageing and Life Extension (ALE) for Oil and Gas Installations 38
6.1.3 Management of Equipment Containing Hazardous Fluids or Pressure 39
6.1.4 Plant Ageing and Management of Ageing for On-Shore Chemical or Nuclear Chemical Facilities 41
6.2 Summary of Aviation RGP 42
6.3 Summary of Other High-Hazard Industry RGP Themes 43
7. Summary of BDL Expectations Benchmarking 45
8. Summary of the Phase 2 Findings, BDL Expectations and Recommendations 50
8.1 Findings 50
8.2 BDL Expectations 51
8.3 Recommendations 52
9. References 53

Appendices

Appendix A. Tables Summarising RGP Reviews

Appendix B. Output of IAEA RGP Reviews

Appendix C. Output of Nuclear Industry Codes & Standards and Other RGP

Appendix D. Output of Other High-Hazard Industries RGP

Appendix E. Comparison of Themes Using Plan–Do–Check–Act Model

Appendix F. Summary of BDL Expectations

Executive Summary

ONR are seeking to develop a new good practice guide for Beyond Design Life (BDL) expectations of mechanical Structures, Systems and Components (SSCs) important to nuclear safety. A four phase project for development of the guide was initiated in 2018. Phase 1 was completed in May 2019 and provided a comprehensive identification of Relevant Good Practice (RGP) related to BDL expectations. The findings of Phase 1 also identified a number of potential gaps in extant ONR guidance.

Due to the large volume of RGP that was identified during Phase 1 of the project, further work was required in order to consolidate the information, benchmark, and carry out other assurance activities to ensure that the final output is credible, authorative, and valued by industry.

Phase 2 builds on the findings of Phase 1 (Reference 1) in order to:

- Undertake detailed reviews of nuclear industry RGP identified in Phase 1 (Reference 1) for different classes and types of mechanical SSCs important to safety in order to develop BDL expectations;
- Perform a benchmarking exercise comparing nuclear industry BDL expectations with those identified from other high-hazard industries;
- Identify minimum expectations against which ONR should determine that BDL considerations have been adequately undertaken when considering the limitations of codes and standards used for such components.

At the discretion of ONR, this phase may be followed by further phases to include production of a good practice guide and industry engagement.

In order to provide confidence to the nuclear industry that this report is comprehensive and authoritative, a wide range of nuclear industry RGP has been reviewed, and cross compared with RGP from other high-hazard industries. The full list of RGP reviewed is included in Appendix A. Reviews of IAEA guidance are presented in Appendix B and summarised in Section 3. Reviews of nuclear industry codes and standards and other RGP are presented in Appendix C and summarised in Section 4. Section 5 provides an overview of the key themes and considerations that have been derived from the nuclear industry RGP reviews.

Reviews of the high-hazard industry RGP are presented in Appendix D and summarised in Section 7. Similar to the nuclear industry reviews, a list of key themes and considerations were developed from the high-hazard industry RGP; this list formed the basis of the benchmarking exercise. The comparison between both RGP groups identified that there is broad alignment between the themes identified. However, a small sub-set of themes were identified from the high-hazard RGP that did not appear in the nuclear industry list (or were not covered to the same extent); these items were added to the final list of BDL expectations.

Throughout this report, BDL expectations have been subjectively grouped according to the ‘Plan-Do-Check-Act’ cycle in order to provide a framework to enable the BDL expectations to be further developed. The list of BDL expectations is further sub-divided to identify those expectations that would usually form part of a BDL submission (e.g. an LC22 submission) and those items that would usually be addressed via a Periodic Safety Review (PSR).

A summary of all BDL expectations against each of the ‘Plan-Do-Check-Act’ groups is presented in Appendix E. Appendix F presents a summary of all BDL expectations, also indicating if each expectation would usually be assessed as part of the PSR or within a BDL submission. Appendix F also presents a number of figures illustrating the distribution of the themes against assessment type and the ‘Plan-Do-Check-Act’ groups, which indicates the source (nuclear or high-hazard RGP) and the combined results.

Section 8.2 presents the final consolidated list of BDL expectations. It is noted that many of the expectations identified can be related to key areas identified in Phase 1 (Reference 1) and linked to the ONR Safety Assessment Principles (SAPs) (Reference 4) and other associated ONR guidance. The lists are comprehensive,

but not necessarily exhaustive given the scope of RGP associated with the subject matter. However, in-line with the overall task objective, this phase represents a stepping-stone to enable the BDL expectations to be further developed.

In addition to consideration of service life assumptions and design conservatisms built into codes and standards for SSCs, which should be addressed as part of a revalidation of Time Limited Aging Analysis (TLAA), the reviews of RGP identified a wide range of other BDL expectations. Several of these other expectations are considered particularly important where TLAA from the design stage is not available, or where there is uncertainty in safety margins. For example, in cases where safety margins are not large, it is considered reasonable to implement move advanced techniques that makes use of data on loads and cycles taken from operational history or experience based data on environmental conditions. Expectations associated with identification and management of consequential effects on people, plant and process should also be addressed in order to provide assurance that all risks have been reduced as low as reasonably practicable (ALARP).

Areas where high-hazard industry guidance was found to be more extensive than the nuclear industry included BDL expectations associated with: data management and trending; obsolescence management; and organisational factors. Guidance on the use of self-assessments, questionnaires and checklists to provide assurance for BDL operation was also found to be more detailed within RGP from high-hazard industry.

The development of a unified BDL expectations document is supported by the results of Phase 1. Phase 1 identified that existing ONR documentation included a number of principles and guidance that would be applicable to the justification of BDL operation. However, it was noted that this information was fragmented across the ONR SAPs, Technical Assessment Guides (TAGs) and Technical Inspection Guides (TIGs). As such it was recommended that the production of a good practice guide and/or dedicated TAG be undertaken as part of a future phase of the project. This new guidance document should present BDL expectations, with clear reference to where the key themes and considerations relate to RGP including extant ONR guidance. This recommendation is further supported by the reviews undertaken in this phase of the project.

As such it is recommended that:

1) Consideration be given to the production of a good practice guide and/or dedicated TAG in order to further develop the BDL expectations identified in this phase of the task with reference to RGP including extant ONR guidance;
2) A series of questionnaires and checklists are developed to support review of BDL submissions, which in turn can inform the development of BDL submissions for facilities other than Nuclear Power Plants (NPPs);
3) The ONR research project (ONR376) undertaken in support of the review of the Ageing and Degradation SAPs (EAD.1 to EAD.5), summarised in Reference 5, be incorporated into the next phase of this task in order to combine the learning from across both projects.

1. Introduction

ONR are seeking to develop a new good practice guide for Beyond Design Life (BDL) expectations of mechanical Structures, Systems and Components (SSCs) important to Nuclear Safety. A four phase project for development of the guide was initiated in 2018. Phase 1 was completed in May 2019 and provided a comprehensive identification of Relevant Good Practice (RGP) related to BDL expectations. The findings of Phase 1 also identified a number of potential gaps in extant ONR guidance.

Due to the large volume of RGP that was identified during Phase 1 of the project, further work was required in order to consolidate the information, benchmark, and carry out other assurance activities to ensure that the final output is credible, authorative, and valued by industry.

Phase 2 builds on the findings of Phase 1 (Reference 1) in order to:

- Undertake detailed reviews of nuclear industry RGP identified in Phase 1 (Reference 1) for different classes and types of mechanical SSCs important to safety in order to develop BDL expectations;
- Perform a benchmarking exercise comparing nuclear industry BDL expectations with those identified from other high-hazard industries;
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At the discretion of ONR, this phase may be followed by further phases to include production of a good practice guide and industry engagement.

This report is structured as follows:

- Section 1 – Introduction;
- Section 2 – Methodology;
- Section 3 – Review of IAEA RGP (with detailed findings presented in Appendix B);
- Section 4 – Review of nuclear industry codes and standards and other RGP, (including other International regulatory documents) (with detailed findings presented in Appendix C);
- Section 5 – Summary of nuclear industry BDL expectations;
- Section 6 – Review of other high-hazard industries RGP (with detailed findings presented in Appendix D);
- Section 7 – Summary of high-hazard industry BDL expectations, with comparison to nuclear industry expectations;
- Section 8 – Consolidated summary of findings, BDL expectations and recommendations.

The latter sections of this report draw together the information presented to provide an overview of the BDL expectations developed, which will form the basis for Phase 3 of the project. Where appropriate, observations and recommendations are also made for ONR consideration.

Further information on the documents identified and reviewed is tabulated in Appendices A to D of this report. These appendices provide summary document information, to permit future referencing, and include a high-level outline, plus any comments relating to the relevance of the source material. Appendices E to F present the final list of BDL expectations which have been subjectively grouped in order to provide a framework for further development.

2. Phase 2 Methodology

Phase 1 of the task produced a comprehensive list of RGP, identifying a total of 125 documents across the nuclear industry and other high-hazard industries, which included various documents, codes and standards, conference papers and conference presentations. Phase 2 has used this material as the basis to identify key considerations and themes which should be addressed in a good practice guide for BDL expectations. A structured process has been applied to the review and processing of the RGP to group RGP and ensure that cross comparisons between nuclear and other high-hazard industry RGP were carried out. This cross comparison provided added assurance that the resulting list of BDL expectations is authoritative and comprehensive.

To help the review process, RGP identified in Phase 1 was sub-divided into the following categories:

- IAEA RGP;
- Nuclear industry RGP codes and standards, (including documents from other regulatory bodies outside of the UK);
- Other nuclear industry RGP (not identified in groups above);
- RGP identified from other high-hazard industries related to the subject matter.

These sub-divisions, enabled associated documents and common processes to be identified. Within Phase 1 a total of 23 documents were subsequently excluded as they were either superseded or otherwise identified as not directly relevant to the identification of BDL expectations. Post Phase 1 a further 20 documents were identified as being potentially relevant, leading to a consolidated list of 122 documents for review during Phase 2 from a total of 145.

Based on the anticipated applicability of the document to identification of RGP (from the high-level review undertaken in Phase 1) the reviews were focused on those documents judged as being the most relevant or adding the most value. This exercise led to a further 79 documents being excluded, including those that were largely focussed on Operational Experience (OPEX) of SSCs common to Light Water Reactors (LWRs). The remaining documents were then split into three groups for review:

- IAEA RGP;
- Nuclear industry codes and standards and other RGP;
- RGP from other high-hazard industries.

An overview of the split of all 145 identified documents is presented in Figure 1 below. It can be seen that in this phase the reviews undertaken were roughly equally split between the three key groups identified above.

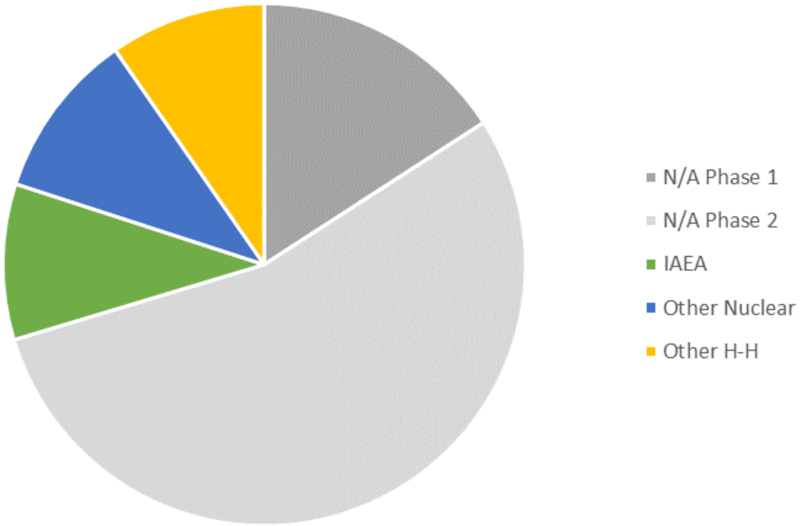


Figure 1 Overview of RGP Reviewed

Below is an outline of the key activities that were undertaken as part of Phase 2 of this task:

Step 1 - Review of Identified Nuclear Industry RGP

The RGP identified in Appendix A broadly falls into two groups; those focussed on plant and those focussed on process. It is noted that within the plant focussed documents, the emphasis is on SSCs predominantly associated with LWRs. In addition, within the process related documents, many of the Long Term Operation (LTO) documents reflect the licencing arrangements outside of the UK (as discussed later in Section 3.1). Although not all of this information is directly applicable to UK nuclear plant and process, it does include a number of important aspects which are relevant to development of BDL expectations for UK nuclear facilities.

To assist the review, a list of keywords was used to identify relevant information. These keywords included:

> Actual Condition;
> Ageing and Degradation;
> Ageing Management;
> Design Life;
> Life Extension;
> Life-Cycle;
> Long-Term Operation;
> Periodic Safety Review (PSR);
> Plant Life Extension;
> Plant Life Management;
> Safety Margin;
> Time-Limited.

The identified information was then collated and summarised in Appendix B to Appendix D of this report. Summarising the information in this way also provides a clear audit trail back to the originating reference.

Step 2 - Develop BDL Expectations

Across the range of nuclear industry RGP a significant number of potential expectations were identified. However, there were common themes and considerations that are repeated across a number of documents. Therefore, the development of the BDL expectations includes the consolidation of common themes and considerations for different classes and types of mechanical SSCs important to safety. The consolidated themes and considerations were also compared to extant ONR guidance in order to identify if any differences or gaps existed.

Step 3 - Benchmarking Exercise

Following the review of nuclear industry RGP and development of BDL expectations, a review of other high-hazard industry RGP was carried out. This review also identified a series of common themes and considerations that were then compared to those identified in Step 2. The comparison, in addition to demonstrating consistency across different industries, also provided an opportunity to identify themes or considerations not included in the list of nuclear industry BDL expectations. The key themes and considerations identified in Steps 1-2 were then updated, based on the findings of the benchmarking exercise, which in turn were compared to the ONR guidance identified in Phase 1.

Step 4 - Prepare Phase 2 Technical Report

The final activity in this phase was to prepare this technical report that outlines the processes undertaken, review findings, results of the benchmarking exercise, consolidated BDL expectations, and an auditable trail to all source documentation.

3. Review of IAEA RGP

The output from the review of individual IAEA RGP is presented in Appendix B. The identified IAEA RGP broadly fall into one of two categories, these include:

> Process related documents that focus on LTO or Ageing Management. This includes reviews of individual country experiences of LTO or Ageing Management, and studies of the application of these processes;

> SSC related documents that look at various (common) SSCs, the observed degradation mechanisms and potential strategies to tackle these. Much of this documentation is focused on SSCs associated with LWRs.

A consolidated summary of the key themes and considerations from Appendix B is presented below.

3.1 IAEA SSG-48

The review of IAEA documents started with IAEA SSG-48 (Ageing Management and Development of a Programme for Long Term Operation (LTO) of Nuclear Power Plants), Reference 2 (identified as A-069 in Appendix A). This guidance document revises and supersedes the Safety Guide on Ageing Management for Nuclear Power Plants, (IAEA NS-G-2.12 identified in Appendix A as A-062) and also supersedes two Safety Reports issued by the IAEA in 1999 and 2007. The first of these is IAEA Safety Reports Series (SRS) No. 15, Implementation and Review of a Nuclear Power Plant Ageing Management Programme, not included in Appendix A due to the date of issue and that it has been superseded by a number of other documents. The other is IAEA SRS No. 57, Safe Long Term Operation of Nuclear Power Plants, included in Appendix A as A-063. Reference 2 takes into account developments in the ageing management of nuclear power plants worldwide and expands the scope to include provisions for maintaining the safety of nuclear power plants during LTO.

This IAEA SSG-48 represents the current guidance from the IAEA on Ageing Management and LTO. It brings together the topics of Ageing Management and LTO into the same document, recognising the links between these two subjects. Prior to this report these were developed separately, with guidance and international OPEX on Ageing Management and Ageing Management Programmes (AMPs) for SSCs being presented independently of the requirements for LTO. This is evident in References A-062 and A-063 in Appendix A. However, in recent years it has been recognised the Ageing Management and the supporting programmes can provide a fundamental part of the evidence to substantiate extended operation and combined with the output from a PSR can provide confidence that a range of topics (from the SSCs to the Safety Management Culture of an organisation) are able to support LTO.

Within Reference 2 there are two key approaches for how LTO is handled, with the approach adopted largely dependent on the licencing arrangements applicable to the country. However, in both cases LTO is generally justified across the whole facility, rather than on a case-by-case basis for individual SSCs. The approaches include:

> If a fixed term licence (for instance 40 years) is granted by the regulator then a stand-alone LTO Submission for a fixed term (10 or 20 years) is presented to the regulator for approval;

> If licence renewal is linked to the submission of a PSR to the regulator, then this becomes the vehicle through which approval for LTO is sought.

Figure 2 below presents a high-level overview of an LTO process, in this case more aligned to the first approach described above. Figure 2 highlights that the LTO submission draws on information from various sources that includes information on individual SSCs, for instance discrete Ageing Management Reviews, and the whole facility, such as the PSR.

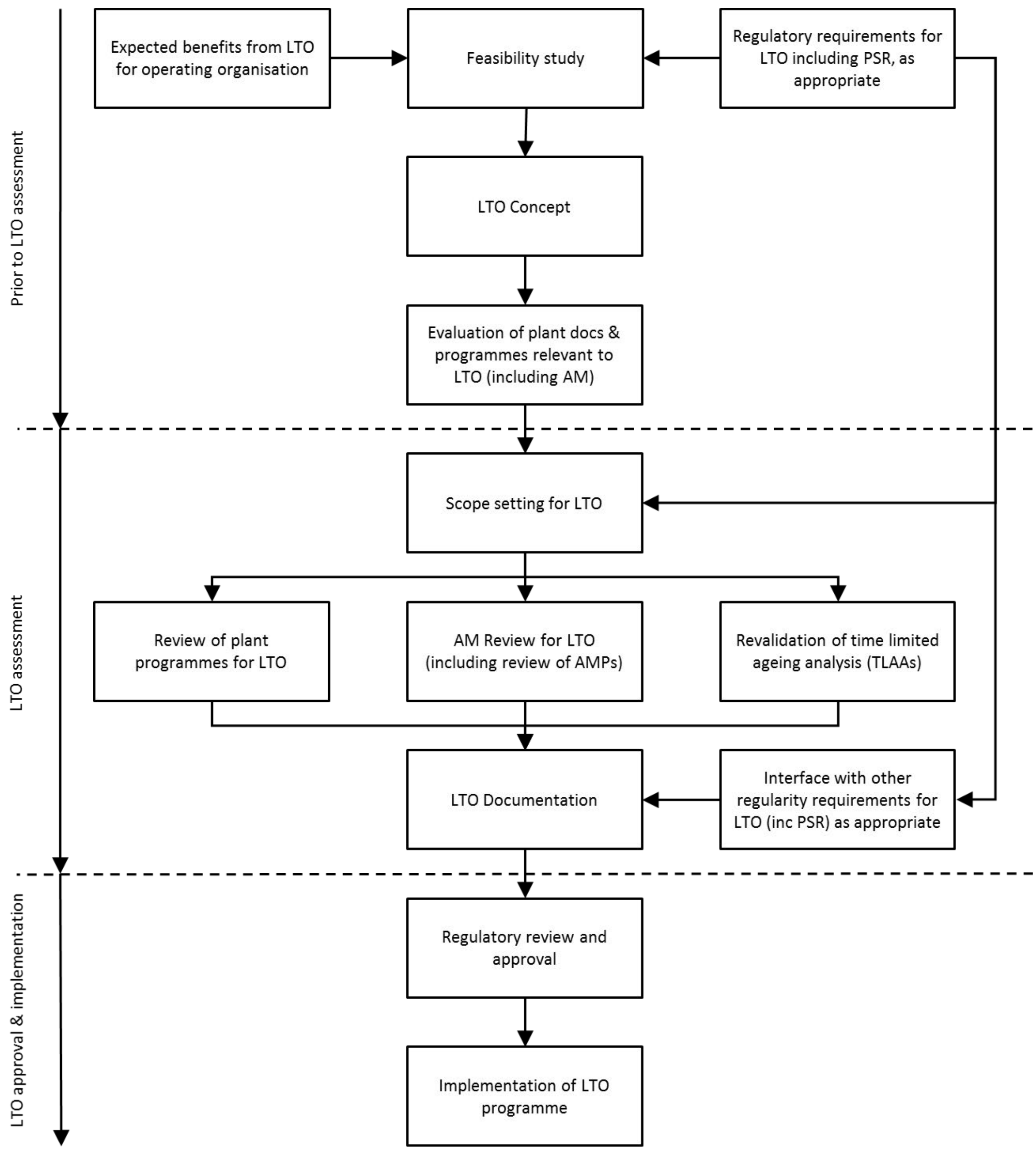


Figure 2 Simplified LTO Process

Within the UK the licencing arrangements are different and neither approach identified above would be applicable. It is likely that justification for operation of an SSC beyond the original design life would be identified on a case-by-case basis as part of the modification process. This would then be supplemented by the PSR, which would assess the cumulative effect of all the modifications across the whole facility. Although it is unclear if the justification for an individual SSC would reference the whole facility impact assessed by the PSR, which in turn may not consider the impact of the change due to the timing of the PSR not aligning with the modification. This difference in the UK approach means that the review of IAEA and other nuclear industry RGP needed to recognise that not all the processes will be applicable to the UK. However, the assessments and analyses identified as supporting LTO may also be applicable for BDL submissions for individual SSCs; and the whole facility assessments may reflect requirements identified in the PSR. This is discussed further in Section 5.

Reference 2 notes that the programme for LTO should include the following activities, evaluations, assessments and results:

4) The method of scope setting, the results obtained (structures or components within the scope and out of the scope of LTO) and supporting technical justifications.

5) Demonstration that the programmes credited for LTO support the conclusion that the intended functions of the SSCs and the required safety margins will be maintained. This demonstration should address the following topics:

   - A description of the intended functions of the SSCs;
   - Identification of applicable ageing effects and degradation mechanisms based on, for example, the materials used, the environment and operating experience;
   - Specification and description of operational programmes and AMPs that manage the identified ageing effects;
   - Demonstration that these operational programmes and AMPs (including new programmes) are effective.

6) Demonstration that the review performed for the SSCs within the scope of LTO is consistent with the AMP. A technical justification should be provided that:

   - Demonstrates that ageing effects will be adequately managed for each SSC in such a way that the intended function(s) of the SSC will be maintained throughout the planned period of LTO in a manner that is consistent with the current licensing basis;
   - Ensures that operating experience and research findings are adequately reflected in assessing the ageing effects of structures or components that are in scope for LTO and will continue to be taken into account during the entire period of LTO.

7) Demonstration that the Time Limited Ageing Analyses (TLAA) have been revalidated and that the evaluation includes:

   - Identification of TLAA in accordance with the definition specified in Reference 2 (paragraph 5.64), which includes that TLAAs should:
     - Involve SSCs within the scope for ageing management;
     - Consider the effects of ageing;
     - Involve time limited assumptions defined by the current operating term and the proposed LTO;
     - Have been determined to be relevant by the operating organisation in making a safety determination as required by national regulations;
     - Involve conclusions or provide the basis for conclusions relating to the capability of SSCs to perform their intended functions;
     - Be contained or incorporated by reference in the licensing basis (current or future).
   - Revalidation of each identified TLAA in accordance with the recommendations provided in Reference 2 (paragraph 7.28) to demonstrate that the intended function(s) of the SSC will be maintained throughout the planned period of LTO in a manner that is consistent with the current licensing basis.

8) The implementation of the programme for LTO, specifying the corrective actions for safe LTO, and the schedule and commitments of the operating organization relating to LTO.

In addition, Reference 2 notes that the programme for LTO should address the safety improvements required for safe LTO, the schedule, and the commitments of the operating organisation relating to LTO. The report identifies that the documentation should provide detailed information on each element outlined above and any other information required by national regulatory requirements, for instance information from the PSR. While this information is directed at a facility-wide LTO programme, each of the elements above can be applied to an individual SSC and form the basis of a BDL submission.

Reference 2 also notes that since LTO is operation beyond the originally established time frame and evaluations for LTO are based on assumptions, the operating organisation should periodically perform the following activities to validate or correct the ageing related assumptions so that plant safety during LTO is ensured and improved:

a) Evaluation of operating experience at the plant or at other nuclear power plants, after entering LTO;

b) Analysis of trends in ageing effects;

c) Review of the effectiveness of the AMPs and existing plant programmes for LTO;

d) Incorporation of relevant research and development results;

e) Evaluation of the need for new research and development.

The document also highlights that decisions concerning ageing management and LTO should take due account of the potential implications for the subsequent decommissioning stage.

A list of the key themes identified in Reference 2 include:

- Ageing Management (Programmes and AMP Reviews)
- Ageing/Degradation Mechanisms of SSCs
- Decommissioning
- Examination, Inspection, Maintenance and Testing (EIMT)
- Equipment Qualification
- General Framework (AM and LTO)
- In-Service Inspection
- Lifetime/Life-Cycle Management
- LTO Submission
- Modifications to Existing Plant Programmes
- Obsolescence
- OPEX
- Periodic Safety Reviews
- Preconditions for LTO
- Preventative/Predictive Maintenance
- Regulatory Approach/Oversight
- Reviews/Revalidate TLAAs
- Scoping and Screening
- System and Data Management

3.2 Other IAEA RGP

The previous subsection represents a summary of the information presented in Reference 2 regarding extended operation and the expectations of the justification presented to support LTO. Reference 2 collates much of the previous guidance and uses OPEX on the application of earlier iterations to focus on key aspects proven in LTO submissions. As a result, many of the key themes and considerations identified in other IAEA RGP mirrored those identified in Reference 2.

Some of the key points highlighted in the other documents (not explicitly covered in Reference 2) are identified below.

- Reference A-052 highlights the importance of AMPs to LTO and states that AMPs should be "*a pre–condition for LTO*". In part this is due to the AMP having "*special characteristics from an LTO perspective*", as they must address the degradation mechanisms that limit the life of the structures. The document also notes that it "was recognised that the majority of the AMPs required, either already exist as plant programmes or are programmes that need to be enhanced to address attributes of an acceptable ageing management programme". A-052 also highlights some of the challenges with AMPs, including:
    - Completeness of the identification of ageing mechanisms and of sensitive locations for each structure and structural component;
    - Criteria for assessment of acceptability of ageing;
    - Adequacy of trending methods;

- Evaluation of ageing at hidden, non-accessible locations;
- Crediting of existing programmes, attributes of adequate AMPs;
- Review methodology of ongoing programmes.

With regard to extended operational lifetime, A-052 notes that the assessment of the AMP experience should enable plants to demonstrate the following:

- The safety and ageing analysis remain valid and could be projected to the end of intended operational lifetime;
- The effects of ageing on the intended function(s) will be adequately managed;
- There is a procedure to deal with unexpected ageing mechanisms that can surface in later years.

> Reference A-052 also looks at other programmes of work that can support LTO, it notes that monitoring the condition of safety significant structures is an essential assumption of LTO and the knowledge of the structure history is the basis for residual lifetime assessment. In addition, it notes that maintenance should be an effective tool of mitigation of ageing processes and that "*the implementation of condition/ageing dependent maintenance should be enforced*". The report suggests that the review for LTO should look at the "*adequacy of maintenance programmes and evaluation of their efficiency*" and whether the criteria and methodology for these programmes is sufficient.

> In addition, Reference A-052 discusses TLAA and links Trend Analysis and TLAA, which it suggests are connected to the evaluation of the life of structures and structural components. The document notes that areas may exist where Trend Analysis cannot be guaranteed and TLAAs from the design stage are not available, the report concludes that "*depending on the safety relevance, a complete re–analysis of the ageing process might be needed and the time limits of safe operation should be set*". A-052 goes on to state that in difficult cases, when the margins are not large, it is reasonable to implement sophisticated state–of–the–art techniques that makes use of data on loads and cycles taken from operational history, experience based data on environmental conditions, etc."

> Reference A-053 includes some general recommendations for LTO, which include:

- Requirements for LTO should be specified within their regulatory framework and a technical basis justifying the period of operation BDL of the facilities should be provided;
- A set of pre-conditions containing plant specific programmes for LTO should be implemented and appropriately documented;
- The implementation of plant activities for LTO should be properly documented in updating the Final Safety Analysis Report (FSAR) or other licensing documents that integrate the results of the LTO engineering process and constitutes the basis documents for LTO application and approval;
- Existing plant programmes may be credited, with some modifications or enhancements upon evaluation/assessment for use in LTO. AMPs may be needed (or need to be modified) for those structures and components that were not in the scope for the current plant programme, but are in the scope for LTO for reasons such as OPEX or Probabilistic Safety Assessment (PSA).

> The plant programmes that are considered pre-conditions for LTO, as identified in A-053, include:

- **In-service Inspection (ISI)**, noting the following recommendations:
  - The methodology, personnel and equipment used for ISI should be qualified as per national standards and regulatory requirements;
  - The development of ISI reviews for ascertaining the effectiveness of the inspections for the detection of ageing mechanisms. The report states "*The review process should provide a technical basis that justifies that the ageing phenomena will be adequately detected with the proposed inspection or monitoring activities*";

- A living database should be used for documenting the effectiveness of the ISI and to "provide technical references to support findings and conclusions".

- **Maintenance**, noting that "*maintenance programmes for LTO should clearly identify the type of maintenance (preventive, predictive and corrective), the links with ageing management programmes, the frequency and tasks, the records, their evaluation and storage for optimization*". A-053 also notes the following recommendations:
  - Consider short-comings in the current programme and technical developments;
  - There is also a living database (as above);
  - Also "*organizations should consider applying destructive testing methods using specimens of electrical cables that were exposed to actual environmental conditions during operation to monitor material degradation during LTO*".
- **Equipment Qualification**, in order to provide assurances that:
  - The equipment will continue to fulfil its function throughout the intended period of operation;
  - The ageing effects would be managed effectively;
  - If required, the equipment would be replaced in order to fulfil its intended function.
- **Surveillance and Monitoring Programmes**, recognising that these may need to be modified or extended to cover LTO. A-053 notes that "*surveillance programmes using representative material samples addressing time limiting mechanisms should be extended or supplemented for LTO, if necessary*".

> Reference A-053 also includes 3 steps of an ageing management review for the SSCs identified in the LTO scoping and screening process. These are:
  - Step 1: An engineering assessment of the current status of SSCs within the scope, and a confirmation of the ageing effects and degradation mechanisms of these SSCs;
  - Step 2: An evaluation process involving a review of the existing programmes and a review of the proposed AMPs;
  - Step 3: The documentation of "the technical justification demonstrating that the structures and components within the scope of LTO, identified in Step 1 will fulfil their safety related functions during the proposed period of LTO".

> Reference A-054 is an INSAG report that deals with a general approach to the safe management of the operating lifetimes of nuclear power plants. The report identifies that in order to meet the general objective for safe management of the operating lifetimes of nuclear power plants, adequate provision is made to confirm that the characteristics of the various SSCs related to the safety of each plant remain better than the limiting characteristics considered at the design stage. The effective application of this principle implies that:
  - The limiting functional characteristics of the various items of equipment related to the safety of the plant are defined and reviewed;
  - The degradation mechanisms for these items of equipment are identified and provisions such as adequate operating procedures and technical specifications are implemented to minimise the expected degradations; the effects of ageing are monitored and the results are used to predict the residual potential lifetime of the plant;
  - A maintenance policy is in place, so that appropriate decisions are taken in a timely manner to maintain the safety characteristics within allowable ranges, by repair, replacement or adjustment of operating conditions.

> Reference A-065 highlights that a TLAA is acceptable if it meets one of the following:

- The analysis remains valid for the intended period of operation;
- The analysis has been projected to the end of the intended period of operation;
- The effects of ageing on the intended function(s) of the SSC will be adequately managed for the intended period of operation.

> Reference A-066 recognises the importance of competence management, which considers the recruitment and training/qualification processes for personnel involved in LTO, and Knowledge Management, including knowledge transfer for LTO. The document notes that a Knowledge Management (KM) plan and processes should be in place to support the LTO activities. KM needs to be a part of the long term strategy of the operating organisation and a plant should consider including knowledge-loss risk management in its KM practices.

> Reference A-077 identifies links between LTO and the PSR, noting that the results of periodic safety reviews are effectively an input to plant life management as they aid plant life extension studies and the decision making regarding the investments required to secure an extended operating life. It also notes that periodic reviews being part of ongoing activities rather than a large single project is more cost effective when implemented as an element of plant life cycle management. A-077 highlights that PSRs are also utilised during the decommissioning stage. In such cases, they are used as a justification to support the decommissioning strategy that take into account the changes in plant configuration and continued availability of SSCs to ensure decommissioning is carried out safely.

> In addition to the PSR, A-077 notes that for a plant seeking life extension, the assessment has to be started in advance of the end of the design life. This is necessary so that the main issues for life extension can be identified early enough to enable an engineering programme to be deployed so that any necessary modifications are completed before life extension begins. Also, this document highlights issues around obsolescence and that LTO should also consider the question of spare parts.

> Reference A-142 also focusses on Obsolescence and relates to the IAEA Technical Obsolescence Programme (TOP). The purpose of this programme is to provide operating organizations with a general format for development and implementation of a proactive obsolescence programme to manage the impact of obsolescence on the availability and reliability of SSCs. The TOP document contains information on the following key points:

- Scope of the technological obsolescence programme;
- Proactive technological obsolescence actions to minimise and control obsolescence;
- Detection of technological obsolescence indicators;
- Monitoring and trending of technological obsolescence;
- Mitigating technological obsolescence;
- Acceptance criteria;
- Corrective actions;
- Operating experience feedback;
- Quality management.

In addition, to the points listed above there are also a number of SSC related documents or parts of documents focussed on SSCs that are identified in Appendix B. These provide information on BDL considerations for a range of mechanical components and in several cases also relate to other disciplines (e.g. civil and electrical). These other discipline related documents have been included as there may be some cross over with mechanical SSCs, and the interfaces between them. However, much of the identified information is focused on SSCs associated with LWRs. Given the range of SSCs within the UK, across all nuclear facilities and not just civil nuclear facilities, compared to other countries there is limited value in reviewing all of this information as part of this process. As such, this information was not reviewed in detail, but high-level information is presented in Reference 1 to enable identification if required.

However, one of the key messages that comes across in the reviews undertaken, is that sharing information and experiences is actively encouraged to support extended operation. This is reinforced by A-054, which states that the identification of possible degradation mechanisms takes into account operating experience and the results of research, it is therefore essential that links among operating organisations are developed and maintained to exchange information on operating experience and to optimise research.

3.3 Summary of IAEA RGP Themes

Across the documents summarised in Appendix B a number of themes and considerations are identified that either mirrored the list presented in Section 3.1 or were additions to the list. These additions were due to the expansion of topics included in Reference 2, for instance in earlier documents where some of the principles and guidelines were being developed. In other case they related to topics not explicitly covered in Reference 2 but were related to the subject matter. In other areas themes were repeated or advanced in more recent iterations of related documents, culminating in the guidance presented in Reference 2. A list of the themes identified is presented below and includes a number of items identified in Section 3.1. It should be noted that this list has been consolidated across all the documents in Appendix B, it includes:

- Ageing Management (Programmes and AMP Reviews)
- Ageing/Degradation Mechanisms of SSCs
- Asset Management
- Decommissioning
- Design Life
- Design Stage Considerations
- Economic Optimisation
- EIMT
  - In-Service Inspection
  - Maintenance
  - Preventative/Predictive Maintenance
- Equipment Qualification
- General Framework for AM and LTO
- Knowledge Management
- Licence Management
- Lifetime/Life-Cycle Management
- LTO Engineering Process
- LTO Submissions or PSR to Demonstrate Safe Operation
  - Periodic Safety Reviews
- Modifications to Existing Plant Programmes
- Obsolescence
- Operational Programmes
- OPEX
- Performance Management
- Pre-Conditions for LTO
- Regulatory Approach
  - Roles and Responsibilities of Operators and Regulators
- Regulatory Oversight
- Review and Update of Processes and Procedures for LTO
- Reviews/Revalidate TLAAs
- Safety Management
- Scoping and Screening
- System and Data Management

This list covers various facets of Ageing Management and LTO requirements that can be linked in numerous ways given the range of aspects associated with each topic. Their relationship to BDL expectations and the current ONR guidance is presented in Section 5.

4. Review of Nuclear Industry Codes and Standards and Other RGP

The output from the review of the selected RGP from across the nuclear industry (but excluding the IAEA guidance) is presented in Appendix C. The identified nuclear industry RGP, like the IAEA guidance, broadly fall into one of two categories, these include:

> Process related documents that focus on LTO or Ageing Management. This includes Codes and Standards from other international regulators or studies around extended operation;

> SSC related documents that look at various (common) SSCs, the observed degradation mechanisms and some potential strategies to tackle these. Much of this documentation is focused on SSCs associated with LWRs;

As noted in Section 2 the list of documents to be reviewed in Phase 2 needed to be focused on those offering the greatest potential insight into BDL expectations. This was done on the anticipated applicability (from the high-level review undertaken in Phase 1) and volume of the RGP within the document. As a result, the initial list of documents was significantly reduced due to the RGP falling into a number of groups excluded at the start of Phase 2, including:

> Short conference papers or presentations that present OPEX or the output of research on specific topics;

> Documents/guidance related to other disciplines (such as Civils or E,C&I) and not directly applicable to Mechanical SSCs;

> Regulatory guidance that replicated current IAEA guidance;

> RGP presented early in the development of Ageing Management and LTO (RGP presented in mid- to late-90's or early-00's) that has been superseded by current guidance.

A number of the documents reviewed date back to the early days of ageing management, Life Cycle Management and licence renewal for extended operation. In the years that have followed significant work has been undertaken in the development of requirements for extended operation. The collation of different experiences from across the industry to promote standardised approaches has contributed to the development of many documents including the current approaches outlined in Reference 2. These documents represented the start of this journey and as such did not add any new or additional themes or considerations to those previously identified in Section 3. The RGP where this was determined to be the case are noted as such within the 'Key Themes' subsection in Appendix C. Summaries of the key documents, where additional themes or considerations were identified, are presented below.

4.1 2019 ASME Boiler and Pressure Vessel Code

Section XI, Division 2 of the 2019 ASME Code identifies the requirements for Reliability and Integrity Management (RIM) programmes for NPPs and is a technology-neutral standard of the ASME Boiler and Pressure Vessel Code. The Division 2 rules require the development of a RIM Programme that considers the combination of design, fabrication, degradation mechanisms, inspection, examination, monitoring, operation, and maintenance of SSCs to ensure they will meet their required reliability target values. The RIM Programme addresses a plant's entire life cycle and is applicable over the entire life of the plant and each passive SSC that is in scope. The RIM process consists of the following steps:

> RIM Program scope definition;

> Degradation mechanism assessment;

> Plant and SSC Reliability Target allocations originating from the probabilistic risk assessment (PRA);

> Identification and evaluation of RIM strategies;

- Evaluation of uncertainties;
- RIM Program implementation;
- Performance monitoring and RIM Program updates.

The requirements of this document broadly follow the requirements of an Ageing Management Plan for SSCs, (as described in Reference 2), with the level of detail of the AMP reflecting the safety significance of the item. For those SSCs that have to be designed in line with the ASME codes, then the level of detail required by the RIM Programme would be consistent with the AMP for equivalent safety significant SSCs. However, the requirements of this document are applicable through the whole lifecycle of an SSC and not specifically supporting extended operation. There are similarities in the key themes outlined above that fit with the approach to an AMP outlined in Reference 2, which provide further support to establishing Ageing Management. The collated information can also be used to support operation beyond the original design life for SSCs.

4.2 ENSREG Topical Peer Review 2017 – Ageing Management

Through the European Nuclear Safety Regulators Group (ENSREG), the Member States of the European Union selected the topic of 'Ageing Management' for the first peer review. This review was to be carried out for all nuclear power plants that were operating on 31st December 2017, as well as research reactors with a power equal to 1 MWth or more. To ensure a consistent structure across of all national reports, the Western European Nuclear Regulators' Association (WENRA) developed the technical specification for the peer reviews. The reviews undertaken as part of Phase 2 could not review the reports from all member states; therefore, only three were considered and these were the reports from France, Germany and Sweden.

The peer reviews enabled countries to review their AMPs, share information and experience, and provided an open and transparent framework for participating countries to develop appropriate follow-up measures to further enhance safety with more effective AMPs. It was identified that all countries have implemented or are gradually introducing a proactive AMP to cover design, construction, commissioning and operation and where relevant supporting the LTO. In the case of the reviews summarised in Appendix C it was identified that they largely focussed on Ageing Management rather than LTO and all demonstrated general adherence to the Plan => Do => Check => Act and Understanding activities identified in Systematic Approach to Ageing Management presented in Reference 2 and the value a PSR adds to the process.

4.3 Organisation for Economic Co-Operation and Development (OECD) – Nuclear Energy Agency (NEA)

A number of documents from the OECD NEA were identified as part of the Phase 1 searches for this task. Many of the reports date from the late-90's or early-00's and reflect the information summarised from Reference 2. However, one report specifically focusses on the implications for regulatory bodies (summarised in Ref. A-102), which was prepared by the Senior Task Group on Long-Term Operation within the Committee on Nuclear Regulatory Activities. The document presents the basic premise for consideration of LTO called the fundamental principle. This principle should underpin any programme on extended operation. Beyond that, three high-level key principles are identified that are intended to define and shape the development of an LTO programme. The key themes identified in this document include:

- **Regulatory Approach/Framework for LTO**: The document identifies the need to review the applicability of the existing regulatory framework for LTO and to determine if there is a need for new regulatory requirements. To some extent Phase 1 of this task reflects this first part of the review and this phase (2) relates to determining the need for new requirements. In addition, the document identifies that there is openness and transparency in the approach to address any potential concerns from the public. However, there is a need to ensure there is clarity within the ONR's approach to LTO and where the interfaces are with an operator, in terms of assessing justification for extended operation and where the oversight is provided. This approach should be mapped out for internal and external use.

- **Scope of Regulatory Assessment**: The approach to regulatory assessment within the UK is more aligned to the PSR approach, although it is recognised that the PSR is not the regulatory instrument for approval to extend the life of a facility. The scope of regulatory assessment outlined in this document (and in many others) is largely within the scope of the PSR either directly (as part of TAG-50) or indirectly (TAG-50 points to SSG-25 as a guide to the PSR scope).

  However, the individual analysis/assessment for specific SSCs to extend the life beyond the original design life will generally be tackled as part of the modification process (LC22) as and when it is required. Internationally, these would be more closely aligned with updated analysis being reported in the PSR and outstanding analysis being part of the forward plan. These assessments, along with a review of the AMP (programmatically and at component level) would form the basis of the LTO justification and the key elements of the regulatory assessment.

  While it is not appropriate to recommend changes to the regulatory approach for LTO, it is worthwhile looking to strengthen the links between the PSR, the development of an AMP and LC22 to recognise the combination these have in the justification for BDL.

- **Use of Operating Experience and R&D**: The document recognises the value of OPEX and R&D can have in supporting an LTO submission or PSR to extend the life of a facility. However, the document highlights the need for both the operator and regulator to consider operating experience from a variety of sources, both domestic and international, on a continuous basis. It notes that regulatory review of adverse operating experience from all sources is critical in providing robust regulatory oversight, assuring that appropriate short-term operator actions are taken and long-term ageing management adjustments are planned for implementation.

- **Safety and Security Improvements**: The report highlights the need for safety improvements to be made on a facility in order to support LTO and that PSR is a method for the identification of potential gaps. While this reflects other documents on the subject there are two aspects that differentiate this document from others. The first is that the document recognises that not all improvements are applicable or appropriate, but all 'reasonably practicable' improvements should be made. The use of the term 'reasonably practicable' is generally understood in the UK; however, it is rare for the term to appear in international documentation. The other difference is that the potential need for safety improvements is extended to consider security improvements also. This crosses over to the Security Assessment Principles (SyAPs) and any PSR type reviews undertaken for security.

- **Emergent Issues**: Where LTO is linked to licence renewal, emerging issues may arise as the facility move into extended operation; or if linked to PSR issues may arise between PSR reviews. The document highlights the need to ensure that a process is established to categorise the significance and consider the appropriate response for the facility. As SSCs age and degrade an emerging issue may have a more significant effect as the plant becomes less tolerant to issues. The PSR would examine such processes as part of the existing PSR scope; however, there is a need to reflect that changes in significance can occur with time as a facility becomes less resilient. In addition, there is a need to reflect that some emerging issues may lead to the extended operation ending earlier than anticipated, especially if it is deemed not technically feasible or financially viable to address the issue.

- **Ensuring Capabilities and Resources**: The document notes that the regulator should require confirmation that the operator has qualified and experienced personnel available to operate and maintain the plant in the period of extended operation. However, there is also a need for the regulator to ensure it has the capability and resources to support extended operation also. This may result in additional demands on the regulator to undertake more frequent inspections and audits or the review of more complex and novel solutions to technical issues posed by extended operations.

4.4 Other Nuclear Industry RGP

Below are some of the key points highlighted within the other nuclear industry RGP:

> Reference A-028 appears to be the start of a larger project looking at how the ageing of SSC can be modelled in the PSA and focuses on data collection and analysis. It provides discussion that focuses on frequent or periodic data collection and general analysis methods. Further work around the overall objective for modelling ageing in the PSA may appear in documentation developed for later stages of the task, but these were not identified. While the detail of this document does not provide meaningful information that could support the development of BDL expectations, it does, however, pose an interesting question around how ageing has been modelled within the PSA to determine if the ageing of specific SSCs has an adverse effect on the overall risk of the facility.

> Reference A-031 presents the regulatory procedures of operation beyond design lifetime from the Hungarian Atomic Energy Authority. The approach outlined in A-031 reflects a regulatory framework that requires a licensee to submit justification to extend the life of the facility as a whole, an LTO submission. It recognises that not all SSCs require justification to extend the life as they will be subject to renewal or replacement as required. The documentation recognises the PSR and the input this may have to an LTO submission, but that it is prepared independent of the LTO submission. The document highlights that the review of the AMP should ensure that acceptance criteria and the need for appropriate corrective actions are considered. The review should also consider the governance of the programmes and that OPEX is being used and managed appropriately. With respect to TLAAs the guidelines recognise that the validity of some TLAAs may not be extended beyond the original design life. In these cases, the guidelines note that the impact can be managed and supplementary AMPs may be developed to compensate.

> The French Nuclear Safety Authority (ASN) organised an international symposium on regulatory aspects of ageing issues for nuclear pressure equipment. Reference A-113 includes the papers presented over the course of the symposium and incorporates the proceedings from the event also. The papers that were presented were from across the international community including the US (from the NRC), various European countries and the IAEA. The papers summarise various approaches to AM and justification for LTO from across the world and provide some OPEX on the implementation of the processes in country. The presentations are broadly consistent with the information presented in SSG-48 and SSG-25; however, it does identify a few things that not readily highlighted in the other nuclear related RGP reviews. These include:

- **Data Recording and Availability**: Data availability is a key aspect in life management and the quality and availability of relevant information is directly related to the quality of the decisions on service life and the reliability of nuclear power plants.
- **Indirect Aspects of AM and LTO**: As part of the BDL submission for certain SSCs, demonstrating knowledge management (including SSC specific computer models or codes) over the period of extended life could be a key part of the arguments presented and the absence of them may need to be challenged.
- **Checklist Review of Programmes**: Here, as in other RGP reviews, are a list of questions/challenges around extended operation that relate to understanding the degradation mechanisms, the preventative or monitoring programmes in place, the corrective measures identified and the governance in place. These appear in a number of places and consolidation of the various questions into a single list would be beneficial.

> Reference A-114 reviews the ageing-degradation mechanisms of materials used in nuclear power plant SSCs, their relevant analysis and mitigation paths, and reactor-type specific plant life management (PLiM) practices. Obsolescence and other less obvious ageing-related aspects in nuclear power plant operation are also examined in depth. The book is broadly consistent with the information presented in SSG-48 and SSG-25; however, it does identify a few areas that not readily highlighted in the other nuclear related RGP reviews. This includes:

- **Importance of SSC Safety Classification**: The importance of the safety classification in determining breadth and extent of justification proportionate with the significance of the SSCs, is an integral part of any LTO or BDL process(es). It is worth highlighting this as part of any future guidance. However, an appropriate challenge to any BDL submission is whether the safety classification changes with time compared to the original design intent. In addition, this challenge should not only be limited to the SSC being considered, but also on other supporting systems if extended operation places further demands on them. While this specific aspect is not identified in this reference, it seems a logical challenge to make when considering the safety categorisation during extended operation.

- **Indirect Aspects of AM and LTO**: One of the elements that stands out in this book as being different, is the human element. The recognition around Safety Culture, Knowledge Management and human factors is not routinely covered in LTO discussions, as the focus tends to be more SSC or technology related issues. These elements would be covered by the PSR and in other countries an LTO submission, but not necessarily as part of an individual SSC BDL submission. As part of the BDL submission for certain SSCs, demonstrating how human aspects will be managed (including knowledge management or human factors) over the period of extended life could be a key part of the arguments presented and the absence of them may need to be challenged.

  Related to this subject (although not identified in this document) is the human aspects associated with performing EIMT tasks and the changes that may occur with time. Some tasks may become more difficult to perform or undertake due to changes in the environmental conditions. For instance, some inspections done visually may no longer be possible during extended operation due to increased dose or other environmental changes. To substantiate an SSC to operate BDL the review of EIMT should also consider if the tasks can feasibly be performed as intended or if new methods or approaches need consideration (e.g. greater use of robotics and imaging technology or wider use of instrumentation).

4.5 Summary of Nuclear Industry RGP Themes

Many of the themes and considerations identified mirrored those already identified by the review of the IAEA RGP. However, a number of additional items were identified and these are identified below. It should be noted that this list has been consolidated across all the documents in Appendix C and excludes items already identified in Section 3, it includes:

- Data Recording and Availability;
- Surveillance and Monitoring Programmes for TLAAs;
- Capabilities and Resources;
- Human Factors;
- LCM Self-Assessments;
- RIM Programme;
  - Ageing/Degradation of SSCs (RIM);
  - Identification of Reliability Targets (RIM);
  - RIM Strategies (Performance of Strategies);
  - RIM Strategies and Uncertainties;
  - RIM Implementation and Documentation;
  - Performance Monitoring and RIM Updates;
- SSC Safety Classification.

This list covers additional facets of Ageing Management and LTO requirements that that can be linked in numerous ways with the other items already identified. How these relate to BDL expectations and the current ONR guidance is presented in Section 5, which presents the combined list of these themes and considerations with those identified in Section 3.

5. Summary of Nuclear Industry Key Themes, Considerations and BDL Expectations

5.1 Key Themes and Considerations

The consolidated list of themes and considerations identified as a result of the review of the nuclear industry RGP is presented below:

- Ageing Management
  - Ageing Management Programmes
  - AMP Review
- Ageing/Degradation Mechanisms
- Asset Management
- Data Recording and Availability
- Decommissioning
- Design Life
- Design Stage Considerations
- Economic Optimisation
- EIMT
  - In-Service Inspection
  - Maintenance
  - Preventative/Predictive Maintenance
  - Refurbishment/Replacement
  - Surveillance and Monitoring Programmes for TLAAs
- Equipment Qualification
- General Framework for AM and LTO
- Human Factors
- Knowledge Management
  - Capabilities and Resources
- Licence Management
- Lifetime/Life-Cycle Management
  - LCM Self-Assessments
- LTO Engineering Process
- LTO Submissions or PSR to Demonstrate Safe Operation
  - Periodic Safety Reviews
- Modifications to existing Plant Programmes
- Obsolescence
- Operational Programmes
- OPEX
- Performance Management
- Pre-Conditions for LTO
- Regulatory Approach to LTO
  - Roles and Responsibilities for Operators and Regulators
- Regulatory Oversight
- Review and Update of Processes and Procedures for LTO
- Reviews/Revalidate TLAAs
- RIM Programme
  - Ageing/Degradation of SSCs
  - Identification of Reliability Targets
  - RIM Strategies (Performance of Strategies)
  - RIM Strategies and Uncertainties
  - RIM Implementation and Documentation
  - Performance Monitoring and RIM Updates
- Safety Management
- Scoping and Screening
- SSC Safety Classification
- System and Data Management

These themes relate to both the process and procedure level and the SSC level and in some instances both. For instance, there is a need to demonstrate that ageing management is being addressed (in line with Reference 2 - SSG-48) within an organisations processes and procedures, in addition, to justify operation beyond the original design life. The latter would require the output of the AMP for the specific SSC to form part of the substantiation. The demonstration of both these aspects of the theme will be assessed separately too; with the programme element largely being covered by the PSR, while the SSC aspect will be included in the BDL submission. The relationship between these elements is presented in Figure 3. This figure also outlines the relationship between asset and ageing management. Asset management provides the top-down requirements for the programmes and SSCs, while ageing management offers the range of programmes and approaches to management of SSCs to meet the defined operational requirements set by asset management.

Figure 3 also highlights (in simple terms) the relationship between a PSR and the BDL submission; with the PSR looking across all programmes (focussing on those related to Nuclear Safety and the scope of a PSR) and the global assessment of SSCs. While the BDL submission will only look at a specific SSC or subset of SSCs and the programmes that apply within the scope. The BDL submission will not necessarily look at the governance or oversight of the applicable programmes or the cumulative impact. Similarly, the PSR will not necessarily look at the detailed assessments and TLAAs for individual SSCs (with the exception of very specific SSCs). Recognising the links between these two methods to justify extended operation and the aspects that are dealt with in each can help determine where specific BDL expectations are placed.

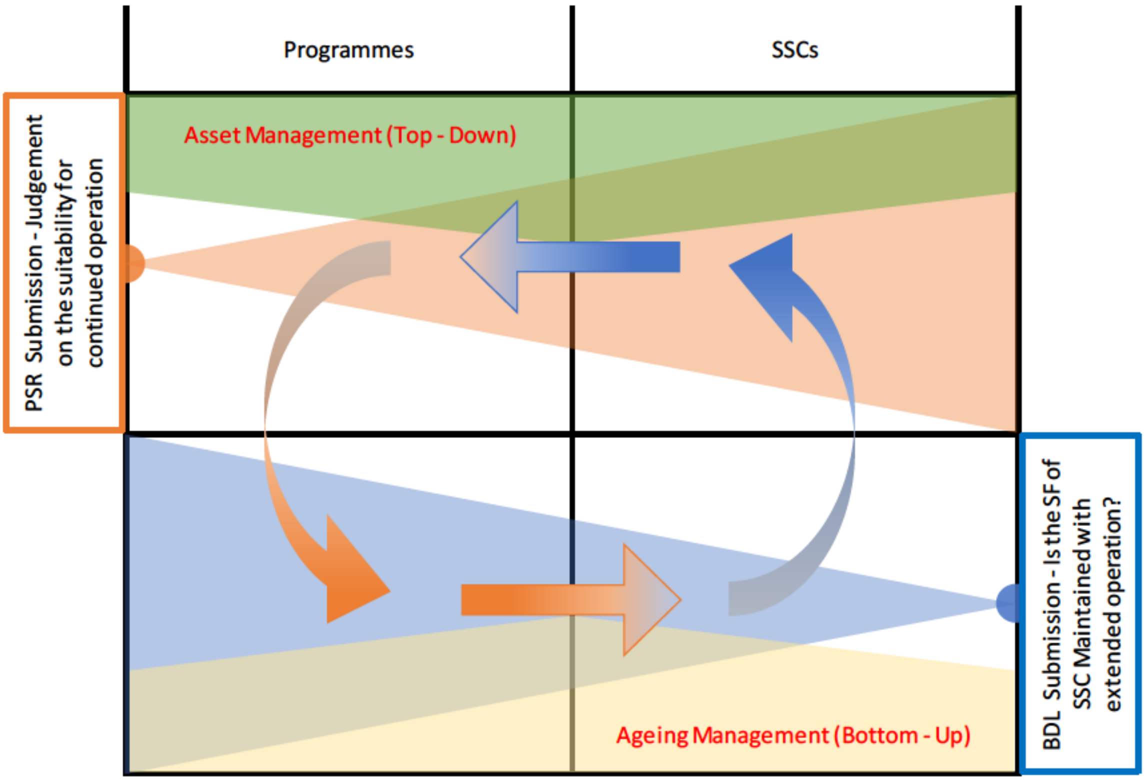


Figure 3 Relationship between PSR and BDL Submissions across Programmes and SSCs

Within all of the nuclear industry RGP reviewed use of the LTO submission and/or a PSR to demonstrate safe operation for an extended period, beyond the original design or licence period, largely brings all of the identified themes into a single assessment. These are all addressed as part of the development of the AMP for LTO, enhancement of existing processes and procedures for LTO or as part of the work to specifically support the LTO submission and/or PSR. However, to provide a framework for coordinating these activities and to group like items in a systematic way (whether programme or SSC related), it is proposed to present these in an adaptation of Deming's 'plan–do–check–act' cycle, similar to that used in ageing management. Reference 2 identifies two different views of this approach. The first, while considering programmes, is more SSC focused and is included in Figure 4 below. The second version, presented in Figure 5, is focussed on the development, implementation, review and improvement of AMPs. A combination of both of these figures would capture most of the themes identified above.

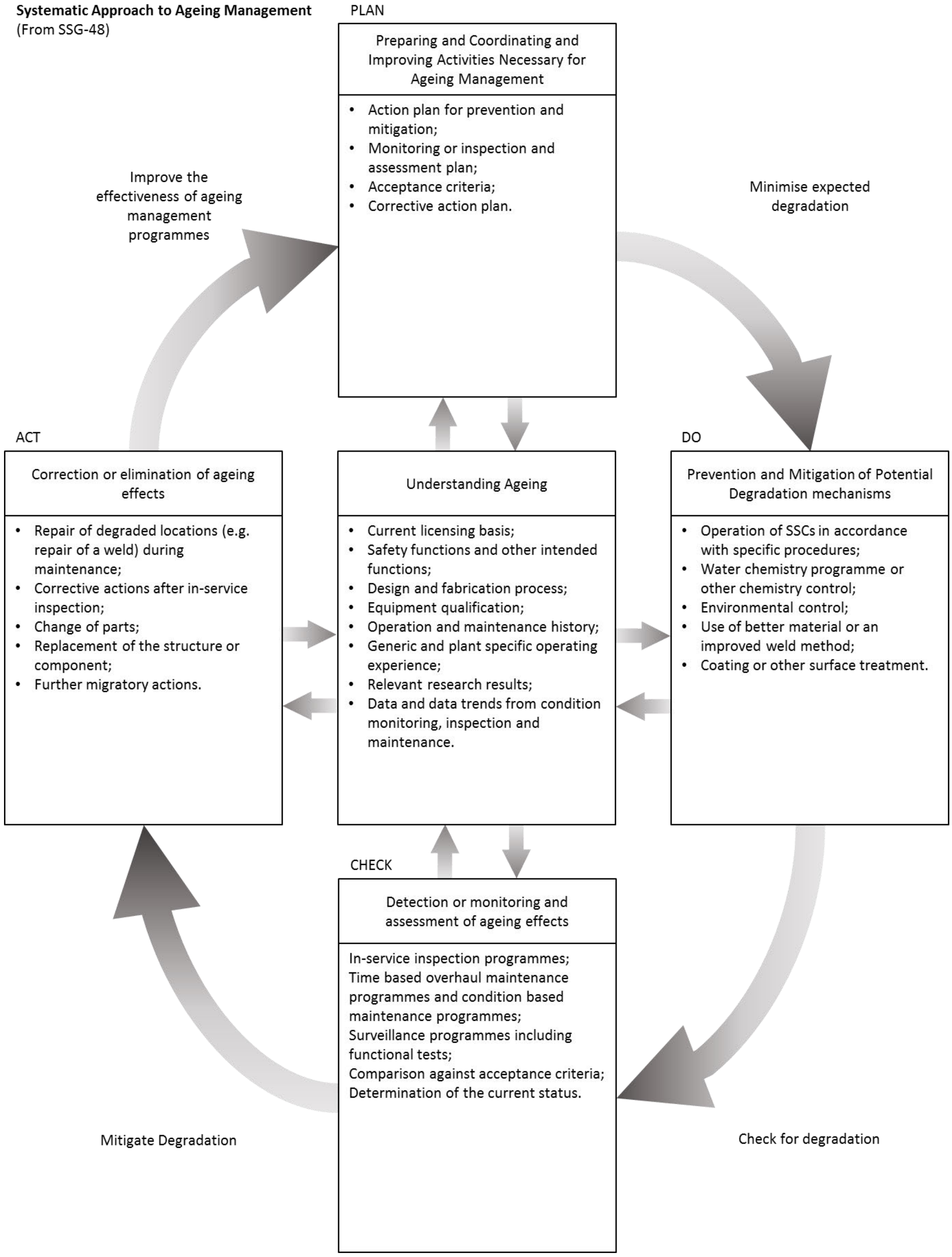


Figure 4 Systematic Approach to Ageing Management (from Reference 2)

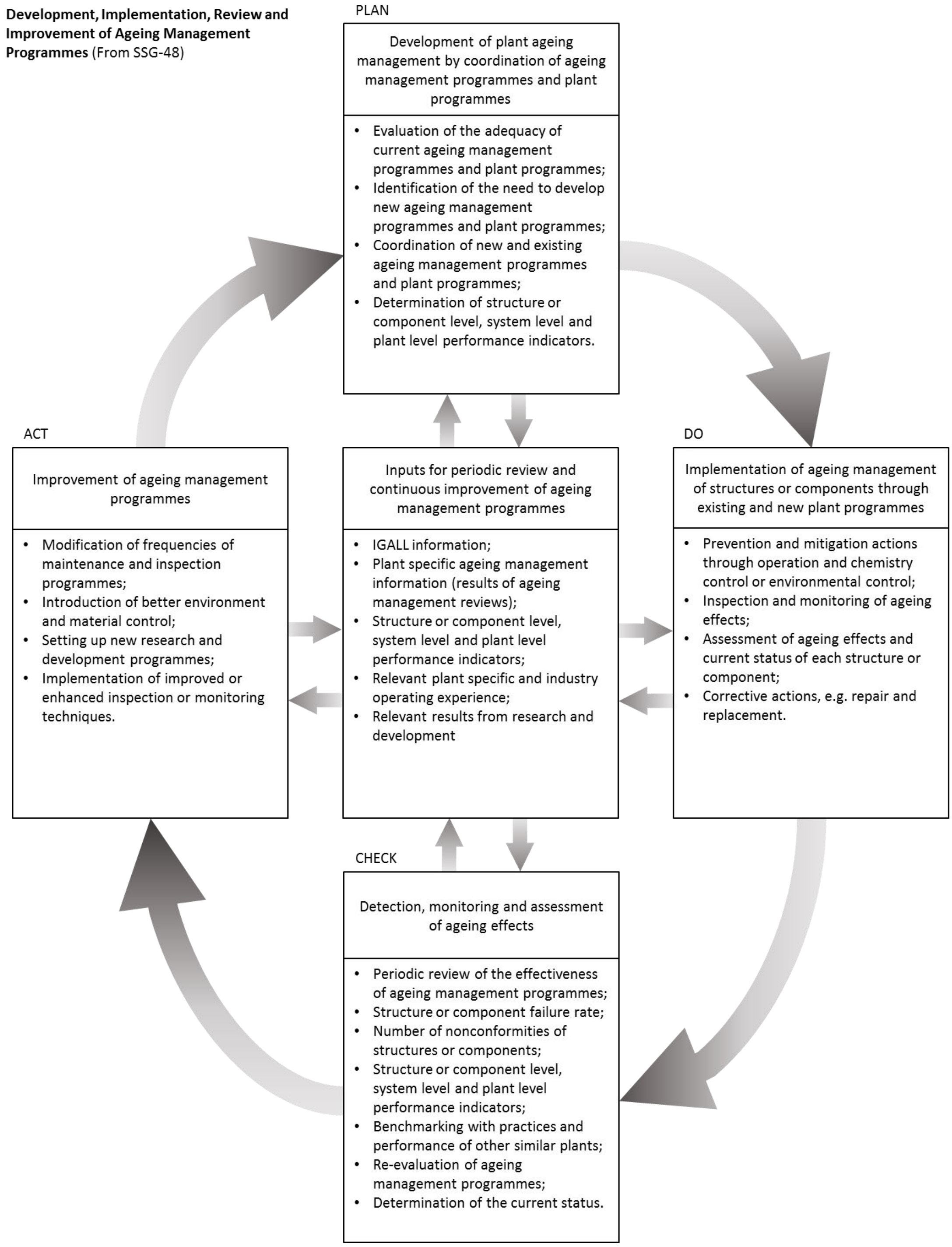


Figure 5 Development, Implementation, Review and Improvement of Ageing Management Programmes (from Reference 2)

The distribution of the identified themes and considerations in line with these figures is presented in Appendix E, which groups the themes against an appropriate heading from the Plan-Do-Check-Review cycle approach. It is appreciated that the grouping of themes against specific headings is subjective and a number of the themes could appear in multiple groups, depending on the aspect of the theme being considered. It should also be noted that in addition to the Understanding heading (which sits at the centre of each cycle) a further sub-heading labelled 'Other' was also added. This heading captures those themes not necessarily covered elsewhere, for instance 'Decommissioning'. Figures that show the split of themes against these headings are presented below, which as well as presenting a summary of the nuclear industry themes also includes the overview from the IAEA RGP and Other nuclear industry RGP.

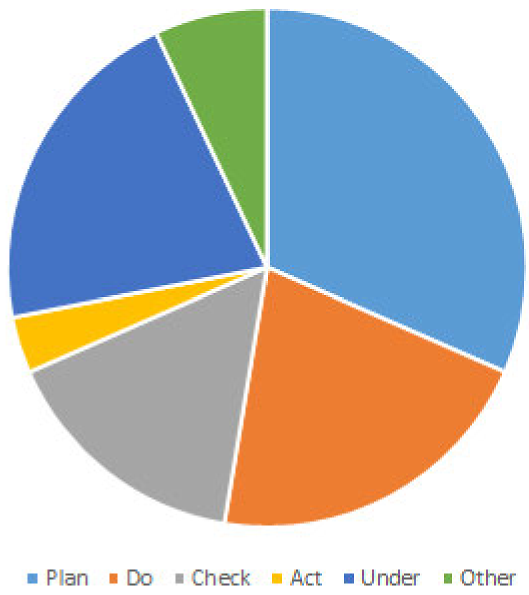


Figure 6 Summary of Themes for Nuclear Industry RGP

5.2 BDL Grouped Themes

The subsections below group identified BDL expectations according to the ‘Plan-Do-Check-Act’ cycle. Each subsection also provides examples of licensee processes under which each expectation could be addressed.

5.2.1 Plan

To undertake extended operation requires the identification and planning of the activities that will demonstrate continued safe operation and that operating SSCs beyond their original design life will not lead to the associated Safety Functions being degraded. In the context of Figure 4 and Figure 5 ‘Plan’ corresponds to coordinating, integrating and modifying existing programmes and activities relating to the ageing management of SSCs, and developing new programmes if necessary. The start of this process will be led by an organisation’s strategy to operate a facility longer than originally intended, the factors that influence this are beyond the scope of this task, although they may have some bearing on level of investment available. The key themes identified within this group include (in no particular order):

> **Ageing Management/Ageing Management Programme**: An AMP should be established to support extended operation, where SSCs exceed their original design life, if an AMP is already in place then a review should be undertaken to ensure the programme can support extended operation. (Also see Pre-Conditions for LTO.)

  To support the justification/substantiation of SSCs beyond the original design life a requirement to have an AMP in place for safety significant SSCs would be considered good practice. The AMPs should be suitably and sufficiently detailed to demonstrate the degradation mechanisms are understood and that there is appropriate management of the SSCs during the extended operation. If no AMP exists then generation of one to support the BDL submission would demonstrate a level of understanding around the SSC and ensure visibility of the information. Where an AMP may already exist then demonstration that the AMP is reviewed/updated to support the BDL submission or this is undertaken as part on-going operations could form an additional leg of the BDL justification.

A PSR will assess if the AMP meets with accepted expectations, including the governance of the programme and the links to other programmes within the facility. The PSR may also look in more detail at SSCs with high Nuclear Safety Significance, especially 'life-limiting' items. However, individual programmes for specific SSCs should be used to support individual BDL submissions and will be assessed on a case-by-case basis.

> **Asset Management/Economic Optimisation**: Asset Management and economic optimisation should inform the essential requirements that cascade down through an organisation, the policies, processes and programmes and define what objectives the extended operation should achieve. In addition, aspects of the strategy and the economic constraints will influence what may be considered reasonable and/or practicable and therefore form part of the ALARP justification underpinning certain decisions within the BDL submission.

Broader assessments around the asset management system and the tools in place to capture information and provide the governance will be assessed as part of the PSR, especially in aspects associated with Nuclear Safety. Some aspects may indirectly be evidenced in individual BDL submissions as part of the ALARP assessments.

> **Knowledge Management/Capabilities and Resources**: The strategic input for the requirements for these themes will be cascaded from asset management, linked with the extended operational requirements. In addition, the broader governance and adopted approach for these will be implemented through the organisation by the policies, processes, procedures and programmes put in place. It is also important to note that the longevity of some nuclear facilities, combined with niche requirements for certain skills, mean these themes should be considered throughout the whole life-cycle and not just extended operation.

The general aspects around governance and approach will be assessed as part of the PSR and specific aspects associated with a discreet SSCs should be captured within the BDL submission. Knowledge management may also need to consider analysis tool and techniques (for instance specific and/or historical computer codes).

> **Data Recording and Availability**: There are multiple aspects associated with data, data recording, storage and availability, these include:

- Original design and build data to support assessments;
- Operational history (including maintenance records) to enable trending and assessment or inspection/examination results to present actual condition of the plant;
- Date required to track degradation for a given SSC, historical and/or future data either for specific mechanisms or general degradation of the SSC;
- Data to support TLAAs and/or to demonstrate lifetime safety margins for extended operation.
- Data associated with the programmes in place, for instance Key Performance Indicators (KPIs) around performance of the SSC or associated programmes;
- With all of the points listed above availability and accessibility is important.

As with the previous themes, elements of these items will be assessed as part of the PSR or within the BDL submission for individual SSCs. The absence of historical data may have a significant impact on the level of effort required to substantiate extended operation.

> **Design Stage Considerations**: Considerations around LTO and the design stage has a number of aspects to it, such as design, material selection and ensuring the capability to extend the life if needed (for instance a 'plug and play' approach). There are also considerations relating to the original design stage for SSCs where operation is being extended, e.g. environmental requirements or the ability to refurbish or replace. Associated with this theme are the changes that occur through the life of the SSCs (planned or otherwise), which links to **Lifetime/Life-Cycle Management** of the SSC and the ability to extend life.

The oversight and governance of these considerations will be reviewed/assessed as part of the PSR. However, a significant part of what decisions/actions have occurred during and since the design stage will impact the level of effort to substantiate extended operation and the depth/detail of analysis required.

> **General Framework for AM and LTO**: The general framework for the management of ageing and extended operation should be visible in the management systems, through the policies, processes, procedures and programmes put in place. However, the general framework should also consider:

  - **Pre-Conditions for LTO**: Understanding the programmes to be established to underpin extended operation, which for many organisations may include programmes already in place at the facility. Where these do not already exist then consideration should be given to including the development and implementation of the programmes.
  - **Modifications to Existing Plant Programmes**: Existing plant programmes may already meet the requirements to support extended operation and provide the information needed to underpin the substantiation. This will include the existing **EIMT** programmes at the facility. However, other programmes may need to be modified or even established to support the process. Within the 'Plan' group the focus of this element is the review and identification of the plan programmes and the recommended changes to meet extended operation. The actual changes and implementation are undertaken under the 'Do' heading.
  - **Roles and Responsibilities for Operators and Regulators**: The roles and responsibilities should be identified within the management system and recognise the roles different parts of an organisation have in the process, including the regulator.
  - **RIM Programme**: Whether ASME related SSCs are subject to the RIM Programme will depend on the degree of implementation and adherence to the ASME codes and standards.
  - **Management Systems**: The management system within an organisation may already reflect and consider how **Safety Management**, **Human Factors** and **Performance Management** are addressed and implemented. However, there is a potential need to ensure that they are conducive to extended operation and do not have elements undermine or are undermined by operating beyond the original design live.

  In general, most of these items may be assessed to confirm fitness for purpose for extended operation as part of the PSR and may have limited visibility within the BDL submission. Depending on the timing, it may be appropriate for the PSR to be the vehicle by which these are assessed to identify changes/improvements to meet extended operation; rather than using the PSR to confirm adequacy of the changes made.

Many of the themes and consideration within the planning group are about ensuring an organisation has the policies, processes, procedures and programmes in place that support extended operation, from providing the right information to make informed decisions through to providing the evidence to support the justification. How these elements are adopted and deployed in a facility will vary depending on the complexity of the facility and the potential risks posed, whatever proportionate approach implemented by a facility it needs to ensure that (with a degree of confidence) extended operation will not compromise safety.

5.2.2 Do

The 'Do' element involves preventing and mitigating expected ageing effects and degradation mechanisms of SSCs and is the implementation of ageing management of structures or components through existing and new plant programmes. In terms of the BDL process this activity relates to the commencement of those programmes or changes identified in the planning stage. Some of the key themes identified include:

> **Equipment Qualification**: Equipment qualification establishes that equipment, while being subject to environmental conditions, is capable of performing its intended safety function or that it will be replaced or repaired so that its intended design functions will not be compromised during the planned period of extended operation. The justification to extend operation for single SSCs will be presented in the BDL

submission for the plant item, which should include updated or amended Equipment Qualification. The assessments should include assumptions around the period of the extension (e.g. time-period, number of cycles, etc.) and any changes to EIMT or operations to support the extension.

It is also important to consider if extended operation changes the claims for specific safety functions due to the development of new ageing and degradation mechanisms (or mechanism not evidenced during the original design life). The changes may lead to SSCs requiring further qualification or potentially the introduction of additional lines of protection (redundancy or diversity).

The EQ programme as a whole should be considered as part of the PSR and it may be used to define a list of areas that would be affected by the extended operation. While the BDL submission will include the assessments for individual SSCs.

> **LTO Engineering Process**: This activity is undertaking the engineering processes that are taken as part of the initial phase of preparing for extended operation and would include **Scoping and Screening**, the modification of existing plant programmes, identification of TLAAs and implementation of the new plant programmes for extended operation. This activity would also incorporate the **Review and Update of Processes and Procedures for LTO**.

Under the current regulatory arrangements these activities may be identified as a result of a PSR or independent assessment on the fitness of plant programmes to support extended operation and the review/assessment of the changes may not occur until the next PSR. At the point of a BDL submission the programmes that are applicable to individual SSCs could be considered and their fitness judged, but this may not always be obvious. However, there should be a demonstration that the programmes in place (including new programmes) are effective.

> **Operational Programmes**: The operational programmes relate to the performance of the EIMT programmes including (but not limited to):

- In-Service Inspection (ISI) Practices for Passive Components;
- Maintenance Codes or Practices for Active Components;
- Component Functional Tests;
- Applied Diagnostic Systems (including load monitoring systems);
- Surveillance Programmes;
- Non-Destructive Testing and Materials Properties Testing;
- Destructive Tests and Material Research carried out during operation;
- Chemical Regimes and Monitoring.

This element is the performance of these activities up to and during extended operation. Some of these programmes may have been amended or introduced to reflect specific requirements of BDL Operation. It should also be noted that the programmes may not be specific to an SSC but relate to the location and/or environment of the SSC (for instance via zonal walkdowns or leak management programmes).

The BDL submission for specific SSCs will contain the expectations for these programmes and in some cases may include the results of them to support the justification for extended operation. The governance and oversight for operational programmes will be assessed as part of the PSR.

> **Reviews and Revalidation of TLAAs**: Where TLAAs exist for specific SSCs these will require review to determine if they can support extended operation or if a revalidation exercise is required. For some SSC the original TLAAs may have included pessimistic or optimistic assumptions that have not been realised during actual operation. In these instances, justification for extended operation may simply be to demonstrate the original analysis remains valid for the proposed period of extended operation. However, this will not always be the case and in some instances assumption that were included will no longer be valid; as a result, the TLAAs will need to be revalidated and in some cases may even need to be redone from scratch.

As with many of the elements identified here the governance and oversight of TLAAs should be assessed via the PSR, which may even include a list of TLAAs across a facility monitoring variation of the PSR review period and expectations for the coming period. Individual TLAAs for specific SSCs should be incorporated into the BDL submission to justify the extended operation.

> **RIM Implementation and Documentation**: Similar to above, this activity is the 'doing' aspects of the RIM Programme including the implementation and **undertaking the RIM Strategies** for the applicable ASME SSCs. As noted previously, these activities are not specific to extended operation, but the documentation to support implementation and the evidence collected in undertaking the strategies for specific SSCs will likely inform the BDL submission.

As with many of the elements identified here the governance and oversight of the RIM Programme (if applicable) should be assessed via the PSR. Individual RIM Programmes for specific SSCs should be incorporated into the BDL submission to justify the extended operation.

The themes identified here are largely the performance or undertaking of those programmes that to some extent already exist within a facility. What is different is the drivers for undertaking the activities and how the information is used. The need for changes, whether it is the modification to existing programmes or the addition of others will largely depend of the nature and duration of extended operation and the level of justification required to extend beyond the original life of an SSC. How these elements are adopted and deployed in a facility will also vary depending on the complexity of the facility and the potential risks posed, whatever proportionate approach is implemented by a facility it needs to ensure that (with a degree of confidence) extended operation will not compromise safety.

One of the key elements identified above relates to the **Scoping and Screening** of SSCs as this will, in part, determine the extent to which existing programmes are amended or new programmes established. The identification of those items that are required to operate beyond the original design life of the SSC will vary from facility to facility and be influenced by a number of different factors. However, ultimately the selected SSCs will be those items that cannot technically or economically be replaced or refurbished and failure of the item would lead to nuclear safety and/or operational effectiveness being compromised. The robustness of the justification and number of legs to the arguments presented will be a function of the nuclear safety significance of the SSC or the novelty of the item. Many of the scoping activities identified within the RGP identify that the typically SSCs should include:

> SSCs important to safety that are necessary to fulfil the fundamental safety functions;

> Other SSCs whose failure may prevent SSCs important to safety from fulfilling their intended functions;

> Other SSCs that are credited in the safety analyses (deterministic and probabilistic) as performing the function of coping with certain types of event, consistent with national regulatory requirements.

And may exclude SSCs that are:

> Subject to periodic replacement or to a scheduled refurbishment plan on the basis of predefined rules;

> Not required by national regulatory requirements to be included in the scope.

The points listed above are derived from NPP experiences and the requirements for scoping and screening at other facilities may need to consider other factors to ensure that the outcome is proportionate, suitable and sufficient. The Safety Classification of an SSC is discussed further in Section 5.2.5.

5.2.3 Check

The themes highlighted against the 'Check' group should in some respects already be in place as part of a continuous learning culture and form an essential element of the governance and oversight to the programmes in place to justify and support extended operation. At the heart of this group of themes the activities involve the timely detection and characterisation of significant ageing effects and degradation mechanisms through the inspection and monitoring of the SSCs. This is achieved through the assessment of collected data using available tools and trending techniques to monitor the SSCs performance or degradation. In addition, this group is about monitoring the effectiveness of the programmes in place, bring together the elements identified in Figure 4 and Figure 5. The sort of activities this may include are

> **AMP Review**: Reviews of the effectiveness of the AMPs in place for an SSC need to be considered at the outset of the programmes. This is to ensure that the programmes remain valid and take on board new OPEX that becomes available from a variety of sources, such as:

- Internal or External OPEX – Newly observed degradation mechanisms, identified internally or externally;
- R&D Programmes – Research and Development projects from internal or external sources.

The AMP Reviews and the assessment of the effectiveness of them should be undertaken at a frequency to enable meaningful change to minimise the impact of the new information.

> **EIMT**: The effectiveness of the EIMT in place for SSCs should be reviewed at an appropriate frequency and based on the evidence presented in the performance of the routines. Key to this is the quality of the data recorded and the monitoring or trending tools and techniques available. In addition, the ability for some routines to introduce errors with time and increase the likelihood of failure needs to be considered, along with the ability to undertake certain tasks during extended operation (for instance due to increasing dose). The assessment of effectiveness should trend the results of the **In-Service Inspections**, **Preventative/Predictive Maintenance** and the **Surveillance and Monitoring Programmes** in place to justify or support extended operation.

> **LCM Self-Assessment**: In understanding the initial gaps and requirements for extended operation the use of self-assessments is an approach advocated in a number of areas and not just for Life-Cycle Management (LCM). Revisiting and redoing the self-assessments are a reasonable approach to review the progress of the implementation and the effectiveness of the programmes established.

> **Periodic Safety Reviews**: The PSRs by its nature is a review of the governance and effectiveness of all relevant programmes in place; in addition, it provides an indication of the actual condition of SSC and demonstrates suitability for continued operation over a defined timeframe into the future (often up to the next PSR typically 10 years).

> **Performance Monitoring and RIM Updates**: Within the RIM Programme it identifies the need to monitor the performance of the programmes and undertake updates to the RIM Strategies for SSCs if and when required.

> **Reviews/Revalidate TLAAs**: TLAAs will be undertaken to substantiate extended operations for applicable SSCs; however, these assessments should periodically be reviewed during extended operation to demonstrate continued compliance with the assumptions used and that safety functions will not be undermined. The reviews maybe undertaken at fixed intervals, on a rolling programme to align with EIMT activities or following an event or other OPEX that potentially alters initial assumptions.

Evidence of these reviews and subsequent changes may or may not be part of the BDL submission; however, the effectiveness of the programmes (including the governance and oversight) should be assessed as part of the PSR.

5.2.4 Act

This group is largely focussed on the activities undertaken on an SSC, it involves the timely correction of ageing effects on structures and components and the introduction of further preventive or mitigatory actions through appropriate maintenance and design modifications, including the repair and replacement of structures and components. As such the key themes identified include:

> **Maintenance**: In the groups identified previously the 'maintenance' element has been focussed on the review and optimisation of maintenance programmes for LTO and the governance to ensure that

appropriate decisions are taken in a timely manner to maintain the safety characteristics within allowable ranges. However, this aspect of the Maintenance theme is about performing the right maintenance at the right time by the right people with the right tools. In order to achieve this element then resources, capabilities, tools and training need consideration; in addition, up front planning may also be required. As part of the BDL submission consideration around the approach to corrective measures may be required, especially if novel or complex solutions are required.

> **Refurbishment/Replacement**: In many instances SSCs will require justification to operate beyond the original design life as refurbishment or replacement may not be possible. However, for complex SSCs refurbishment or replacement of constituent parts or sub-components may be possible. Similar to above, the BDL submission should include consideration around the approach to refurbishment or replacement, especially if novel or complex solutions are required. This may should also consider the potential for obsolescence.

  Alternatively, the refurbishment/replacement programme can only be completed over an extended time period that may result in some SSC having to operate beyond the original life until the programme is complete. Under these circumstances the approach to the justification/substantiation for the SSCs will need to reflect the requirements of the programme and the risks associated with it.

The evidence for the programmatical elements will largely be assessed as part of a PSR, with the findings and impact of work undertaken being incorporated into the BDL submission. This may include the trending of any results, information around the actual condition of the SSCs (historical and current) or any changes to maintenance practices to reflect ageing plant, changes in the environment and the development of new maintenance techniques. The BDL submission should also consider the approach to corrective measures, in the event that maintenance reveals hidden or accelerated ageing and degradation mechanisms.

5.2.5 Understanding

Understanding the ageing of SSCs is the key to effective ageing management and key part of any arguments presented to extend the life of an SSC beyond the original design life. However, there are also broader aspects of demonstrating continued safe operation around the requirements for managing safety, capabilities and resources and interactions with the regulator that need to be understood to ensure suitable and sufficient programmes and processes are being established. As such the themes within this 'Understanding' group are focussed on understanding the SSCs, the applicable ageing and degradation mechanisms and the wider requirements that support and substantiate extended operation. Therefore, some of the key themes identified include:

> **Ageing/Degradation Mechanisms of SSCs**: The understanding of applicable mechanisms that arise from the materials used for the SSCs, the operational and environmental demands placed on them historically and in the future. Understanding the codes and standards used in the original **Design Life** assessments and any assumptions that were in the analysis. This understanding will be enhanced by the appropriate use of **OPEX** or Research and Development.

> **SSC Safety Classification**: Understanding the safety classification of the SSC and the criteria used to determine the classification will ensure that the justification for extended operation is suitable and sufficient and proportionately robust for the SSC.

> **System and Data Management**: The collection of data, such as performance monitoring, condition monitoring or examinations, performing assessments of data either trending or updating analysis/models and interpreting these to underpin BDL submissions and on-going monitoring needs to be understood. This will ensure that the interfaces between the various steps are identified and that information is passed on in the correct format.

> **Capabilities and Resources**: The capabilities and resources to support extended operation may change the requirements within an organisation. The impact for doing activities more frequently or differently (for instance increasing inspection frequencies and/or using remote inspection techniques including robotics)

may alter the skill sets and numbers of personnel. Understanding these, upfront, and presenting them in the BDL submission can provide additional confidence in BDL operations.

> **Periodic Safety Reviews**: Understanding the role a PSR can play in supporting extended operation in presenting evidence that suitable and sufficient programmes and processes are in place is important. This may lead to changes to PSR scope to support BDL submissions. The timing of the PSR relative to the BDL submission also needs to be understood, as potential gaps may need to be filled in the BDL submission if a significant lag occurs.

> **Regulatory Interactions**: The interactions with regulators such as ONR, EA or SEPA and other bodies, such as the NDA, or internal regulatory support, such as independent nuclear safety committees, also need to be understood and appropriately planned. In some instances, the submissions may involve complex or novel/new processes as part of justification for extended operation that need suitable time to ensure robust and appropriate challenge.

Within the ASME RIM Process (Reference A-006) there are a couple aspects that require understanding of the SSC, its safety and performance targets, and the strategies employed to maintain the reliability and integrity of the SSC. While the RIM Process will not be applicable to all SSCs, the intent of the process identifies some good practice that would enhance submissions to extend the life of an SSC beyond the original design intent. The areas identified include:

> **Identification of Reliability Targets**: The process identifies that the PSA should be used to derive the reliability targets for the applicable SSCs and that the RIM strategies will be used to ensure that the Reliability Targets are met. Understanding what these targets are and where significant contributors are to this target will inform what can be done as part of extended operation. It should be noted that across the documentation review some recognition of the role the PSA has in supporting justification for extended operation was identified and updates to the PSA should consider the effects of ageing when determining the reliability targets.

> **RIM Strategies and Uncertainties**: A key step in the RIM process is the evaluation of uncertainties and in particular the uncertainties associated with predicting SSC reliability performance. This also includes uncertainties within the measuring and monitoring techniques used by the RIM strategies. The process notes that the uncertainties should be identified and in some cases specific RIM strategies may be added to address these uncertainties and these should be documented.

As previously noted an important part of justifying extended operation is understanding the SSCs, the applicable ageing and degradation mechanisms and the programmes and processes being put in place to mitigate or minimise the ageing and degradation effects. The majority of the themes identified above should be evidenced in the BDL submission or supporting safety case. As with many of the other groups above, the programmatical aspects associated with these themes should be covered by the scope of the PSR.

5.2.6 Other

In using the groups outlined above a number of themes were identified that did not necessarily fit under these headings. These have therefore been grouped under the heading of 'Other'. This includes:

> **Decommissioning**: Extending the life of a facility will potentially have an impact on the decommissioning strategy, whether through the creation of additional waste or items having a greater dose than originally planned. In other parts of the world, the LTO submissions includes an assessment of the global impact of extending the life of a facility and is presented in the submission to the regulator; in addition, this is generally outside of the PSR process. While individual BDL submissions may address the specifics of decommissioning for applicable SSCs, it is not clear where or how the global review is captured. In addition, with multiple agencies potentially interested in this global assessment (e.g. ONR, NDA, EA, etc.) then some consideration should be given for the approach to be taken.

> **Obsolescence**: Obsolescence can have multiple aspects associated with extending the operational life of a facility. For instance, extended programmes to address obsolescence may result in some SSCs operating

beyond the original design life. Alternatively, extending the life of a facility may lead to the obsolescence of SSCs during extended operation, this is often the case for C&I equipment that may be used/claimed for performance or environmental monitoring. The BDL submission should consider the potential for obsolescence as part of the process and also inform many of the groups above, (notably 'Understanding' and 'Plan').

- **Regulatory Approach to LTO**: The approach taken by a regulator for extended operation and whether an **LTO Submissions or PSR to Demonstrate Safe Operation** are used as the vehicle for regulatory approval is raised in a number of the documents reviewed. Whatever the approach taken is, it is important that guidance is provided to ensure that operators and regulators understand the approach to be adopted.

In addition to the themes noted above a couple of other themes were identified that will not be carried forward as part of this task. These are presented below for completion and include:

- **Early approaches to AM or LTO superseded or evolved into SSG-48**: Over the years the approaches to Ageing Management and LTO have evolved, coming together in IAEA SSG-48 (Reference 2). Many of the documents reviewed presented early iterations or variations of them that have been superseded by SSG-48. Some of these earlier approaches may have informed the processes deployed by an organisation on AM or LTO and should be reviewed/assessed as part of the PSR process to ensure the adopted approach meets current standards (i.e. SSG-48).
- **Indirect Aspects of AM and LTO**: A number of the themes above identify aspects of extended operation not directly associated with the SSCs and associated assessments/justification for operating beyond the original design life. These relate to wider programmes and processes such as resources and capabilities, human factors or Knowledge Management. However, there were other items related to the organisation and culture that should also be considered when looking to extend the life of a facility. Many of these would not directly be covered by the BDL submission and may be captured, indirectly, as part of the PSR.

Another item identified of note, not explicitly captured elsewhere relates to security improvements. Reference A-102 discusses improvements made in Safety and Security, which crosses over with the SyAPs and whether extended operation of a facility would also lead to security improvements as a result of reviews of 'modern' codes and standards (and where this might be captured).

5.2.7 Summary of BDL Themes

By grouping the themes against an appropriate heading from the Plan-Do-Check-Review cycle approach it is possible to consider when these themes may be considered and where they may be assessed (i.e. as part of the PSR or within a BDL submission, as indicated in Figure 3). Each of the quadrants in Figure 3 represent different aspects associated with extended operation and can be simplified as:

- **A –** Programmes assessed as part of the PSR;
- **B –** Global assessment of SSCs assessed as part of the PSR;
- **C –** Programmatical elements associated with the SSCs assessed as part of the BDL submission;
- **D –** Justification for SSCs extended operation within the BDL submission.

Figure 7 below is an amended version of the previous figure that shows the relationship between PSR and BDL submissions across programmes and SSCs, which includes the A to D labels.

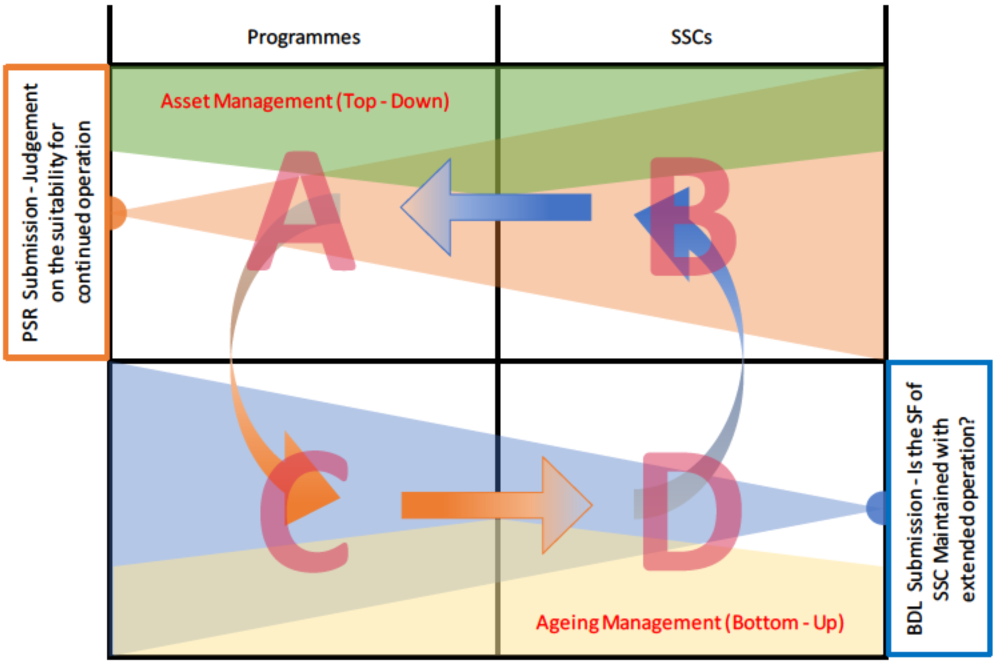


Figure 7 Figure 3 Including Assessment Group Labels

For each of the themes it is possible to assign them in to one or more of the quadrants. This is in some cases subjective, but has been based on the interpretation of the themes identified in the previous sections and the authors experience gained working in this area for many years. A list of the themes and which labels are applicable is presented in Table 1 and is summarised in Figure 8.

Table 1 BDL Themes against each Assessment Group

Nuclear Industry Key Themes	A	B	C	D
> Ageing Management	Yes			
▪ Ageing Management Programmes			Yes	
▪ AMP Review		Yes		
> Ageing/Degradation Mechanisms				Yes
> Asset Management	Yes			
> Data Recording and Availability	Yes			
> Decommissioning		Yes		Yes
> Design Life				Yes
> Design Stage Considerations			Yes	
> Economic Optimisation	Yes			
> EIMT	Yes		Yes	
▪ In-Service Inspection		Yes		Yes
▪ Maintenance				Yes
▪ Preventative/Predictive Maintenance		Yes		Yes
▪ Refurbishment/Replacement				Yes
▪ Surveillance and Monitoring Programmes for TLAAs		Yes		Yes
> Equipment Qualification				Yes
> General Framework for AM and LTO	Yes			

Nuclear Industry Key Themes	A	B	C	D
> Human factors	Yes			
> Knowledge Management	Yes			
▪ Capabilities and Resources		Yes	Yes	
> Licence Management	Yes			
> Lifetime/Life-Cycle Management	Yes			
▪ LCM Self-Assessments			Yes	
> LTO Engineering Process			Yes	
> LTO Submissions or PSR to Demonstrate Safe Operation	Yes			
▪ Periodic Safety Reviews	Yes	Yes		
> Modifications to existing Plant Programmes	Yes		Yes	
> Obsolescence				Yes
> Operational Programmes			Yes	
> OPEX			Yes	
> Performance Management			Yes	
> Pre-Conditions for LTO	Yes			
> Regulatory Approach to LTO	Yes			
▪ Roles and Responsibilities for Operators and Regulators	Yes			
> Regulatory Oversight	Yes			
> Review and Update of Processes and Procedures for LTO			Yes	
> Reviews/Revalidate TLAAs				Yes
> RIM Programme	Yes			
▪ Ageing/Degradation of SSCs				Yes
▪ Identification of Reliability Targets				Yes
▪ RIM Strategies (Performance of Strategies)			Yes	
▪ RIM Strategies and Uncertainties				Yes
▪ RIM Implementation and Documentation			Yes	
▪ Performance Monitoring and RIM Updates		Yes		
> Safety Management	Yes			
> Scoping and Screening			Yes	
> SSC Safety Classification			Yes	
> System and Data Management	Yes			

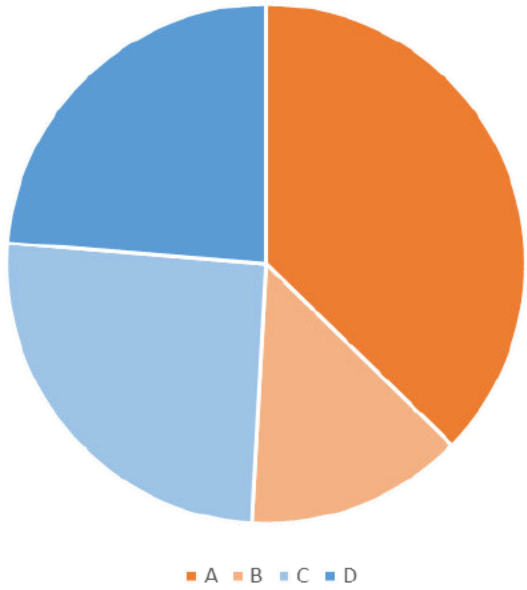


Figure 8 BDL Themes against each Assessment Group

From Table 1 and Figure 8 it can be seen that there is a (roughly) equal split between those themes that might be assessed as part of the PSR Process (A and B) and those elements that are covered by the BDL submission (C and D). Given the scope of this overall task is focused on the BDL submission it is the BDL expectations that should be captured. The scope of this task is not necessarily to review or update the PSR requirements in this area; however, these identified themes will be presented, along with the recommendation that these are considered when PSR Guidance is updated in the future.

5.3 BDL Expectations

Based on the information presented in the sections above a list of expectations that should be considered within a submission to extend the life of an SSC beyond the original design life includes the items listed in Table 2. This table also indicates if the theme should be considered programmatically, for instance a holistic review of EIMT requirements for the specific SSCs. In addition, the table also indicates whether programmatical and governance aspects should also be captured as part of the PSR assessments; for instance, global changes to processes and procedures to support extended operation and not just those specific to the SSCs.

Table 2 Identified Themes to be considered in a BDL Submission

NI BDL Submission	C	D	PSR
> Ageing Management Programmes	Yes		
> Ageing/Degradation Mechanisms		Yes	
> Ageing/Degradation of SSCs		Yes	
> Capabilities and Resources	Yes		Yes
> Decommissioning		Yes	Yes
> Design Life		Yes	
> Design Stage Considerations	Yes		
> EIMT	Yes		Yes
> Equipment Qualification		Yes	
> Identification of Reliability Targets		Yes	

> In-Service Inspection		Yes	Yes
> LCM Self-Assessments	Yes		
> LTO Engineering Process	Yes		
> Maintenance		Yes	
> Modifications to existing Plant Programmes	Yes		Yes
> Obsolescence		Yes	
> Operational Programmes	Yes		
> OPEX	Yes		
> Performance Management	Yes		
> Preventative/Predictive Maintenance		Yes	Yes
> Refurbishment/Replacement		Yes	
> Review and Update of Processes and Procedures for LTO	Yes		Yes
> Reviews/Revalidate TLAAs		Yes	
> RIM Implementation and Documentation	Yes		
> RIM Strategies (Performance of Strategies)	Yes		
> RIM Strategies and Uncertainties		Yes	
> Scoping and Screening	Yes		
> SSC Safety Classification	Yes		
> Surveillance and Monitoring Programmes for TLAAs		Yes	Yes
Totals	**15**	**14**	**8**

The corresponding list of items to be considered by the PSR Assessment is summarised in Table 3 below.

Table 3 Identified Themes to be considered as Part of the PSR Assessment

NI PSR Assessment	**A**	**B**	**BDL**
> Ageing Management	Yes		
> AMP Review		Yes	
> Asset Management	Yes		
> Capabilities and Resources		Yes	Yes
> Data Recording and Availability	Yes		
> Decommissioning		Yes	Yes
> Economic Optimisation	Yes		
> EIMT	Yes		Yes
> General Framework for AM and LTO	Yes		
> Human factors	Yes		
> In-Service Inspection		Yes	Yes
> Knowledge Management	Yes		
> Licence Management	Yes		
> Lifetime/Life-Cycle Management	Yes		
> LTO Engineering Process			Yes
> LTO Submissions or PSR to Demonstrate Safe Operation	Yes		
> Modifications to existing Plant Programmes	Yes		Yes
> Obsolescence	Yes		Yes
> Performance Monitoring and RIM Updates		Yes	
> Periodic Safety Reviews	Yes	Yes	

NI PSR Assessment	A	B	BDL
> Pre-Conditions for LTO	Yes		
> Preventative/Predictive Maintenance		Yes	Yes
> Regulatory Approach to LTO	Yes		
> Regulatory Oversight	Yes		
> Review and Update of Processes and Procedures for LTO	Yes		Yes
> RIM Programme	Yes		
> Roles and Responsibilities for Operators and Regulators	Yes		
> Safety Management	Yes		
> Surveillance and Monitoring Programmes for TLAAs		Yes	Yes
> System and Data Management	Yes		
Totals	**22**	**8**	**10**

Both of these lists are discussed further in Section 7 and Section 8.

6. Review of Other High-Hazard Industries RGP

To enable a benchmarking exercise to be undertaken, searches for documents relating to the issues around extended operation and BDL expectations was widened to consider other high-hazard industries. The objective of this was to identify themes and considerations and learning from experience that is similar in nature to the BDL expectations developed in Section 5. In addition, it was recognised that by extending the search criteria outside of the nuclear industry that items could be identified that are applicable to the nuclear industry and worthy of inclusion within the final list of BDL expectations. The initial searches identified a significant number of potential documents, but while most might be considered 'Relevant', it was not always clear if the documents reviewed represented acknowledged RGP. Therefore, the starting point was to review documents that were produced by (or in association with) the UK Health and Safety Executive (HSE).

The HSE documents cover a range of industries, such as Oil and Gas, Nuclear Chemical Facilities, and industries that have equipment containing hazardous fluids or pressure. High-level reviews of the identified documents, particularly relating to Oil and Gas, indicated that the HSE had worked in partnership with the Petroleum Safety Authority – Norway. As a result, further searches of Petroleum Safety Authority – Norway documents were carried out around the topics of life extension and BDL operation. Searches against these two key sources identified a total of twenty documents, all of which have been included (and are highlighted) in Appendix A.

Similar to the nuclear industry RGP, at the start of the Phase 2 task, the list of documents needed to be limited to a manageable number. Based on the anticipated applicability (from the high-level review undertaken in Phase 1) and size of the RGP, the list was focused on those documents perceived as being the most relevant or adding the most value. However, this led to a very limited list of documents due to the nature and scope of the high-hazard industry RGP. As a result, an additional search was undertaken looking at other industries, this search identified some additional documents related to the aviation industry and these are identified in Appendix A.

The output from the review of individual RGP from other high-hazard industries is presented in Appendix D. Like the nuclear industry RGP, the identified documents broadly fall into one of two categories, these include:

- Process related documents that focus on Ageing and Life Extension (ALE) or equivalent Ageing and/or extended operation processes;
- SSC related documents that look at various (common) SSCs, the observed degradation mechanisms and some potential strategies to tackle these.

A consolidated summary of the key themes and considerations from Appendix D is presented below.

6.1 Summary of HSE RGP

6.1.1 Beyond lifetime criteria for offshore cranes

The first HSE document reviewed was Reference A-032 and dates back to 2002 and looks at the beyond lifetime criteria for offshore cranes. The report presents a review of regulatory requirements (as of 2002) and best practice to enable checklists to be produced to assist HSE (OSD) inspectors when reviewing/auditing a duty holder's safety case justifying the continued operation of a pedestal crane once it has gone beyond its design life. The approach considered the contents of the duty holder's crane safety case submission, and how they would be affected by BDL issues. This guide is divided into two main parts;

1) The front sections of the document that discuss, in general terms, the various issues affecting operation beyond the design life of cranes, and;
2) The checklists contained in the Appendices that could be used as part of an audit specific to BDL issues.

The report identifies that information such as the original design specifications, operating history, incident records, history of modification, inspection and maintenance records or fault analysis should be assessed in order to determine the current condition of the crane. The document notes that all the relevant life limiting mechanisms must be assessed such that a greater operating life may be justified. In addition, the assessment should look at the reviews of the operations and categorisation of cranes, splitting the safety significance of each into 3 categories, including:

1) Major safety significance;
2) Minor safety significance;
3) No safety significance.

Reference A-032 notes that a review of the routine lifting operations of each crane should be presented which establishes the safety significance of each crane and its suitability for routine use for the duration of the proposed life extension validity period. In addition, the document identifies that part of the assessment for considering using a crane beyond its design life, the original codes, testing standards, etc., specified at the time of crane manufacture should be reviewed. This is to ascertain there were no shortcomings during the original supply of the crane.

A-032 identifies that the maintenance and operating history of the crane must be presented and be examined in order to identify potential ageing and degradation mechanisms. It notes that physical ageing leads to a reduction in the safety margins of the crane and should be counteracted by a regime of detection, monitoring and mitigation to ensure that safety margins are not eroded to the extent that there is an increased risk to Health and Safety. In addition, procedures addressing how the operating and maintenance risks will be eliminated or adequately controlled are required.

A-032 also considers the human factor criteria for operating beyond the cranes design life. It states that there are 3 significant areas which may arise from the BDL phase.

- **Area 1 –** The first of these areas is where, as part of the justification for beyond lifetime extension, the operating limits (envelope) for the crane have been changed from those in operation prior to the lifetime extension. This would give rise to a number of concerns:
  - There must be clear communication/warnings detailing of the changed operating limits for the crane, particularly for operators who have used the particular crane before and may have expectations based on the previous operating limits;
  - Where a particular crane will be used as part of a not normally manned installation, the risk of an operator attempting to operate the crane outside of its new operating limits is likely to be increased due to lack of familiarity and infrequency of use.
- **Area 2 –** The second area where care needs to be taken is where a modification is made to the crane to allow continued operation beyond lifetime. It notes that communication of the modification status needs to be carefully managed to ensure that all maintainers and operators are aware of the modification and that all documentation is in place where it is required to support changed maintenance or operating procedures.
- **Area 3 –** Finally, there is the consideration of the effects of increased frequency of revealed and unrevealed faults which will be associated with the crane operation in the wear out phase. As the frequency of faults associated with the crane increases (even though they may not be critical), this may have an effect on the operator perception of a ‘tolerable’ level of background faults. Against this increased background ‘noise’ of faults, occasional critical faults may be missed. Similarly, there may be faults occurring that would not normally be seen by the maintainers and operators, and which they do not have the requisite experience to recognise or deal with.

The document incorporates much of the discussion around the subjects covered above, as the basis for a checklist for the HSE Inspectors, which contains the following topics:

1) Policy/Objectives;
2) Design, Manufacture and Testing;
3) Management Procedures and Controls;
4) Operating and Maintenance History;
5) Structural and Mechanical Integrity;
6) Protection against Dropped Loads.

6.1.2 Ageing and Life Extension (ALE) for Oil and Gas Installations

A number of documents identified in Appendix D relate to guidance on the management of Aging and Life Extension (ALE) in relation to all structures, topside plant and equipment associated with offshore production installations on the UK Continental Shelf (UKCS). The first of these (Reference A-034) was designed to inform duty holders, involved in the management of asset life cycles, about management systems in respects to asset ageing and life extension factors. The document, which is aligned to the Safety Management System Model, cover aspects of ALE as they relate to Policy, Organising, Planning and Implementation, Measuring Performance, Reviewing Performance and Auditing (that can be linked to any topics previously identified). Each of these are discussed in the points below.

- **Policy**: The document notes that in common with other aspects of reasonable and prudent ownership; sound management of Ageing and Life Extension issues is largely shaped by effective leadership, which should be expressed in the duty holder's HSE policy and management system. The extent to which senior managers drive company efforts in these key areas, significantly influences successful implementation of ALE related activities. Areas such as ownership and accountability, commitment and engagement, business strategy and management systems are discussed further in A-034.
- **Organising**: This section considers organisational factors, such as training and competence, communication, contact strategy and staff turnover and succession planning. It is notable that this element is highlighted so early in the approach being presented and reflects the importance given to these aspects in the success of ALE.
- **Planning and Implementation**: One of the first points raised in this section of the document is that duty holders should have management systems in place that have attributes similar to Safety Management System Model outlined initially. Existing systems and processes should be reviewed, and the duty holder should look to address any shortfalls in the systems and ensure that any ALE factors are included where necessary. The section provides guidance on the development and implementation of practical arrangements for the management of ageing and life extension. It covers a number of aspects that the duty holders need to take account for in order to ensure that ALE features appropriately in the management systems. The section then goes onto highlight areas to be considered such as design and procurement, Management of Change, operational controls, inspection, test and maintenance regimes, information management, acquisition and divestment, safety case, obsolescence and decommissioning.
- **Measuring Performance**: The guide gives some examples which will provide reasonable assurance that there is compliance with ALE management arrangements and that the arrangements continue to be effective in practice.
- **Reviewing Performance**: The review should provide an overview of ALE management processes and identify areas of improvement and raise senior management's awareness of ALE issues and challenges.
- **Auditing**: Audits should be implemented as part of an internal assurance process. Such audits could be used to; assess compliance with ALE management processes, assess third parties who could influence ALE (suppliers etc.), and assess internal management processes by an external party.

The document also noted that Action Management Systems should also be in place. These systems should be used to track any corrective or improvement actions arising from the monitoring, audits and reviews to ensure that the activities are recorded, documented and tracked to closure. In addition, ALE related lessons learned from assurance activities or from incidents should be captured and communicated within the duty holder organisation and across the wider industry as necessary.

A further document on ALE Programmes is presented in Reference A-035. The report presents inspection findings of the HSE's Energy Division's (ED's) Key Programme 4 (KP4) covering ALE challenges facing hydrocarbon exploration and production installations on the UKCS. The programme investigated the impact of ALE on the risk of major accidents involving the death or serious personal injury to people on an offshore installation. The report notes that the KP4 programme found a range of areas where ALE management was developing well, and areas where extra focus is required. Examples of KP4 findings:

- Some Safety Critical Elements (SCE)/Safety Related Equipment (SRE) lists and engineering drawings needed updating;
- More focus is required on forecasting potential failure mechanisms;
- Not enough ALE consideration at the component level;
- Evidence of missing data and insufficient data trending;
- Audits were generally to follow previous rather than addressing future needs;
- Insufficient use of data for forecasting equipment failure.

The document notes that management of ageing requires a good understanding of the condition of safety critical elements (SCEs), how that condition is changing over time, and carrying out maintenance in a timely manner to minimise risk of major accidents. A-035 notes that there is evidence that installation age is not necessarily a reliable indicator of condition or likelihood of hydrocarbon leak frequency. Management of life extension requires the advanced, and continuing, assessment of SCEs to ensure they are fit for purpose, and safe to use when required to operate longer than their anticipated service, with particular consideration for primary structures.

6.1.3 Management of Equipment Containing Hazardous Fluids or Pressure

A number of the HSE documents identified relate to the management of plant ageing for equipment containing hazardous fluids or pressure, the key document identified relating to this is included in Reference A-038. The purpose of this report was to increase awareness of the factors to consider when managing equipment containing hazardous fluids or pressure, and to help those responsible for the equipment to understand and assess the risks of accumulated damage and deterioration. The information presented was at a general rather than an equipment-specific level, so that it could be applied to a wide range of static equipment and associated machinery. A-038 identifies that the management of equipment begins with an awareness that ageing is not about how old the equipment is, but is about what is known about its condition, and the factors that influence the onset, evolution and mitigation of its degradation. Once the symptoms of ageing are understood, and detected from inspection, a decision can be made how to proceed. The options can include putting together a case to justify continued service, re-rating, repair, or scrapping the equipment. A-038 contains the following 4 sections:

- Awareness of Ageing;
- Getting Organised for Managing Ageing;
- Identification of Ageing;
- Addressing Ageing.

Also included in this document are four appendices:

- Process Map and Audit Tool;
- Case Studies;

> General Approach to Inspection and a Process Map;

> Capabilities and Limitations of Various NDT Methods.

The Process Map and Audit Tool presented in Appendix 1 of A-38 provides a simple approach to some key aspects of ageing management, which are covered in more detail in Appendix D. This figure is presented below and links a series of questions/challenges regarding ageing management in a logical series of steps from high-level policy and culture to detailed aspects for individual equipment. While this figure may not be directly applicable to civil nuclear plants, there is merit in considering something like this for other nuclear facilities. The range of nuclear facilities in the UK includes sites where the consequences of equipment failure of hazardous fluids or pressure are as significant (if not more so) as a failure of nuclear related equipment. Even for the civil nuclear plants the intent of the steps is applicable and also reflects the Safety Management System Model outlined in Section 6.1.2.

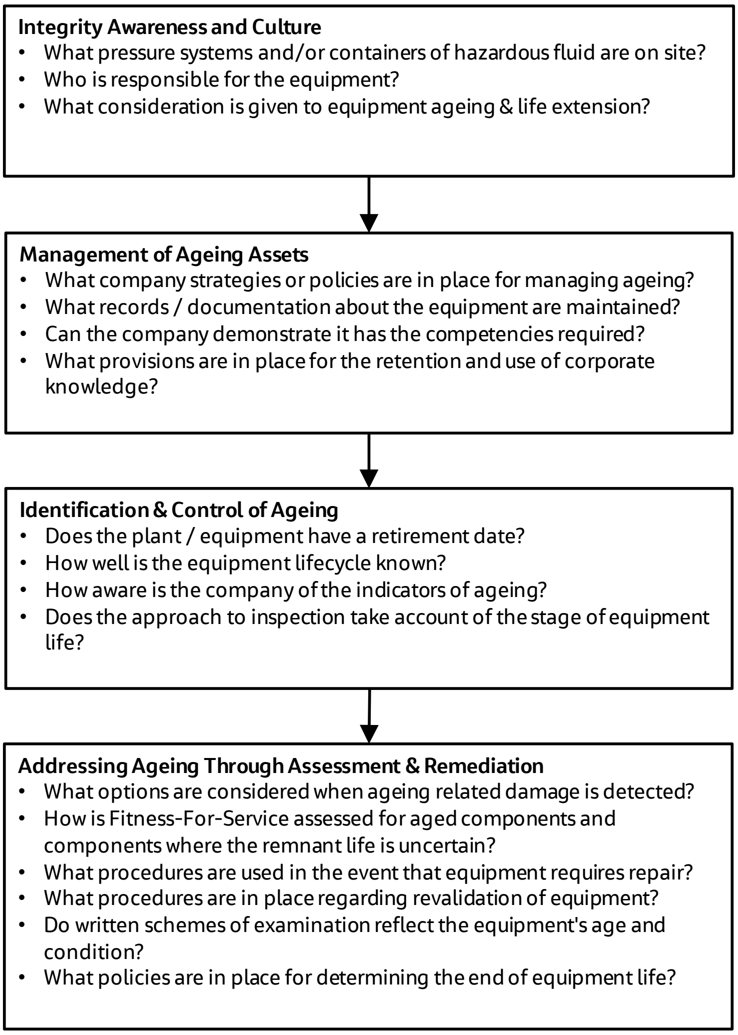


Figure 9 Process Map and Audit Tool presented in Appendix 1 of A-038

It should be noted that there are direct links between this report and A-040 (HSE RR912, Management of Ageing – A Framework for Nuclear Chemical Facilities), where it is stated that these two documents should be cross-referenced. In addition, A-033 is associated with this document, it relates to the mechanical integrity of plant containing hazardous substances and references A-038.

A-033, although not directly linked to plant ageing or extended operation, provides a guide to periodic examination and testing. The document was developed and written by the Safety Assessment Federation (SAFed) and the Engineering Equipment and Materials Users' Association (EEMUA) in consultation with the Health and Safety Executive's (HSE) Hazardous Installations Directorate, together with other interested stakeholders who use such plant, including operators, inspection bodies (including 'competent persons') and providers of specialist services to the process. The aim of the document was to provide guidance on managing the mechanical integrity of such equipment. This is a matter for the whole lifecycle, from original specification and design, through its operation to decommissioning and focuses on the issue of ensuring integrity through periodic examination and testing. The document, which is summarised in Appendix D, notes that rates of deterioration should be determined to substantiate that the equipment will remain safe to operate until the next inspection. Trending of deterioration following several inspections should be carried out (e.g. corrosion rates, crack growth rates) as this data can then be utilised to assist in the prediction of end of life when repairs/replacement of equipment will be necessary. A-033 also identifies that as part of an integrity management system it is necessary for the operator to keep accurate, timely records, this ensures that decisions about the specific integrity of an individual piece of equipment can be easily traced and justified. This publication considers the types of internal assessments and audits required to substantiate a BDL claim. The examples within this publication direct the organisation through the Written Scheme of Examination (WSE) requirements via the integrity assessment and provides a good list of what should be included in an assessment.

6.1.4 Plant Ageing and Management of Ageing for On-Shore Chemical or Nuclear Chemical Facilities

Two significant bodies of work were identified in Phase 1 relating to chemical and nuclear chemical facilities within the UK. The documents presented the findings of two HSE research tasks identified in references A-039 and A-040. The first of these is a Phase 1 Report of a Plant Ageing Study (HSE RR823). A-039 states that on-shore chemical plant in the UK is ageing and the HSE field inspectors often have to consider an Operators' safety justification for continued use of ageing plant taking account of a variety of issues such as usage, design life, known research, known operational and failure history, maintenance and inspection history, etc. The issues also need to be considered against a background of increasing competition from overseas, and the pressure on resources and investment which this has had over recent years, with reductions in manning levels, early retirement of experienced staff, and pressure on operating budgets. At the heart of the task the objective is to try to answer the fundamental question '*is plant ageing really a problem?*'; to address this question a review of OPEX is presented using data from various sources.

Throughout the document various questions and/or challenges are raised as a result of the reviews. A-039 summarises these ageing related questions and groups them against areas such as Primary Containment Systems, Management System, Civil Structures and Safeguards. Overall, the document concludes that, plant ageing does constitute a threat to health and safety performance of hazardous installations onshore in the UK. Within the uncertainties of the review conducted a reasonable statement to describe the size of the issue is "60% of incidents are Technical Integrity issues and 50% of those are associated with ageing of one type or another". Aside from the scale of the problem highlighting the significance of this type of work, the questions and challenges identified represent a reasonable starting point for a checklist of things to consider when reviewing justification for extended operation.

Reference A-40 (HSE RR912, Management of ageing – A framework for nuclear chemical facilities) focuses on the competencies and processes required to proactively manage ageing in nuclear chemical facilities. The report identifies that rather than being a prescriptive set of rules, it was intended as a hands-on resource, describing what is required to effectively manage ageing within the wider context of asset management. The ONR commissioned the report to examine the procedures and practices necessary to identify and assess ageing within the overarching asset management processes of the British Standard Publicly Available Specification for Asset Management (PAS 55), this has since been withdrawn (2015) and replaced with an ISO 55000 family of documents. This report collates information on good practices for the management of ageing that Site Licence Companies (SLCs) across the nuclear industry could use to achieve their strategic objectives. ONR site inspectors would also find it helpful when making statutory inspections.

A-040 identifies a number of 'Good Practices' associated with ageing management and effective implementation. In the assessment of BDL justification ensuring an effective AMP exists will provide confidence that the ageing and degradation mechanisms are understood and that appropriate prevention, mitigation and monitoring is in place for the extended period of operation. As such, questions and/or challenges around these items are a reasonable starting point for a checklist of things to consider when reviewing justification for extended operation. A-040 also includes the Process Map and Audit Tool outlined in Figure 8 (originally presented in Appendix 1 of A-038). The document provides a brief commentary on each of the questions in Figure 6 and link to the main body of the report. In addition, it notes that it has been designed for duty holders to use to stimulate, develop and audit their processes and procedures. A-040 also identifies that this may be useful to regulatory inspectors too, when assessing the management of ageing.

6.2 Summary of Aviation RGP

As previously noted, within the scoping stage of this Phase 2 activity an additional search was undertaken looking at other industries, this search identified some additional documents centred around the aviation industry. A suite of documents was identified that were prepared by the Ageing Aircraft Programmes Working Group for the UK MOD, the documents relate to:

- A Framework for Ageing Aircraft Audits (Reference A-134);
- Guidance on the Conduct of Aircraft Zonal Hazard Analysis (ZHA) (Reference A-135);
- Understanding the Corrosion Threat to Ageing Aircraft (Reference A-136);
- Continuing Airworthiness Management its Contribution to Identifying Evidence of Ageing in Aircraft (Reference A-137).

In addition to these documents, a Military Aviation Authority (MAA) Regulatory Article (RA) was identified that related an Ageing Aircraft Audit (AAA), (RA 5723). This Military Aviation Authority (MAA) Regulatory Article identifies that the risk to airworthiness due to the ageing of aircraft in service is partly mitigated by Integrity Management in accordance with RA 5720, RA 5721 and RA 5722. However, the insidious nature of degradation and the interaction of apparently unrelated ageing processes are often found only by an additional rigorous periodic audit of trend data, procedures and the aircraft's physical condition. This whole process is known as an Ageing Aircraft Audit and it is achieved by observing the regulation and guidance in this Regulatory Article.

The UK MOD policy for ageing aircraft centres round carrying out an Ageing Aircraft Audit (AAA) 15 years after a type's In-Service Date (ISD) or at the mid-point between the declared ISD and the initial planned Out of Service Date (OSD) whichever is soonest. Repeat audits should be conducted at 10 year intervals thereafter. However, it is recognised that ageing is a progressive process that commences from manufacture and an in-service programme of monitoring ageing would be advantageous. The responsibilities of both a Type Airworthiness Authority (TAA) and a Continuing Airworthiness Management Organisation (CAMO) include data collection and associated analysis, functions which are recognised as essential tools in identifying potential ageing in aircraft.

An AAA provides assurance that the Structural Integrity, System Integrity and Propulsion Integrity, and hence the airworthiness risks, of a fleet's aircraft are being managed appropriately from the perspective of ageing. Therefore, the aims of AAA are to:

1) Conduct a periodic, independent assessment of the Airworthiness management of the fleet, with consideration to ageing;
2) Consider individually and collectively the SI (Structural Integrity), SysI (System Integrity) and PI (Propulsion Integrity) activities, often carried out in isolation, to assess the effectiveness of the fleet's Integrity Management;
3) Undertake an independent review of the continued applicability of procedures, management processes, assumptions and documentation that are in place to ensure Airworthiness, integrity and functionality;

4) Undertake a detailed, independent condition survey of representative Air System from the fleet, unless an equivalent examination is conducted routinely;

5) Identify patterns or trends that suggest future Airworthiness or integrity issues;

6) Identify significant risks to the Airworthiness or integrity of the Air System that would threaten the achievement of its planned OSD (Out of Service Date).

Where MOD aircraft fleets are required to operate significantly beyond their originally certified life, the airworthiness of the fleet can be underwritten by a Life Extension Programme (LEP) as detailed in RA 5724 (not included in Appendix A as identified late on in this phase of the project, as such included as Reference 3). Reference 3 notes that the requirement to extend the certified life of any UK military aircraft type, in any parameter, shall be identified to the Type Airworthiness Authority (TAA). A LEP should be undertaken when it is identified that an aircraft type needs to be extended beyond its current certified life measured in any applicable lifing parameter (such as calendar time, flying hours, Fatigue Index (FI), landings or pressure cycles). The scope of the LEP should be determined by the TAA using a risk-based approach: all structure, systems components and propulsion components whose failure could compromise airworthiness should be identified and considered for inclusion within the LEP.

Reference 3 also identifies that AAA have been carried out on MOD fleets since the early 1990s. Initially, these audits were focussed solely on structural issues but the remit of the audit has since been widened to include systems and propulsion aspects. The content of the AAA has evolved considerably since its inception and hence it is likely that there will be a marked variation in the approach taken and the information available from an AAA, depending upon when it was completed and what aspects were included within the audit. Nevertheless, an AAA has potential to provide much valuable information in support of a LEP in both LEP component categorisation and in assembling evidence to support the life extension.

The similarities between these processes and those outlined in Reference 2 associated with Ageing Management and LTO show a high degree of commonality.

6.3 Summary of Other High-Hazard Industry RGP Themes

The consolidated list of themes and considerations identified as a result of the review of the RGP from other high-hazard industries includes:

- Ageing and Life Extension
  - Self-Assessments for ALE
- Ageing Management
- Ageing/Degradation Mechanisms
  - Corrosion
  - Definition of Ageing
  - Non-Metallic Materials
  - Pipelines
- Asset Integrity Management
- Change, Audit and Review
- Data Management and Trending
  - Record Keeping
- Databases
- Decommissioning
- Economic Optimisation
- EIMT
- Mechanical Integrity
- Monitoring, Audit and Review
- Obsolescence
  - Obsolescence Management
- Operational Programmes
- OPEX
- Organisational Factors
- Planning and Implementation
- Plant Ageing Questionnaires and Checklists
- Process Integrity
- Revalidation
- Safeguards
- Safety Cases and Reviews
- Safety Management Systems
- Scoping and Screening
- Self-Assessments for Other AM or Life Extension Type Tasks

- Examination Policy
- Fire and Explosion
- Human Factors
- Integrity Assessment
- Integrity Management
- Knowledge Management
- Skills, Training and Competence
- Strategy
- Structural Integrity
- Structures
- Workforce Involvement

Similar to the nuclear industry information, to provide a framework for coordinating these activities and to group like items in a systematic way, it is proposed to present these in an adaptation of Deming's 'plan–do–check–act' cycle similar to that used in ageing management. The distribution of the identified themes and considerations in line with Figure 4 and Figure 5 is presented in Appendix E, which groups the themes against an appropriate heading from the Plan-Do-Check-Review cycle approach. Again, similar to the nuclear industry themes, in addition to the Understanding heading, a further sub-heading labelled 'Other' was added. This heading captures those themes not necessarily covered elsewhere, for instance 'Decommissioning'. Figure 9 shows the split of themes against these headings and is presented below.

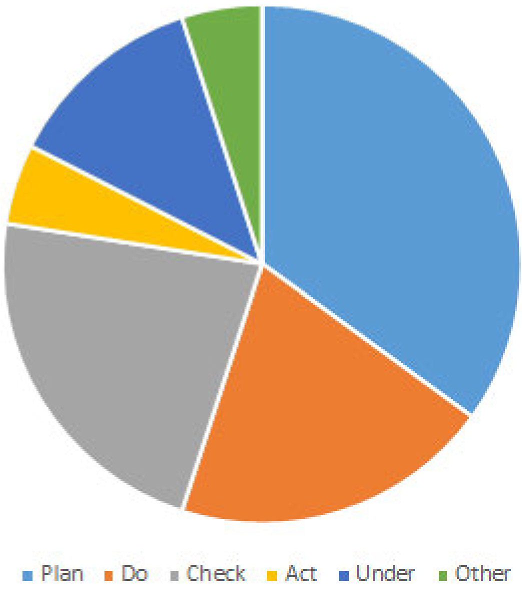


Figure 10 Summary of Themes in Other High-Hazard RGP

7. Summary of BDL Expectations Benchmarking

One of the key purposes of reviewing RGP from other high-hazard industries was to perform a benchmarking exercise through comparison of the key themes between those identified from the nuclear industry. The comparison, in addition to demonstrating consistency across different industries, also provides an opportunity to identify themes or considerations not currently included in the list of BDL expectations.

Table 4 provides a side-by-side comparison of the key themes identified from the reviews of the nuclear industry and other high-hazard industries RGP, identifying items that are the same (or similar), as well as those items within the high-hazard reviews not covered in nuclear industry (or to the same extent). The items mirrored across the reviews are indicated in **Red**, while the additional high-hazard themes not included in the nuclear industry RGP are indicated in **Blue**.

Table 4 Comparison of Nuclear Industry Themes with Other High-Hazard Industry Themes

Nuclear industry	Other High-Hazard Industries
> **Ageing Management** ▪ Ageing Management Programmes ▪ AMP Review > **Ageing/Degradation Mechanisms** > Asset Management > **Data Recording and Availability** > **Decommissioning** > Design Life > Design Stage Considerations > **Economic Optimisation** > **EIMT** ▪ **In-Service Inspection** ▪ **Maintenance** ▪ **Preventative/Predictive Maintenance** ▪ **Refurbishment/Replacement** ▪ **Surveillance and Monitoring Programmes for TLAAs** > Equipment Qualification > General Framework for AM and LTO > **Human Factors** > **Knowledge Management** ▪ **Capabilities and Resources** > Licence Management > Lifetime/Life-Cycle Management ▪ **LCM Self-Assessments** > LTO Engineering Process	> Ageing and Life Extension ▪ **Self-Assessments for ALE** > **Ageing Management** > **Ageing/Degradation Mechanisms** ▪ **Corrosion** ▪ **Definition of Ageing** ▪ **Non-Metallic Materials** ▪ **Pipelines** > Asset Integrity Management > Change, Audit and Review > **Data Management and Trending** ▪ **Record Keeping** > **Databases** > **Decommissioning** > **Economic Optimisation** > **EIMT** > **Examination Policy** > Fire and Explosion > **Human Factors** > Integrity Assessment > Integrity Management > **Knowledge Management** > Mechanical Integrity > Monitoring, Audit and Review > **Obsolescence** ▪ **Obsolescence Management**

Table 4 Comparison of Nuclear Industry Themes with Other High-Hazard Industry Themes

Nuclear industry	Other High-Hazard Industries
> LTO Submissions or PSR to Demonstrate Safe Operation ▪ Periodic Safety Reviews > Modifications to existing Plant Programmes > **Obsolescence** > **Operational Programmes** > **OPEX** > Performance Management > Pre-Conditions for LTO > Regulatory Approach to LTO ▪ Roles and Responsibilities for Operators and Regulators > Regulatory Oversight > Review and Update of Processes and Procedures for LTO > Reviews/Revalidate TLAAs > RIM Programme ▪ Ageing/Degradation of SSCs ▪ Identification of Reliability Targets ▪ RIM Strategies ▪ RIM Strategies and Uncertainties ▪ RIM Implementation and Documentation ▪ Performance Monitoring and RIM Updates > **Safety Management** > **Scoping and Screening** > SSC Safety Classification > System and Data Management	> **Operational Programmes** > **OPEX** > **Organisational Factors** > **Planning and Implementation** > **Plant Ageing Questionnaires and Checklists** > Process Integrity > Revalidation > Safeguards > **Safety Cases and Reviews** > **Safety Management Systems** > **Scoping and Screening** > **Self-Assessments for Other AM or Life Extension Type Tasks** > **Skills, Training and Competence** > **Strategy** > Structural Integrity > Structures > **Workforce Involvement**

Items that appear in both lists are focussed around key aspects of Ageing Management, understanding of the SSC and the impact extending the life will have. The key areas include:

- Understanding the safety significance of the SSC and associated ageing and degradation mechanisms;
- Ensuring that appropriate programmes and processes are in place to manage ageing and degradation;
- EIMT programmes are able to determine actual condition of the SSCs with a degree of confidence;
- Appropriate and applicable data is used to demonstrate Safety Functions will be met through the extended period of operation and beyond;
- Ensuring suitable and sufficient infrastructure (including capabilities and resources) is in place to meet extended operation;

> Demonstrating extended operation will not undermine decommissioning activities or that it will create disproportionate levels of waste, (including any potential environmental impact);

> The use of OPEX to support and/or inform all of the areas identified above.

The areas noted above are common, to some extent, across all of the documents reviewed irrespective of the industry the documents originate from. These items are also captured within the ONR Safety Assessment Principles (SAPs) presented in Reference 4. As noted in Phase 1 of this task (Reference 1) the ONR SAPs, Technical Assessment Guides (TAGs) and Technical Inspection Guides (TIGs) reflect items that support BDL; however, the interfaces between specific principles for BDL are not always evident or minor amendments could be made to capture BDL considerations. In addition, some principles could have broader applicability over and above the specific discipline the principles are currently linked with; for instance, some principles currently assigned to the civil and structural related SAPs could also be applied to mechanical SSCs when considering BDL actions.

Overall, the benchmarking exercise demonstrates broad alignment between the themes identified by the review of nuclear industry RGP compared with RGP from other high-hazard industries. However, there were a small number of themes identified during the review of other high-hazard industries RGP that were either not included in the themes identified from the nuclear industry RGP review or items that were broadly similar but the differences may add value if considered with the nuclear industry themes. The items identified include:

> **Data Management and Trending**: Reference A-035 identifies that '*information should be complete, and exploited to manage future risk, with data trending being used to forecast future potentially unsafe conditions*.' While trending is sometimes covered in the Nuclear RGP the importance of ensuring information is complete and that this is exploited for trending is not always highlighted. Specific performance monitoring activities may be used for some (types of) SSCs; however, corrective and routine maintenance data could be exploited more to give indication/confidence on the actual condition of the plant and future performance.

> **Obsolescence Management**: Across a number of the high-hazard documents there are recommendations to develop obsolescence management, which is also common in applicable nuclear industry RGP. The distinction is that in addition to developing an obsolescence programmes there is also a requirement for duty holders to improve data trend analysis of equipment performance so that future repair and replacement requirements can be identified and resolved early. For long-term safety management the RGP identifies that the organisations should:

- Identify and manage obsolescence in a timely manner;
- Work together to improve prediction and develop solutions;
- Use data trending to improve equipment performance prediction.

The greater use of data to predict future performance and closer co-operation across an industry are key aspects over the overall obsolescence management identified in nuclear industry documents

> **Organisational Factors**: Outside of the scope of this task organisational factors and expectations on the (nuclear) safety culture are significant subjects widely covered across a range of RGP. The difference in the high-hazard RGP is that issues around **Skills, Training and Competence**, staff turnover and succession planning are incorporated into the considerations for life extension. **Workforce Involvement**, through engagement and communication is a key part of the considerations for extended operation that recognises that current and future skills shortages, need to be resolved to deliver current and future upgrade projects. In addition, it is noted that for long-term safety management the industry should continue to use the skills of the workers to gather information, feedback improvements, contribute to guidance, and to promote the importance of life extension. The importance of these softer issues, not necessarily related to the SSCs, can have a significant impact on the quality of data or information used to underpin performance and provide confidence in operation beyond the original design life of the SSC.

> **Plant Ageing Questionnaires and Checklists**: Within the nuclear industry RGP most of the documents reviewed (if not all) relate to Civil NPPs and there is little information that might apply to nuclear facilities other than NPPs. However, the other high-hazard industry RGP cover a range of facilities and as such includes a variety of approaches to operating beyond the original design life of the plant. This includes the use of self-assessments, questionnaires and checklists. The examples identified focus on different aspects of Ageing Management or Life Extension Type process, including (but not limited to):
>
> - Understanding the significance of the SSCs and associated ageing and degradation mechanisms;
> - Identification of the skills, competencies and resources to maintain the SSCs;
> - Availability and accessibility of SSC information, e.g. from the Original Equipment Manufacturer (OEM);
> - Determining the actual condition of SSC;
> - Identification of potential obsolescence issues.
>
> Given that the level of effort to substantiate for extended operation should be commensurate with the consequences of failure. The development of self-assessments, questionnaires or checklists should be considered for non-NPP facilities; as such, enabling a proportionate approach to be developed that reflects the level of risks posed by the facility extending operation.

These aspects (and the themes they originate from) will be added to the list of themes and expectations identified in Section 5.3. The distribution of the consolidated list against the review type is presented in Figure 11, below, and Figure 12 presents the distribution of the consolidated list against the 'Plan-Do-Check-Act' groups.

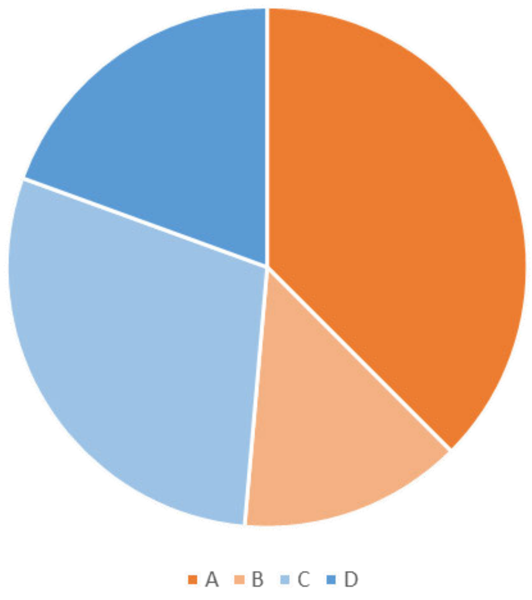


Figure 11 Summary of Consolidated List of Themes against Review Group

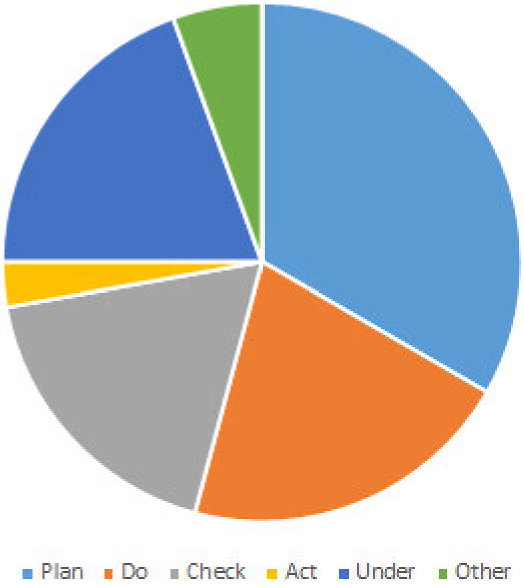


Figure 12 Summary of Consolidated List of Themes against the 'Plan-Do-Check-Act' Groups

8. Summary of the Phase 2 Findings, BDL Expectations and Recommendations

8.1 Findings

Over the course of this phase of the task the objectives were to:

> Undertake detailed reviews of nuclear industry RGP identified in Phase 1 (Reference 1) for different classes and types of mechanical SSCs important to safety in order to develop expectations for BDL submissions;

> Perform a benchmarking exercise comparing nuclear industry BDL expectations with those identified from other high-hazard industries;

> Identify minimum expectations against which ONR should determine that BDL considerations have been adequately undertaken when considering the limitations of codes and standards used for such components.

In order to provide confidence to the nuclear industry that this report is comprehensive and authoritative, a wide range of nuclear industry RGP has been reviewed, and cross compared with RGP from other high-hazard industries. Section 8.2 presents the final consolidated list of BDL expectations. It is noted that many of the expectations identified can be related to key areas identified in Phase 1 (Reference 1) and linked to the ONR SAPs (Reference 4) and other associated ONR guidance. The lists are comprehensive, but not necessarily exhaustive given the scope of RGP associated with the subject matter. However, in-line with the overall task objective, this phase represents a stepping-stone to enable the BDL expectations to be further developed.

Throughout this report, BDL expectations have been subjectively grouped according to the 'Plan-Do-Check-Act' cycle in order to provide a framework to enable the BDL expectations to be further developed. The list of BDL expectations is further sub-divided to identify those expectations that would usually form part of a BDL submission (e.g. an LC22 submission) and those items that would usually be addressed via a PSR.

In addition to consideration of service life assumptions and design conservatisms built into codes and standards for SSCs, which should be addressed as part of a revalidation of TLAA, the reviews of RGP identified a wide range of other BDL expectations. Several of these other expectations are considered particularly important where TLAA from the design stage is not available, or where there is uncertainty in safety margins. For example, in cases where safety margins are not large, it is considered reasonable to implement move advanced techniques that makes use of data on loads and cycles taken from operational history or experience based data on environmental conditions. Expectations associated with identification and management of consequential effects on people, plant and process should also be addressed in order to provide assurance that all risks have been reduced ALARP.

Comparison between nuclear-industry and high-hazard industry RGP identified that there is broad alignment between the themes identified. However, a small sub-set of themes were identified from the high-hazard RGP that did not appear in the nuclear industry list (or were not covered to the same extent); these items have been added to the final list of BDL expectations presented in Section 8.2. Areas where high-hazard industry guidance was found to be more extensive than the nuclear industry included BDL expectations associated with: data management and trending; obsolescence management; and organisational factors. Guidance on the use of self-assessments, questionnaires and checklists to provide assurance for BDL operation was also found to be more detailed within RGP from high-hazard industry.

8.2 BDL Expectations

PSR BDL Expectations

- Ageing Management
- AMP Review
- Asset Management
- Capabilities and Resources
- Data Management and Trending
- Data Recording and Availability
- Databases
- Decommissioning
- Economic Optimisation
- EIMT
- General Framework for AM and LTO
- Human factors
- In-Service Inspection
- Knowledge Management
- Licence Management
- Lifetime/Life-Cycle Management
- LTO Submissions or PSR to Demonstrate Safe Operation
- Modifications to existing Plant Programmes
- Obsolescence
- Obsolescence Management
- Organisational Factors
- Performance Monitoring and RIM Updates
- Periodic Safety Reviews
- Pre-Conditions for LTO
- Preventative/Predictive Maintenance
- Regulatory Approach to LTO
- Regulatory Oversight
- Review and Update of Processes and Procedures for LTO
- RIM Programme
- Roles and Responsibilities for Operators and Regulators
- Safety Cases and Reviews
- Safety Management
- Self-Assessments and Audits for AM or Life Extension Tasks
- Surveillance and Monitoring Programmes for TLAAs
- System and Data Management
- Workforce Involvement

BDL Submission Expectations

- Ageing Management Programmes
- Ageing/Degradation Mechanisms
- Ageing/Degradation of SSCs
- Capabilities and Resources
- Data Management and Trending
- Decommissioning
- Design Life
- Design Stage Considerations
- EIMT
- Equipment Qualification
- Identification of Reliability Targets
- In-Service Inspection
- LCM Self-Assessments
- LTO Engineering Process
- Maintenance
- Modifications to existing Plant Programmes
- Obsolescence
- Operational Programmes
- OPEX
- Performance Management
- Plant Ageing Questionnaires and Checklists
- Preventative/Predictive Maintenance
- Record Keeping
- Refurbishment/Replacement
- Review and Update of Processes and Procedures for LTO
- Reviews/Revalidate TLAAs
- RIM Implementation and Documentation
- RIM Strategies and Uncertainties
- RIM Strategies (Performance of Strategies)
- Safety Cases and Reviews
- Scoping and Screening
- Self-Assessments and Audits for AM or Life Extension Tasks
- Skills, Training and Competence
- SSC Safety Classification
- Surveillance and Monitoring Programmes for TLAAs

8.3 Recommendations

It is recommended that:

1) Consideration be given to the production of a good practice guide and/or dedicated TAG in order to further develop the BDL expectations identified in this phase of the task with reference to RGP including extant ONR guidance;

2) A series of questionnaires and checklists are developed to support review of BDL submissions, which in turn can inform the development of BDL submissions for facilities other than NPPs;

3) The ONR research project (ONR376) undertaken in support of the review of the Ageing and Degradation SAPs (EAD.1 to EAD.5), summarised in Reference 5, be incorporated into the next phase of this task in order to combine the learning from across both projects.

9. References

1) 203171/0024/001, Review of Current ONR Guidance and Relevant Good Practice on Beyond Design Life Expectations for Mechanical SSCs Related to Safety, Version 1.0, May 2019
2) IAEA SSG-48, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants, November 2018
3) Regulatory Article 5724, Issue 4, Life Extension Programme
4) Safety Assessment Principles for Nuclear Facilities, 2014 Edition, Revision 0 (*It is noted that Revision 01 this document was issued January 2020; however, this was issued after the majority of the RGP reviews were performed.*)
5) 203171/0026/004, Review of Current ONR Guidance on Management of Ageing and Degradation of SSCs: Summary Report, Version 2.0, October 2019

Appendix A. Tables Summarising RGP Reviews

Table A1 List of Identified Documents and RGP Reviewed

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-001	ACI	ACI 349.3R-18	Report on Evaluation and Repair of Existing Nuclear Safety-Related Concrete Structures	Other	N	N/A
A-002	AFCEN	ETC-C – 2010 Edition	EPR Technical Code for Civil Works	Other	N	N/A
A-003	AREVA	PESS-G/2010/en/0041	Ageing Management Review - Methodology Report	Other	N	N/A
A-004	ASME	N/A	16th International Conference on Nuclear Engineering	C&S	N	N/A
A-005	ASME	OMAE2008-57451	Assessment of Offshore Structures for Life Extension	HH	N	N/A
A-006	ASME	ASME XI Div 2	2019 ASME Boiler and Pressure Vessel Code, SECTION XI Rules for Inservice Inspection of Nuclear Power Plant Components, Division 2 Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Power Plants	C&S	Y	C
A-007	British Standards	IEC 62402:2007	Obsolescence management — Application guide	C&S	N	N/A
A-008	British Standards	IEC 62342:2007	Nuclear power plants – Instrumentation and control systems important to safety – Management of ageing	C&S	N	N/A
A-009	CNSC	N/A	Canadian Regulatory Oversight of Ageing Management for Nuclear Power Plants	C&S	N	N/A
A-010	CNSC	e-Doc 5008579	Canadian Regulatory Oversight of Ageing Management for Nuclear Power Plants	C&S	N	N/A
A-011	CNSC	REGDOC-2.3.3	Periodic Safety Reviews	C&S	N	N/A
A-012	CNSC	REGDOC-2.6.3	Fitness for Service: Aging Management	C&S	N	N/A
A-013	CSA	N287.8-15	Aging management for concrete containment structures for nuclear power plants	C&S	N	N/A
A-014	EPRI	TR-106109	Nuclear Plant Life Cycle Management Implementation Guide	Other	Y	C
A-015	EPRI	TR-1001413	Safety System Obsolescence and Maintainability	Other	N	N/A

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-016	EPRI	TR-1007933	Aging Assessment Field Guide	Other	N	N/A
A-017	EPRI	TR-1009743	Aging Identification and Assessment Checklist (Mechanical Components)	Other	N	N/A
A-018	EPRI	TR-1011223	Aging Identification and Assessment Checklist (Electrical Components)	Other	N	N/A
A-019	EPRI	TR-1011223	Aging Identification and Assessment Checklist (Civil and Structural Components)	Other	N	N/A
A-020	EPRI	TR-1016692	Plant Support Engineering: Obsolescence Management Program Ownership and Development	Other	N	N/A
A-021	EPRI	TR-1019161	Plant Support Engineering: Proactive Obsolescence Management Program Implementation and Lessons Learned	Other	N	N/A
A-022	ENSREG	HLG_p(2016-33)_345	ENSREG Stakeholder Engagement Plan - Topical Peer Review on Ageing Management of Nuclear Power Plants	C&S	N	N/A
A-023	ENSREG	HLG_p(2016-33)_348	Topical Peer Review 2017 Ageing Management of Nuclear Power Plants - Terms of Reference for Topical Peer Review Process	C&S	N	N/A
A-024	ENSREG	**ENSREG-SW2017**	Topical Peer Review 2017 Ageing Management - Swedish National Assessment Report	C&S	Y	C
A-025	ENSREG	**ENSREG-GER17**	Report by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) on Topical Peer Review Ageing Management of Nuclear Power Plants and Research Reactors	C&S	Y	C
A-026	ENSREG	**ENSREG-FR2017**	Safety Assessment of Nuclear Facilities in France Ageing Management National Report	C&S	Y	C
A-027	Eskom	N/A	Koeberg Nuclear Power Station: Plant Life Extension and Ageing Management 1st NNR Regulatory Information Conference – Pretoria, Centurion	Other	N	N/A
A-028	EU	EUR 22483 EN - 2007	Models and data used for assessing the ageing of systems, structures and components (European Network on Use of Probabilistic Safety Assessment (PSA) for Evaluation of Ageing Effects to the Safety of Energy Facilities)	C&S	Y	C
A-029	EU	EUR 25142 EN - 2011	Operation of Ageing Reactors: Approaches and associated Research in the European Union	C&S	Y	C

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-030	FNR (Russia)	NP-017-2000	Basic requirements for nuclear power plant (NPP) unit lifetime extension.	C&S	N	N/A
A-031	HAEA	Hungarian Atomic Energy Authority - Guideline 1.28	Regulatory procedures of operation beyond design lifetime	C&S	Y	C
A-032	HSE	2001/088	Beyond lifetime criteria for offshore cranes	HH	Y	D
A-033	HSE	EEMUA Publication 231 (Ed 1)	The mechanical integrity of plant containing hazardous substances A guide to periodic examination and testing	HH	Y	D
A-034	HSE	HS073 ISBN: 1 903 003 816	Guidance on the Management of Ageing and Life Extension for UKCS Oil and Gas Installations	HH	Y	D
A-035	HSE	Key Programme 4 (KP4)	Ageing and life extension programme A report by the Energy Division of HSE's Hazardous Installations Directorate	HH	Y	D
A-036	HSE	Offshore Information Sheet 4/2009	Guidance on management of ageing and thorough reviews of ageing installations	HH	N	N/A
A-037	HSE	CRR 363/2001	Best practice for risk based inspection as a part of plant integrity management	HH	N	N/A
A-038	HSE	RR509	Plant ageing - Management of equipment containing hazardous fluids or pressure	HH	Y	D
A-039	HSE	RR823	Plant Ageing Study - Phase 1 Report	HH	Y	D
A-040	HSE	RR912	Management of ageing - A framework for nuclear chemical facilities	HH	Y	D
A-041	HSE	RR1075	Benefits of data management and data trending in the UK Continental Shelf oil and gas industry	HH	N	N/A
A-042	HSE		Managing Ageing Plant - A Summary Guide	HH	Y	D
A-043	IAEA	DS485	Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants	IAEA	N	N/A
A-044	IAEA	N/A	Material Degradation and Related Managerial Issues at Nuclear Power Plants Proceedings of a Technical Meeting, Vienna, 15–18 February 2005	IAEA	Y	B

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-045	IAEA	IAEA-CN-155-069	Russian Regulatory Approach to Extension of Nuclear Power Plant Service Life	IAEA	Y	B
A-046	IAEA	IAEA-CN-194-0XX	Risk Informed Safety Margin Characterization for Effective Long Term Nuclear Power Plant Safety Management	IAEA	N	N/A
A-047	IAEA	IAEA-CN-194-016	Digital Image Correlation (DIC): An Advanced Non-destructive Testing Method for Life Extension of Nuclear Power Plants	IAEA	N	N/A
A-048	IAEA	IAEA-CN-194-036	Long Term Operation For EDF Nuclear Power Plants : Towards 60 years…	IAEA	N	N/A
A-049	IAEA	IAEA-CN-194-041	Safety requirements for long term operation of NPPs	IAEA	N	N/A
A-050	IAEA	IAEA-CN-194-051	Life Limiting Issues for Long Term Operation of Nuclear Power Plants	IAEA	N	N/A
A-051	IAEA	IAEA-CN-194-1P28	Material aging and degradation detection and remaining life assessment for plant life management	IAEA	N	N/A
A-052	IAEA	IAEA-EBP-LTO-23	Long Term Operation – Structures and Structural Components	IAEA	Y	B
A-053	IAEA	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	IAEA	Y	B
A-054	IAEA	INSAG-14	Safe Management of the Operating Lifetimes of Nuclear Power Plants	IAEA	Y	B
A-055	IAEA	INSAG-19	Maintaining the Design Integrity of Nuclear Installations throughout their Operating Life	IAEA	Y	B
A-056	IAEA	INSAG-25	A Framework for an Integrated Risk Informed Decision Making Process	IAEA	N	N/A
A-057	IAEA	NP-T-3.2	Heavy Component Replacement in Nuclear Power Plants: Experience and Guidelines	IAEA	N	N/A
A-058	IAEA	NP-T-3.5	Ageing Management of Concrete Structures in Nuclear Power Plants	IAEA	N	N/A
A-059	IAEA	NP-T-3.18	Plant Life Management Models for Long Term Operation of Nuclear Power Plants	IAEA	N	N/A
A-060	IAEA	NP-T-3.20	Buried and Underground Piping and Tank Ageing Management for Nuclear Power Plants	IAEA	Y	B
A-061	IAEA	NP-T-3.24	Handbook on Ageing Management for Nuclear Power Plants	IAEA	N	N/A
A-062	IAEA	NS-G-2.12	Ageing Management for Nuclear Power Plants	IAEA	N	N/A

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-063	IAEA	SRS-57	Safe Long Term Operation of Nuclear Power Plants	IAEA	N	N/A
A-064	IAEA	SRS-62	Proactive Management of Ageing for Nuclear Power Plants	IAEA	N	N/A
A-065	IAEA	SRS-82	Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL)	IAEA	Y	B
A-066	IAEA	SS-26	SALTO Peer Review Guidelines - Guidelines for Peer Review of Safety Aspects of Long Term Operation of Nuclear Power Plants	IAEA	Y	B
A-067	IAEA	SSG-25	Periodic Safety Review for Nuclear Power Plants	IAEA	N	N/A
A-068	IAEA	SSG-30	Safety Classification of Structures, Systems and Components in Nuclear Power Plants	IAEA	N	N/A
A-069	IAEA	SSG-48	Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants	IAEA	Y	B
A-070	IAEA	SSR-2/1	Safety of Nuclear Power Plants: Design	IAEA	N	N/A
A-071	IAEA	SSR-2/2	Safety of Nuclear Power Plants: Commissioning and Operation	IAEA	N	N/A
A-072	IAEA	TECDOC-540	Safety Aspects of Nuclear Power Plant Ageing	IAEA	N	N/A
A-073	IAEA	TECDOC-1025	Assessment and management of ageing of major nuclear power plant components important to safety: Concrete Containment Buildings	IAEA	N	N/A
A-074	IAEA	TECDOC-1147	Management of aging of I&C equipment in nuclear power plants	IAEA	N	N/A
A-075	IAEA	TECDOC-1188 - Volume I	Assessment and management of ageing of major nuclear power plant components important to safety: In-containment instrumentation and control cables Volume I	IAEA	N	N/A
A-076	IAEA	TECDOC-1188 - Volume II	Assessment and management of ageing of major nuclear power plant components important to safety: In-containment instrumentation and control cables Volume II	IAEA	N	N/A
A-077	IAEA	TECDOC-1305	Safe and effective nuclear power plant life cycle management towards decommissioning	IAEA	Y	B
A-078	IAEA	TECDOC-1361	Assessment and management of ageing of major nuclear power plant components important to safety: Primary Piping in PWRs	IAEA	N	N/A
A-079	IAEA	TECDOC-1402	Management of life cycle and ageing at nuclear power plants: Improved I&C maintenance	IAEA	N	N/A

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-080	IAEA	TECDOC-1556	Assessment and management of ageing of major nuclear power plant components important to safety: PWR Pressure Vessels	IAEA	N	N/A
A-081	IAEA	TECDOC-1557	Assessment and management of ageing of major nuclear power plant components important to safety: PWR Vessel Internals	IAEA	N	N/A
A-082	IAEA	TECDOC-1668	Assessment and management of ageing of major nuclear power plant components important to safety: Steam Generators	IAEA	N	N/A
A-083	IAEA	TECDOC-1736	Approaches to Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL) Final Report	IAEA	Y	B
A-084	IAEA	Technical Report Series No. 338	Methodology for the Management of Ageing of Nuclear Power Plant Components Important to Safety	IAEA	N	N/A
A-085	IAEA	N/A	Resources for Plant Life Management in Nuclear Power Plants (October 2017)	IAEA	N	N/A
A-086	IEEE	INL/CON-11-21865	Prognostics and Life Beyond 60 Years for Nuclear Power Plants	C&S	N	N/A
A-087	NNR (SA)	N/A	Ageing Management & Long Term Operation of NPP	C&S	N	N/A
A-088	NNR (SA)	RG-0019 (Rev 0)	Regulatory Guide - Interim Guidance on Safety Assessments of Nuclear Facilities	C&S	N	N/A
A-089	NNR (SA)	RG-0027 (Rev 0)	Interim Regulatory Guide - Ageing Management and Long Term Operations of Nuclear Power Plants	C&S	N	N/A
A-090	NRC	N/A	International Approaches to Long Term Operation and License Renewal	C&S	N	N/A
A-091	NRC	NUREG-1412	Foundation for the Adequacy of the Licensing Bases – A Supplement to the Statement of Considerations for the Rule on Nuclear Power Plant License Renewal (10 CFR Part 54)	C&S	N	N/A
A-092	NRC	NUREG-1555, Supplement 1	Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan for Operating License Renewal	C&S	N	N/A
A-093	NRC	NUREG-1611	Aging Management of Nuclear Power Plant Containments for License Renewal	C&S	N	N/A
A-094	NRC	NUREG-1801 (Rev 2)	Generic Aging Lessons Learned (GALL) Report	C&S	N	N/A

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-095	NRC	NUREG-2214	Managing Aging Processes In Storage (MAPS) Report	C&S	Y	C
A-096	OECD - NEA	NEA/CNRA/R(99)1	Regulatory Aspects of Ageing Reactors - 1998 CNRA Special Issue Meeting	C&S	Y	C
A-097	OECD - NEA	NEA/CNRA/R(2001)1	Regulatory aspects of life extension and upgrading of NPPs - CNRA Special Issue's Meeting 2000	C&S	Y	C
A-098	OECD - NEA	NEA/CSNI/R(2002)26	Technical Aspects of Ageing for Long-Term Operation	C&S	Y	C
A-099	OECD - NEA	NEA/SEN/NDC(2000)6	Status Report on Nuclear Power Plant Life Management	C&S	N	N/A
A-100	OECD - NEA	Nuclear Development ISBN 92-64-05842-7	Glossary of Nuclear Power Plant Ageing	C&S	N	N/A
A-101	OECD - NEA	Nuclear Development ISBN 978-92-64-99205-4	The Economics of Long-term Operation of Nuclear Power Plants	C&S	N	N/A
A-102	OECD - NEA	Nuclear Regulation - NEA/CNRA/R(2012)5 ISBN 978-92-64-99187-3	Challenges in Long-term Operation of Nuclear Power Plants - Implications for Regulatory Bodies	C&S	Y	C
A-103	ONR	Licence Condition Handbook February 2017	Licence condition handbook - The standard licence conditions attached to nuclear site licences	C&S	N/A	N/A
A-104	ONR	2014 Edition Revision 0	Safety Assessment Principles for Nuclear Facilities	C&S	N/A	N/A
A-105	ONR		ENSREG Topical Peer Review on Ageing Management United Kingdom National Assessment Report – December 2017	C&S	N	N/A
A-106	Other	N/A	A general LTO assessment project approach using IAEA guidelines applied to Borssele (The Netherlands) and Ringhals (Sweden)NPPs	Other	N	N/A
A-107	Other	N/A	Ageing Management and LTO of NPPs – Swedish perspective	Other	N	N/A
A-108	Other	N/A	Slovenian Regulatory Approach to Design Lifetime Extension	Other	N	N/A
A-109	Other	N/A	Sensitivity study of a new model for assessing time-dependent risk in ageing NPP	Other	N	N/A

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-110	Other	N/A	Ageing management in NPP. Effectiveness of the methods for control, examination and monitoring in relation to mechanisms of degradation of mechanical properties	Other	N	N/A
A-111	Other	N/A	Ageing related events at nuclear power plants	Other	N	N/A
A-112	Other	N/A	Long-Term Operation of VVER Power Plants	Other	N	N/A
A-113	Other	N/A	NuPEER Dijon 2005 Symposium. Ageing issues in nuclear power plants	Other	Y	C
A-114	Other	ISBN 978-1-84569-511-8	Understanding and Mitigating Ageing in Nuclear Power Plants - Materials and Operational Aspects of Plant Life Management (PLiM)	Other	Y	C
A-115	Other	Powder Technology 321 (2017) 390–408	Ageing management and life extension of concrete in nuclear power plants	Other	N	N/A
A-116	Other	ENERGIFORSK REPORT 2016:265	ACCEPPT – Ageing of Concrete and Civil Structures in Nuclear Power Plants Project summary	Other	N	N/A
A-117	Other	E-Journal of Advanced Maintenance Vol.5-1 (2013) 70-76 Japan Society of Maintenology	LWR Sustainability: Assessment of Aging of Nuclear Power Plant Safety Related Concrete Structures	Other	N	N/A
A-118	Other	The European Physical Journal Conferences · July 2013 DOI: 10.1051/epjconf/20135603001	Developing a Computerized Aging Management System for Concrete Structures in Finnish Nuclear Power Plants	Other	N	N/A
A-119	PSA Norway	CGI Report 06:21	Performance Monitoring of Systems and Active Components	HH	N	N/A
A-120	PSA Norway	CGI Report 06:22	Condition Monitoring of Passive Systems, Structures, and Components	HH	N	N/A
A-121	PSA Norway	CGI Report 06:23	Aging Management and Life Extension in the US Nuclear Power Industry	HH	N	N/A

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-122	PSA Norway	OSL-804-R04	Ageing of Offshore Concrete Structures	HH	N	N/A
A-123	PSA Norway	OSL-821-R02	Structural Integrity Barrier Management - Capability Maturity Model	HH	N	N/A
A-124	PSA Norway	N/A	Ageing and Life Extension of offshore installations - Conference September 2008	HH	N	N/A
A-125	PSA Norway	N/A	Safety and Inspection Planning of Older Installations	HH	N	N/A
A-126	PSA Norway	SINTEF A15322 ISBN: 978-82-14-04874-2	Ageing and Life extension for offshore facilities in general and specific systems	HH	N	N/A
A-127	SMiRT	SMiRT 19, Toronto, August 2007 Paper # D01/2	Nuclear Power Plant Mechanical Components Ageing Management Programs in Slovakia	Other	N	N/A
A-128	SMiRT	SMiRT-22 August 18-23 2013 (Div VI)	Nuclear Power Plant Concrete Structures	Other	N	N/A
A-129	SMiRT	SMiRT-23 Manchester, United Kingdom August 10-14, 2015 Division VIII, Paper ID 548	Ageing Management of Concrete Structures in Nuclear Power Plants	Other	N	N/A
A-130	STUK	GUIDE YVL A.8	Ageing Management of a Nuclear Facility	C&S	N	N/A
A-131	WENRA	March 2011	Pilot study on Long term operation (LTO) of nuclear power plants	C&S	N	N/A
A-132	WENRA		Topical Peer Review 2017 - Ageing Management Technical Specification for the National Assessment Reports	C&S	N	N/A
A-133	WENRA		WENRA Safety Reference Levels for Existing Reactors - Update in Relation to Lessons Learned from TEPCO Fukushima Daiichi Accident	C&S	N	N/A

ID	Source	Ref No.	RGP Title	Review Grp	Reviewed Y/N	App
A-134	AAPWG	Paper 010	Ageing Aircraft Programmes Working Group - A Framework for Ageing Aircraft Audits	HH	Y	D
A-135	AAPWG	Paper 011	Ageing Aircraft Programmes Working Group - Guidance on the Conduct of Aircraft Zonal Hazard Analysis (ZHA)	HH	Y	D
A-136	AAPWG	Paper 012	Ageing Aircraft Programmes Working Group - Understanding the Corrosion Threat to Ageing Aircraft	HH	Y	D
A-137	AAPWG	Paper 013	Ageing Aircraft Programmes Working Group - Continuing Airworthiness Management its Contribution to Identifying Evidence of Ageing in Aircraft	HH	Y	D
A-138	CNSC	REGDOC-2.6.1	Reliability Programs for Nuclear Power Plants	C&S	Y	N/A
A-139	HSE	HSE-4/2009	Guidance on management of ageing and thorough reviews of ageing installations	HH	Y	D
A-140	HSE		Ageing of Composites	HH	N	N/A
A-141	IAEA	IAEA-EBP-LTO-21	Long Term Operation- Mechanical Components and Material Issues	IAEA	Y	B
A-142	IAEA	IAEA-TOP-401	Technical Obsolescence Programme	IAEA	Y	B
A-143	IAEA	IAEA-TRS-439	Decommissioning of Underground SSCs	IAEA	N	N/A
A-144	MAA	RA 5723	MAA Regulatory Article (RA) 5723 - Ageing Aircraft Audit	HH	Y	D
A-145	Other	ISO 14692-4	Petroleum and natural gas industries- Glass Reinforced Plastic (GRP) piping	HH	N	N/A

1. Considered not relevant to this task, excluded in Phase 1
2. Document excluded at the start of Phase 2, due to time
3. Document part of IAEA Group in Phase 2
4. Document part of Codes, Standards & Regulatory Group in Phase 2
5. Document part of 'Other' nuclear Group in Phase 2
6. Document part of Other High-hazard Group in Phase 2
7. New RGP identified in subsequent Phase 1 searches

Table A2 Summary of Key Themes Against RGP Reviews

ID	Source	Ref No.	RGP Title	App	Plan	Do	Check	Act	Under-stand	Other
A-006	ASME	ASME XI Div 2	2019 ASME Boiler and Pressure Vessel Code, SECTION XI Rules for Inservice Inspection of Nuclear Power Plant Components, Division 2 Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Power Plants	C	Y	Y	Y		Y	
A-014	EPRI	TR-106109	Nuclear Plant Life Cycle Management Implementation Guide	C	Y		Y		Y	
A-024	ENSREG	ENSREG-SW2017	Topical Peer Review 2017 Ageing Management - Swedish National Assessment Report	C	Y	Y	Y		Y	
A-025	ENSREG	ENSREG-GER17	Report by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) on Topical Peer Review Ageing Management of Nuclear Power Plants and Research Reactors	C	Y		Y	Y	Y	
A-026	ENSREG	ENSREG-FR2017	Safety Assessment of Nuclear Facilities in France Ageing Management National Report	C	Y		Y		Y	Y
A-028	EU	EUR 22483 EN - 2007	Models and data used for assessing the ageing of systems, structures and components (European Network on Use of Probabilistic Safety Assessment (PSA) for Evaluation of Ageing Effects to the Safety of Energy Facilities)	C			Y		Y	
A-029	EU	EUR 25142 EN - 2011	Operation of Ageing Reactors: Approaches and associated Research in the European Union	C						Y
A-031	HAEA	Hungarian Atomic Energy Authority - Guideline 1.28	Regulatory procedures of operation beyond design lifetime	C						Y
A-032	HSE	2001/088	Beyond lifetime criteria for offshore cranes	D	Y	Y	Y		Y	
A-033	HSE	EEMUA Publication 231 (Ed 1)	The mechanical integrity of plant containing hazardous substances	D	Y	Y	Y			

ID	Source	Ref No.	RGP Title	App	Plan	Do	Check	Act	Under-stand	Other
			A guide to periodic examination and testing							
A-034	HSE	HS073 ISBN: 1 903 003 816	Guidance on the Management of Ageing and Life Extension for UKCS Oil and Gas Installations	D	Y		Y		Y	Y
A-035	HSE	Key Programme 4 (KP4)	Ageing and life extension programme A report by the Energy Division of HSE's Hazardous Installations Directorate	D	Y		Y		Y	Y
A-038	HSE	RR509	Plant ageing - Management of equipment containing hazardous fluids or pressure	D	Y	Y	Y		Y	Y
A-039	HSE	RR823	Plant Ageing Study - Phase 1 Report	D	Y				Y	Y
A-040	HSE	RR912	Management of ageing - A framework for nuclear chemical facilities	D	Y	Y	Y			Y
A-042	HSE		Managing Ageing Plant A Summary Guide	D	Y				Y	
A-044	IAEA	N/A	Material Degradation and Related Managerial Issues at Nuclear Power Plants Proceedings of a Technical Meeting, Vienna, 15–18 February 2005	B			Y		Y	
A-045	IAEA	IAEA-CN-155-069	Russian Regulatory Approach to Extension of Nuclear Power Plant Service Life	B	Y	Y			Y	
A-052	IAEA	IAEA-EBP-LTO-23	Long Term Operation – Structures and Structural Components	B	Y	Y	Y			

ID	Source	Ref No.	RGP Title	App	Plan	Do	Check	Act	Under-stand	Other
A-053	IAEA	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	B	Y	Y	Y	Y	Y	
A-054	IAEA	INSAG-14	Safe Management of the Operating Lifetimes of Nuclear Power Plants	B	Y		Y		Y	Y
A-055	IAEA	INSAG-19	Maintaining the Design Integrity of Nuclear Installations throughout their Operating Life	B	Y				Y	
A-060	IAEA	NP-T-3.20	Buried and Underground Piping and Tank Ageing Management for Nuclear Power Plants	B	Y			Y	Y	Y
A-065	IAEA	SRS-82	Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL)	B	Y		Y			
A-066	IAEA	SS-26	SALTO Peer Review Guidelines - Guidelines for Peer Review of Safety Aspects of Long Term Operation of Nuclear Power Plants	B	Y	Y	Y		Y	Y
A-069	IAEA	SSG-48	Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants	B	Y	Y	Y		Y	Y
A-077	IAEA	TECDOC-1305	Safe and effective nuclear power plant life cycle management towards decommissioning	B	Y		Y		Y	Y
A-083	IAEA	TECDOC-1736	Approaches to Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL) Final Report	B	Y	Y			Y	Y
A-095	NRC	NUREG-2214	Managing Aging Processes In Storage (MAPS) Report	C	Y					

ID	Source	Ref No.	RGP Title	App	Plan	Do	Check	Act	Under-stand	Other
A-096	OECD - NEA	NEA/CNRA/R(99)1	Regulatory Aspects of Ageing Reactors - 1998 CNRA Special Issue Meeting	C						Y
A-097	OECD - NEA	NEA/CNRA/R(2001)1	Regulatory aspects of life extension and upgrading of NPPs - CNRA Special Issue's Meeting 2000	C						Y
A-098	OECD - NEA	NEA/CSNI/R(2002)26	Technical Aspects of Ageing for Long-Term Operation	C						Y
A-102	OECD - NEA	Nuclear Regulation - NEA/CNRA/R(2012)5 ISBN 978-92-64-99187-3	Challenges in Long-term Operation of Nuclear Power Plants - Implications for Regulatory Bodies	C	Y	Y	Y	Y	Y	Y
A-113	Other	N/A	NuPEER Dijon 2005 Symposium. Ageing issues in nuclear power plants	C	Y	Y	Y	Y	Y	Y
A-114	Other	ISBN 978-1-84569-511-8	Understanding and Mitigating Ageing in Nuclear Power Plants - Materials and Operational Aspects of Plant Life Management (PLiM)	C	Y				Y	Y
A-134	AAPWG	Paper 010	Ageing Aircraft Programmes Working Group - A Framework for Ageing Aircraft Audits	D	Y	Y	Y		Y	Y
A-135	AAPWG	Paper 011	Ageing Aircraft Programmes Working Group - Guidance on the Conduct of Aircraft Zonal Hazard Analysis (ZHA)	D	Y					
A-136	AAPWG	Paper 012	Ageing Aircraft Programmes Working Group - Understanding the Corrosion Threat to Ageing Aircraft	D	Y				Y	

ID	Source	Ref No.	RGP Title	App	Plan	Do	Check	Act	Under-stand	Other
A-137	AAPWG	Paper 013	Ageing Aircraft Programmes Working Group - Continuing Airworthiness Management its Contribution to Identifying Evidence of Ageing in Aircraft	D					Y	
A-139	HSE	HSE-4/2009	Guidance on management of ageing and thorough reviews of ageing installations	D	Y	Y			Y	
A-141	IAEA	IAEA-EBP-LTO-21	Long Term Operation- Mechanical Components and Material Issues	B	Y	Y	Y			
A-142	IAEA	IAEA-TOP-401	Technical Obsolescence Programme	B					Y	Y
A-144	MAA	RA 5723	MAA Regulatory Article (RA) 5723 - Ageing Aircraft Audit	D	Y				Y	

Appendix B. Output of IAEA RGP Reviews

Reference: A-044 [IAEA-Unknown Ref]
Document Title/Version Number: Material Degradation and Related Managerial Issues at Nuclear Power Plants
Date of Issue: September 2006 (Proceedings from Feb 2005 IAEA Technical Meeting)
Summary: This publication presents the main results and lessons learned from the IAEA Technical Meeting on Material Degradation and Related Managerial Aspects held on 15–18 February 2005. Managerial aspects and influences are seen to be just as important to the safe and reliable operation of nuclear power plants (NPPs) as technical issues and are frequently the root cause of incidents that occur. The background statement suggests *"problems associated with materials (in more general terms, system, structure and component (SSC) degradation followed by spontaneous failure) have been observed. These material problems may, however, not be of a purely technical nature but may have factors present in the management system of the NPP concerned"*. As the title and the quote above state, this document looks at aspects of management within NPPs and the understanding of the degradation mechanisms within the plant they are responsible for. It also states that *"continued research into the mechanisms of material failure, transparency in sharing information, avoidance of complacency, and optimised knowledge management is needed"*. This document has 5 sessions: • Report of incidents; This session was to share information on recent events involving material and managerial issues affecting safe operation of NPP and to share lessons learned from those issues. • Technical Issues; This session was to share technical updates on material issues and to identify outstanding technical problems in the field. • Managerial Issues; This session shared lessons learned on the aspects of the management system coping with technical issues presented in the previous session, and to identify outstanding managerial issues in the field. • Regulatory Aspects; This session discussed the sharing of roles and responsibilities among parties involved in NPP operation and regulation. • Special Session; This session contained two papers regarding surveillance of reactor pressure vessels and investigations into the behaviour of corrosion. Each of these sessions included case studies from various NPPs regarding degradation of SSCs. These include the lessons learned from these incidents and recommendations to prevent these occurring again in the future.
Key Themes: <u>OPEX</u> Section 2.3 Erosion-corrosion in the secondary system piping and components in Finland. (p.8).

Reference: A-044 [IAEA-Unknown Ref]
Management of EC of the secondary system piping and components has turned out to be an important factor for the safety, plant availability and for the long-term operation of the plant. The following summarises lessons-learned from this incident: • It is not sufficient to assume that EC will be less in other areas: the exact conditions of flow (local turbulence and multi-phase conditions) may impact such assumptions; • Evaluating accidents in other NPPs will give indications to inspect similar situations in other NPPs. Additional inspections may not lead to improved safety, if the inspection is not done in the suspected danger areas. 3.3. COMSY software to assist lifetime management activities (p.13). (Condition Oriented ageing and plant life Monitoring System). Some of the papers in this document refer to the COMSY software and its benefits. The points to be taken from what this software is trying to achieve can be utilised in all NPPs for the benefit of the maintenance and management programmes. *"The objective is to establish economically optimized inspection and maintenance programmes, while maintaining high levels of plant safety and availability. This is accomplished by focusing on inspection activities on the actual degradation-relevant locations".* *"The capability to perform service life predictions is the key function of a software system for ageing and plant life management".* OPEX (Operating experience) tell us that trending data of SSCs leads to optimised maintenance strategies, allows for planned maintenance to be implemented at a time to suit the plant operation and can be used to model/predict the SSCs degradation. This document uses the COMSY software example, which states; *"Trending functions support the comparison of the as-measured condition with the predicted progress of degradation while making allowance for measurement tolerances. The results of this comparison are used to improve the accuracy of future life expectancy predictions".* Regarding Long-term operation (LTO) of SSCs it states; *"on the basis of reliable and damage-relevant predictions, maintenance management and plant availability can be optimized. This capability is particularly useful for the service life extension of systems and components.* <u>EIMT and Programmes.</u> Section 4.3. Aspects of Unexpected Events in Nuclear Power Plants. (p.20). *"The paper examined aspects concerning events or accidents in NPPs, despite generally high levels of SSC monitoring and inspection and regulatory oversight. The importance of materials selection at the design stage, and the need for vigilance and questioning attitudes was stressed. The necessity to learn from accidents or events that have occurred in other NPPs is shown to be an important tool and source of information for NPP designers, manufacturers, operators and regulators".* <u>Technical Issues</u> (Session 2). p.80 The COMSY software discussion raised some interesting questions which should be noted for NPPs looking into LTO and the extension of SSCs.

Reference: A-044 [IAEA-Unknown Ref]
"In order to assess the service life of a component, the following questions have to be answered: • *Which degradation mechanisms are relevant to the material under its intended conditions of use?* • *What rate of component degradation progression is to be expected under those conditions?* • *Which limiting condition caused by the progression of the degradation restricts the service life of the component?"* <u>Roles and responsibilities of operators and regulators.</u> (p.125). *"As NPPs approach their originally planned operating lives, and utilities and operators apply for license renewal for long-term operation, they must do so using arguments and facts based on evidence that the SSCs can still reliably perform within design requirements and technical specifications (TS). Periodic safety reviews (PSR), repairs, replacements, inspection and monitoring and improvements to operating conditions are therefore essential elements in the overall process".* *"As NPP SSCs accrue time under their specific operating conditions (temperature, load cycling, pressure, irradiation, chemical environment) it may be necessary, or make economic sense, to modify or re-evaluate their inspection schedules".* *"Credit for implementing improvements, such as water chemistry adjustment, neutron shielding and low-leakage core configuration and for substituting better-designed components featuring optimised materials (e.g. better alloys) and production methods (e.g. surface and heat treatments), must be given. Actions such as these must be scientifically validated (state of science and technology) to obtain regulatory approval".*
Document Relationships & Referencing Various standards and documents are referred to in this paper due to the variety of sources used. One regulatory standard is referred to in this document (S-98, Reliability Programs for Nuclear Power Plants7), which has been superseded by CNSC REGDOC2-6-1 (Reliability Programmes for NPPs) which may be of interest and could be considered for future review.
Applicability to Beyond Design Life Expectations This paper uses these examples to show that the understanding of the ageing and degradation mechanisms is important for operating organisations, this knowledge should be used to implement programmes for plant maintenance and ageing management which should then be used as justification within the arguments for (LTO).
Applicability to the ONR SAPs The reference to the Condition Oriented ageing and plant life Monitoring System (COMSY) relate to SAPs such as ERL.2 and EMT.1.
Future Considerations N/A
Additional Notes Possible future review of REGDOC 2-6-1 could prove beneficial to the project.

Reference: A-045 [IAEA-CN-155-069]
Document Title/Version Number: Russian Regulatory Approach to Extension of Nuclear Power Plant Service Life.
Date of Issue: October 2007
Summary: The report presents not only general system of regulatory legislative acts in the field of nuclear and radiation safety but also all legislative acts and regulatory documents concerning plant life extension (PLEX) in the Russian Federation. This report lists the legislative acts and regulatory documents broken down into 5 stages and refers to two stages of NPP preparation for operational life extension. A presentation has also been identified, this was used by the author at the Second International Symposium on Nuclear Power Plant Life Management in Shanghai, China. (15-18 October 2007). This presentation relates directly to this report. This report relies heavily on the information in NP-017-2000 (Basic Requirements for Power Unit Lifetime Extension of Nuclear Power Plant) with some slight deviations within its wording. The main themes within this report are the review of the current state of the NPP and the justifications and measures for the continuing reliability of the SSCs. This document also refers to a DSAR (in-depth safety report) which, with recommendations from Rostechnadzor, builds a safety case for the operation of the site.
Key Themes Referring to NP-017-2000 the author lists the requirements of the NPP units operating lifetime, above that of the *“design operating lifetime (DOL) (or 30 years)”,* and suggests that the following *“technical and economic factors”* should be taken into account: • Possibility of interim storage of additional amount of spent nuclear fuel or its removal from the NPP site; • Possibility of safety ensuring during management with radwaste formed during additional operation term; • Possibility of NPP unit safety assurance during its decommissioning. This links with and adds to the IAEA document SSG-48 (Ref: A-069) paragraph 3.42 (Decommissioning): *“The operating organization should establish and implement ageing management activities in decommissioning plans and procedures for SSCs that are required to remain available and functional during decommissioning (e.g. ensuring the long term integrity of SSCs to prevent their deterioration and to allow the safe dismantling, handling and transport of components until the completion of decommissioning….”* The report suggests that there are two main stages of NPP unit preparation for long term operation. <u>Stage 1</u>: • comprehensive survey of the unit;

Reference: A-045 [IAEA-CN-155-069]

- estimation of technical possibility of the operational life extension for unit components or their replacement;
- safety assessment of the NPP unit.

Regarding the comprehensive survey it states, *"the real technical state of NPP unit and residual life of its components are defined. The main attention shall be paid to the technical state of the components important for safety*". It also states that it is "*necessary to define the following"*:

- Components important for safety with expired operating lifetime that are to be replaced;
- Components important for safety with expired operating lifetime, but having possibility of its extension at the expense of periodical maintenance and repair;
- Components important for safety which have residual lifetime and their operation may be extended for a definite period of time;
- Non-recoverable (irreplaceable) components and preliminary assessment of their residual lifetime;
- Possibility of storage of spent nuclear fuel and radwaste formed during additional operating lifetime;
- Possibility of safe radwaste management.

Referring back to the list above, specifically points 2 and 3, the author suggests that *"special importance"* should be given to the *"technical state and justification of residual lifetime"*.

As part of this survey *"justification analysis of the design deviations from the modern requirements of the regulatory and technical documentation"* should be carried out along with the analysis of the component's operational histories.

From the results of the comprehensive survey the following conclusions are made:

- "About results of expert evaluation of residual lifetime, including the list of overage components;
- About the current state of the systems (components) according to the results of control, tests and research during survey;
- About the state of the systems (components) and recommendations on measures, which are necessary for guaranteeing their working capacity and reliability".

To conclude stage 1 the report states *"NPP unit safety level is estimated, assumptions on the programs of additional activities for definition of residual life of NPP unit systems (components) are done"* and *"the scope and nomenclature of activities on preparation for PLEX are defined"*.

<u>Stage 2</u>:

This stage of the preparation for long term operation includes:

1. "justification of operational life extension for non-recoverable and irreplaceable elements;
2. implementation of complex program for unit modernization;
3. justification of NPP unit safety during additional operating lifetime;
4. receiving of Rostechnadzor license for operation during additional operating lifetime".

Reference: A-045 [IAEA-CN-155-069]
The in-depth safety analysis (DSAR) is implemented with a "*more profound NPP unit safety analysis*". The concepts within the DSAR are: • "presents design criteria and safety principles; • shows how nuclear and radiation safety requirements are met; • defines and describes safety systems; • gives the value of safe operation limits and design limits for design basis accidents; • carries information on fire safety; • gives the list of expected levels of extreme natural and man-induced impacts with recurrence more than 10-2/year; • presents conditions of normal operation at design modes; • expounds general principles and criteria of physical safety; • gives arrangements plans in case of accidents". The author refers to four appendices which are included within the DSAR: *Appendix 1 "Materials on technical safety justification (TSJ)";* *Appendix 2 "Materials on additional safety justification";* *Appendix 3 "Probabilistic safety analysis";* *Appendix 4 "Analysis of beyond design basis accidents".* This section concludes with the following short statement; *"There are arrangements aimed at assurance of further NPP unit safe operation (beyond design lifetime) listed in the report on in-depth safety analysis".* The remainder of this report focuses on the current operating NPPs in Russia and the implementation of PLEX for each of these.
Document Relationships & Referencing This report relies heavily on the information in NP-017-2000 (Basic Requirements for Power Unit Lifetime Extension of Nuclear Power Plant) with some slight deviations within its wording. A presentation has also been identified, this was used by the author at the Second International Symposium on Nuclear Power Plant Life Management in Shanghai, China. (15-18 October 2007). This presentation relates directly to this report. NP-017-2000, Basic Requirements for Power Unit Lifetime Extension of Nuclear Power Plant. (Nov. 2000). This has been superseded by NP-017-18, (so far unable to find the new document).
Applicability to Beyond Design Life Expectations The approach to long-term operation is similar to that listed in SSG-48 (Review Ref: A-069). Due to the age of the document it is safe to assume that some of these steps may have been developed further or removed from the preparation process.

Reference: A-045 [IAEA-CN-155-069]
As part of a BDL submission it is not unreasonable to assume that some of the legs of the original safety case for an SSC may no longer be applicable. In these instances, other safety assessments/analysis or additional monitoring/inspections may be required to demonstrate continued operation is ALARP. However, the BDL submission should clearly identify any original assessments that may no longer be valid and present alternative strategies to support the justification for extended operation.
Applicability to the ONR SAPs This document focuses on the preparation for LTO and the required analysis and inspection for the justification of LTO. Some of the statements here relate to SC.6 and although no specific components are mentioned EMC.3 and EMC.20 regarding evidence and records of the activities for components are mentioned. A statement in Stage 1, relevant to EAD.5, refers to the need to define the current state of components and those which are important to safety and may become obsolete.
Future Considerations N/A
Additional Notes The Basic Requirements for Power Unit Lifetime Extension of Nuclear Power Plant (NP-017-2000) document (or updated NP-017-18 if found) may be a worthwhile review as part of this phase.

Reference: A-052 [IAEA-EBP-LTO-23]
Document Title/Version Number: Working Group 4, Final Report: Structures and Structural Components
Date of Issue: September 2006
Summary: This is the final report of Working Group 4 of the Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water Moderated Reactors. Working Group 4 focused on Structures and Structural Components. WG 4 is broken down into 6 sections, these sections are: Section 1; Introduction Section 2; Requirements Section 3; Scoping and Screening Section 4; Ageing Management Programmes Section 5; Operational Programmes, and Section 6; Time Limited Ageing Analysis. WG 4 includes several tables which use examples from each country for the classifications that are to be applied to SSCs, facility supporting documents for long-term operation (LTO) and an LTO requirement appendix, listed by country. Also included in the appendix is a description of some Asset Management Programmes (AMP), a list of the degradation mechanisms and their affects and the links to the monitoring method, frequency and criteria. This document makes suggestions for future considerations and recommendations to its member states regarding their current programmes and improvements to the regulatory systems in place. WG 4 objectives: 1. Develop tools to support the identification of safety criteria and practice for structures and structural components associated with the LTO; 2. Identify operators approaches, process, practices associated with ageing and ageing management of structures and structural components; 3. Establish guidance on approaches to LTO; 4. Discuss future challenges; 5. Provide recommendations. The WG 4 scope looked at: 1. All safety–related SSC that are important to the fundamental safety functions: – the control of the reactivity; – the removal of heat from the fuel; and

Reference: A-052 [IAEA-EBP-LTO-23]
– the confinement of radioactive materials and control of operational discharges, as well as limitation of accidental releases. 2. All non–safety related systems, structures, and components whose failure could prevent satisfactory accomplishment of, or initiate challenges to, any of the safety functions defined above. 3. Other areas dedicated to a specific functional purpose that may be essential to safe operation of the plant, such as: – fire protection; – environmental qualification; – pressurized thermal shock; – anticipated transients without scram; – severe accident management; – station blackout. The primary focus of WG 4 activities for SSCs: 1. that are needed through LTO; 2. that are difficult or impossible to replace; 3. whose integrity is essential to ensure safe LTO. *"WG 4 coordinated its activity with WG 2 in relation to material aspects of ageing of steel containments and structural steel, support structures of mechanical components and the interfaces with the items identified above. WG 4 also coordinated its activity with both WG 2 and 3 in relation to procedures for environmental data acquisition".* With regard to the above quote, review of WG 2 is recommended (WG 2 Report "Mechanical Components and Materials").
Key Themes: <u>Section 2; Requirements</u> This section discusses the general safety regulations which have been adopted by various nations within the programme group. The section refers to cases where IAEA documentation has been used to implement ageing management programmes and finishes with a focus for the objectives to come from this discussion: *With respect to LTO, the members of Working Group 4 considered the country practices from the following points of view:* *1. whether the requirements exist for the definition of the scope of structures and structural components within the scope of LTO;* *2. whether the ageing management requirements for structures and structural components are established for LTO.* <u>Section 3; Scoping and Screening.</u>

Reference: A-052 [IAEA-EBP-LTO-23]
3.1, Background; considers the scope and screening that may already exist within the countries and that some high level regulatory documents may exist currently. "*It is recognised that the basis for defining the scope of LTO should be the safety and seismic classification of structures and structural components".* Two flow diagrams are referred to showing the scoping process for LTO (Fig.1, p.7), and the screening process for LTO (Fig.2, p.8). 3.2, Common Elements and Differences; looks at the different approaches by member states, two examples of this are given. The research found that: 1. interacting non–safety structures and structural components are not always included; 2. sometimes non–safety considerations (economy, modernization, reparability) influence the scope; 3. overlapping items (supports, buried pipelines) are not always consistently handled (e.g. in some countries structural supports are considered part of the scope of mechanical SSCs). 3.3, Future Challenges; recognises that the scoping of SSCs requires attention for LTO, this part of the report states; *"The scope has to be defined properly and be all–inclusive to ensure the safety of LTO. In case of missing items or improperly managed SSCs, irreversible ageing processes may result in serious safety issues*". The section considers the impact of non-safety related SSCs on other safety items and suggests that support may be required to identify these within the scope. 3.4, Recommendations; refers to the tables included in the appendix. These tables show *"the typical scope of structures and structural components for each reactor type".* They suggest here that research is required to develop a risk-informed approach to scoping. They also state that *"As techniques develop, it may be possible to relax scoping"*. <u>Section 4; Ageing Management Programmes.</u> 4.1, Background; looks at the technical requirements of AMP for LTO. The report states that it is *"recognised that the AMP should have special characteristics from an LTO perspective: they must address the degradation mechanisms that limit the life of the structures"*. The report states, "*the performance and safety margins of passive long–lived SSCs are assumed to be guaranteed by design"*. Operational experience tells us that this is not always the case, therefore NPPs should monitor the effects of processes and environment on SSCs. The paragraph continues by concluding that AMPs should be a condition of operation and states that AMPs should also be *"a pre–condition for LTO"*. This section also eludes to the connection between asset management/plant maintenance programmes and ageing management, it states, *"ageing management is intended to provide a cross–cutting connection among all maintenance and inspection activities, and to provide a unified understanding and treatment of the degradation phenomena".* Also, *"It was recognised that the majority of the AM programmes required either already exist as plant programmes or are programmes that need to be enhanced to address attributes of an acceptable ageing management programme"*.

Reference: A-052 [IAEA-EBP-LTO-23]
Working Group 4 suggest that the core elements of LTO are: 1. Systematic identification of the ageing effects on structures and components; 2. Review of the relevant existing plant programmes; 3. Evaluation of existing programmes against the attributes considered necessary for an acceptable ageing management programme; 4. Improvement of the existing programme or development of new ageing management programmes based on the attributes, if necessary. 4.1.1, Applicable ageing effects; refers to the requirement for a *"systematic approach to the identification of ageing mechanisms relevant to LTO"* and a *"consistent and all-inclusive list of degradation mechanisms"* of SSCs which includes the materials and the site specific effects which should be considered. (References example Table 3-2 of the appendix). They also recognise the importance of the degradation acceptance criteria which some of the member states have not yet developed. 4.1.2, Ageing mitigation measures; the report states here that *"there are cases where the monitoring, evaluation and trending of ageing processes are not integrated together with the corresponding mitigation measures into one coherent programme. The mitigating measures are standalone programmes or they are part of another programme"*. 4.3, Future Challenges; refers to the aims of an AMP and lists some issues which they deem as decisive: 1. Completeness of the identification of ageing mechanisms and of sensitive locations for each structure and structural component; 2. Criteria for assessment of acceptability of ageing; 3. Adequacy of trending methods; 4. Evaluation of ageing at hidden, non-accessible places; 5. Crediting of existing programmes, attributes of adequate AMPs; 6. Review methodology of ongoing programmes. When considering the safety functions of the SSCs it states, *"the actual condition of structures and structural components has to be compared with licence conditions and requirements in order to provide proof of the capability of the building structure to fulfil its assigned safety functions"*. 4.4, Recommendations; Here the report states that *"The review of the ageing management programmes should be conducted in the frame of LTO programme, in order to check whether the control of ageing is adequate to support a decision on LTO and to ensure the safety for long term"*. A list of attributes for AMPs has been listed as follows: 1. A defined programme scope; 2. Identification of preventive actions or parameters to be monitored or inspected; 3. Detection of ageing degradation/effects;

Reference: A-052 [IAEA-EBP-LTO-23]
4. Monitoring and trending including frequency and methodologies; 5. Pre–established acceptance criteria; 6. Corrective actions if a component fails to meet the acceptance criteria; 7. Confirmation that required actions have been taken; 8. Administrative controls that document the programme's implementation and the actions taken; 9. Operating experience feedback. *Essential elements of the review are the assessment of the AMP experience. The plants should demonstrate the following for the extended operational lifetime:* 1. The safety and ageing analysis remain valid and could be projected to the end of intended operational lifetime; 2. The effects of ageing on the intended function(s) will be adequately managed; 3. There is a procedure to deal with unexpected ageing mechanisms that can surface in later years. Suggestions are made regarding maintaining the safety margins by implementing *"state-of-the-art methods"* and *"reviewing the existing design analysis for conservatism"*. These assumptions may have been made regarding the environment and processes which may not currently be valid. To conclude this section a list of recommendations has been created following the review of member state current practices. They suggest coordinated research activities, development of master AMPs, generalising experience to provide methods and criteria and finding solutions to inaccessible safety related SSCs for monitoring. <u>Section 5, Operational Programmes.</u> 5.1; This section refers to in-service inspections (ISI) regarding LTO. They state that the ISI practice is included in the framework of the PSR, however "*the criteria (safety factor description) for the review can be rather generic".* A list of ISI methods is given e.g. visual inspections (walk-downs) and NDT. WG 4 refers to the data collected as part of an ISI and states: *"The data and information obtained from the inspections and condition monitoring programmes are subject to evaluation and assessment. In some countries state–of–the–art databases and evaluation software were developed to store the ISI and monitoring data and to support the evaluation of the data. Results are to be compared with licence conditions and requirements in order to provide proof of the capability of the building structure to fulfil its assigned safety functions".* *"An acceptable ISI programmes should include the method of monitoring for each degradation factor important for long term operation including information on frequency of performed measurements and/or inspections".* *"Monitoring the condition of safety significant structures is an essential assumption of long term operation and the knowledge of the structure history is the basis for residual lifetime assessment".*

Reference: A-052 [IAEA-EBP-LTO-23]
This section continues the theme of in-service inspections considering the various practices across the member states. They refer to the appendix for the LTO scope and the list of degradation mechanisms and state that in most cases the member states use visual inspections as the basic method of ISI and some permanent monitoring systems which are analysed by computerised systems. 5.1.4, Recommendations; the report concludes this part by recommending that *"NPP operators should prepare the detailed procedures covering the scope selected for LTO"*. Suggestions are made here that these procedures should be based on the current programmes and the operational experience of the NPP. The programmes found to be compatible for LTO should *"address all the selected/expected ageing mechanisms and that they include a feedback procedure to adapt the ISI to the outcome of the operational experience".* Section 4.4 recommendations are referenced here as valid for ISI and monitoring programmes. 5.2.1; Referring back to the statement in section 5.1 regarding the PSR "*the criteria (safety factor description) for the review can be rather generic"* the report also suggests that the *"Implementation of condition dependent maintenance is also a generic tendency or practice"* and the success of these practices are directly linked to the monitoring, ISI and AM programmes. 5.2.2; Regarding maintenance practices the report notes that the understanding of the degradation mechanism is essential for the implementation of the correct maintenance program and the overall effectiveness of that maintenance. It states here that, *"a well-established and effective maintenance programme is one of the basic tools for ensuring long term operation"*. 5.2.3; This paragraph considers the development of the maintenance in relation to limitations and accessibility issues. The evaluation of the current maintenance practices will be required where accessibility issues restrict some maintenance activities. Suggestions here revolve around the development of the current techniques and use of experience to gauge the efficiency of the maintenance based on the safety criteria for the item in question. Regarding LTO it states, *"Development of the maintenance should be in line with the requirements of LTO and should address the ageing processes, locations and structures".* 5.2.4; This recommendation section refers to the previous paragraphs on maintenance and states *"The maintenance should be an effective tool of mitigation of ageing processes. Therefore, the implementation of condition/ageing dependent maintenance should be enforced"*. The report suggests here that the review for LTO should look at the *"adequacy of maintenance programmes and evaluation of their efficiency"* and whether the criteria and methodology for these programmes is sufficient. Also noted here is how a standard preventative maintenance programme is not suitable to support LTO, this programme should be condition based. *"The attributes of such a programme should be made clear in terms of target performance goal, identification of the functional failure, feedback on the ISI and feedback on the operational limits and conditions"*. <u>Section 6; Time Limited Ageing Analysis</u>. 6.1; This section refers to two tasks, Trend Analysis and Time Limited Ageing Analysis (TLAA), which it suggests are connected to the evaluation of the life of structures and structural components. In reference to the first task they define Trend Analysis as an aim to predict changes to the SSCs while considering the environment and operational conditions. Taking the previous conditions into account has this altered the design life of the SSC?

Reference: A-052 [IAEA-EBP-LTO-23]
The second task, TLAA, is referred to as licensee calculations and analysis. The following are listed as criteria for the TLAA to satisfy: 1. Involve systems, structures, and components within the scope of licence renewal; 2. Consider the effects of ageing; 3. Involve time–limited assumptions defined by the current operating term, for example, 40 years; 4. Were determined to be relevant by the licensee in making a safety determination; 5. Involve conclusions or provide the basis for conclusions related to the capability of the system, structure, and component to perform its intended functions; and 6. Are contained or incorporated by reference in the current licensing basis (CLB). Suggestions are made here for re-evaluations of assumptions of plant lifetime prior to LTO. The report lists some of possible outcomes of this review. This list has appeared in other documents within the review area of the IAEA and is not as extensive as that listed in the A-069 review of SSG-48 (Para 3.34 & 3.35). In both cases, Trend Analysis and TLAA, should the analysis show a change in design life of the SSC or the design information is not available for the SSC, the following statement is relevant, *"a complete re–analysis of the ageing process is needed"*. This should be done to set the time limits of safe operation for this SSC in relation to its potential LTO. *"The review of TLAAs is a regulated part of the license renewal process. In the case of PSR, the resolution of the time limitation due to ageing should be valid at least for the next PSR period".* *"The knowledge of time limits set by TLAA is also recognised as very important from the point of view of condition monitoring. The assumptions made in TLAAs and the ISI and monitoring records provide a solid basis for the assessment of the time limits of safe operation".* Regarding extension of life for SSCs the report states, *"it is necessary to take into account changes in material parameters caused by ageing and then assess the residual lifetime and safety margin".* The report continues with suggestions of further developed trending and evaluations, applying deterministic and probabilistic approaches along with a combination of *"experimental verification and numerical modelling"*. Parts 6.2 and 6.3 of this section refer to the member states and the types of challenges they have and the different approaches. They discuss the different analysis methods and conclude that the probabilistic approach is needed as *"degrading factors"* on structures are of a random nature, stating *"For lifetime assessment, safety margin determination and trends evaluation, the probabilistic approach represents a very progressive and perspective method"*. 6.4; As part of the recommendations for this section the report concludes that the trending methods and TLAA are important tasks for LTO submission. In the context of a review the report considers the operational time limits due to ageing and the related issues that this brings as *"an obligatory task for LTO"*. In reference to the earlier statement regarding areas where Trend Analysis cannot be guaranteed and TLAAs from the design stage are not available, the report concludes that, *"depending on the safety relevance, a complete re–analysis of the ageing process might be needed and the time limits of safe operation should be set. In difficult cases, when the margins are not large, it is reasonable to implement*

Reference: A-052 [IAEA-EBP-LTO-23]
sophisticated state–of–the–art techniques, data on loads and cycles taken from operational history, experience based data on environmental conditions, etc.”
Document Relationships & Referencing This programme was carried out between 2003 and 2006, many of the themes here have been developed further and documented in the 2009 publication NS-G-2.12 which has since been superseded by SSG-48 in 2018. The parent document for this report is the Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water Moderated Reactors (SALTO). This document references back to the other Working Group reports (1-3).
Applicability to Beyond Design Life Expectations The themes from this document list some of the key issues/requirements recognised by the SALTO group 4. These could aid the creation of questions to gain insight into or evidence of, the preparation for LTO for a specific site or SSC.
Applicability to the ONR SAPs Several SAPs may be relevant to this document, some examples of these include ECE.12 and ESS.10 which are referred to in the AMP theme when considering the capability of the safety functions of structures and the comparison with the original analysis. The operational theme refers to the method and frequency of inspections and testing which relate to EMT.1 and 2. Section 6 considers the TLAAs, this refers to the lifetime margins (EAD.2) and the effects of time on the SSCs (EAD.3 and 4).
Future Considerations N/A
Additional Notes As stated in the summary, a review of Working Group 2 should be considered.

Reference: A-053 [IAEA-EBP-LTO-25]

Document Title/Version Number: Final report on the Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water Moderated Reactors (SALTO).

Date of Issue: Programme dates May 2003 to September 2006

Summary:

The Extrabudgetary Programme on Safety Aspects of Long Term Operation of Water Moderated Reactors contains 4 working groups lead by a steering committee. Each working group produced a final report based on their findings in the area allocated. The programme also contained a final report which summarises the results, conclusions and recommendations of the programme with regards to long term operation, mechanical components and materials, E/I&C and SSCs. More detailed information is included in the 4 working group reports prepared in the framework of this Programme.

This review contains an overview of the SALTO program's working groups (1-4) and a review of the final report on the safety aspects of LTO.

Programme overview.

Increasing numbers of IAEA member states are looking into the long term operation (LTO) of existing Nuclear Power Plants (NPPs), this programme was devised after the IAEA recognised that *"internationally agreed-upon, comprehensive guidance was needed to assist regulators and operators in dealing with the unique challenges associated with the LTO"*.

The report defines long term operation as *"operation beyond an initial time frame set forth by licence term, design limits, standards, and/or regulations etc., which has been justified by safety assessment considering life limiting processes and features for systems, structures and components (SSCs)".* (Definition reference; Final report [25] Section 2 'General Framework').

"The Programme was carried out by means of exchange of experience and formulation of guidance, which will assist regulators and plant operators considering long term operation".

The programme uses the IAEA Safety Guide for PSRs (NS-G-2.10) as a reference, this document is also referred to in the review of SSG-48 (Ref; A-069). The Safety Guide contains Safety Factors which each of the Working Groups identified as part of their objectives.

The scope:

"The scope of the Programme included general long term operation framework, mechanical components and materials, electrical components and instrumentation and control, and structural components and structures".

The program's objectives were to *"assist those Member States considering LTO of water moderated reactors in how best to reconcile the related processes and practices; how to establish a general LTO framework; and finally, it provides a forum in which Member States can freely exchange information"*.

A steering Committee was set up to guide the programme through 4 working groups and one final report, these groups were:

- Working Group 1: General Long Term Operation Framework (IAEA-EBP-LTO-20)
- Working Group 2: Mechanical Components and Materials (IAEA-EBP-LTO-21)

Reference: A-053 [IAEA-EBP-LTO-25]

- Working Group 3: Electrical Components and I&C (IAEA-EBP-LTO-22)
- Working Group 4: Structures and Structural Components (IAEA-EBP-LTO-23)
- Final report of the programme on S.A.L.T.O. of water moderated reactors (IAEA-EBP-LTO-25)

There is also another document (IAEA-EBP-LTO-24) which contains the minutes from the meetings of the working group leaders and secretaries.

Overview of the reports.

Working Group 1, Final Report: General Long Term Operation Framework IAEA-EBP-LTO-20.

WG 1 objectives were to identify the pre-conditions for LTO, review current laws and regulations relevant to LTO and to consider the programmes and analysis required for LTO. Current design requirements, considerations for planned LTO activities, existing programmes, research results and operating experiences were considered. This was not considered for review in this phase of the project.

Working Group 2, Final Report: Mechanical Components and Materials IAEA-EBP-LTO-21.

WG 2 objectives were to look at the practices in the area of mechanical components and materials, to consider tools that can be developed to support these practices and assist operators and regulators to achieve the required safety levels.

A review of this document is recommended.

Working Group 3, Final Report: Electrical Components and I&C IAEA-EBP-LTO-22.

WG 3 objectives were to look into the guidance to help identify the safety criteria and good practice for E/I&C. This was not considered for review in this phase of the project.

Working Group 4, Final Report: Structures and Structural Components IAEA-EBP-LTO-23.

This document has been reviewed as part of this phase of the project. Review reference A-052 (IAEA-EBP-LTO-23).

Final Report: Safety Aspects of Long Term Operation of Water Moderated Reactors IAEA-EBP-LTO-25.

This report is split into sections covering:

- Summary
- General framework for LTO
- Plant activities for LTO
- Research programmes
- Appendix (including the WG 1-4 reports)

LTO-25, Summary.

This report covers the main outcomes and recommendations to come from the programme, referring back to the above Working Group reports (1-4). This final report could be used to assist regulatory bodies and operators in preparation for LTO.

Reference: A-053 [IAEA-EBP-LTO-25]

The report lists 4 main principles for the approach to LTO, these are;

1. Current operational practices meet national regulations and international guidelines and are adequate to ensure safe operation of the NPP during the current period of operation.
2. The existing regulatory process is adequate to maintain safe operation of the NPP and should be carried over the period of LTO provided the effects of ageing are managed.
3. The current licensing basis provides an acceptable level of safety and should be carried over the LTO in the same manner to the same extent, with the exception of any changes specific to LTO.
4. NPP programmes may be credited for use in LTO provided that they meet the evaluation criteria that are provided in Section 3.2.

Key Themes

Preconditions (referred to in section 2.6).

"It is recommended that the following plant programmes and documentation, which were specifically selected by WG1, be considered preconditions for LTO, because these plant programmes and documentation impact all areas of plant operation identified in the scope of Working Groups 2, 3 and 4.

1. Existing plant programmes;
    - In-service inspection
    - Maintenance
    - Equipment qualification
    - In-service testing
    - Surveillance
2. Quality assurance, and configuration management;
3. Original time limited ageing analyses (TLAA) or residual life assessment;
4. Updated final safety analysis report (FSAR).

LTO Engineering Process (referred to in section 2.4).

This part of the first section gives a brief overview of the LTO evaluation process;

1. SSCs which fall within the scope of LTO should be evaluated (scoping and screening for SSCs is included in WG.4, refer to Ref. A-052, Section 3).
2. Identification of current programmes and their effectiveness for LTO and consider adjustments or new programme developments to ensure the safety functions are met during LTO.
3. Consider each of the SSCs within the scope of LTO for the effects of ageing and ensure these are managed accordingly.

Reference: A-053 [IAEA-EBP-LTO-25]

4. Time Limited Ageing Analysis (TLAA) data for existing plant equipment should be reviewed and reassessed, new assumptions should be made regarding the time limits and the design safety margin should be confirmed. (Trending/TLAAs for SSCs is included in WG.4, refer to Ref. A-052, Section 6).
5. Regarding the plant programmes identified, implement the changes or develop the new programmes as required.
6. Referring back to the preconditions (above), the results from this process should be updated into the final safety analysis report.

<u>Modifications to Existing Plant Programmes.</u>

If modifications to current programmes are required, these must be evaluated for their effectiveness in detecting the ageing effects and clarification is required to prove that the safety functions will be maintained.

The report lists 5 current plant programmes which it considers to be preconditions and therefore candidates for LTO;

1. In-service inspection
2. Maintenance
3. Equipment qualification
4. In-service testing
5. Surveillance

<u>Review of Ageing Management Programmes.</u>

The report lists nine attributes for an *"effective ageing management programme"*.

These are;

1. A defined programme scope
2. Identification of preventive actions or parameters to be monitored or inspected
3. Detection of ageing degradation/effects
4. Monitoring and trending including frequency and methodologies
5. Preestablished acceptance criteria
6. Corrective actions if a component fails to meet the acceptance criteria
7. Confirmation that required action has been taken
8. Administrative controls that document the programmes implementation and actions taken
9. Operating experience feedback

<u>Revalidation of Time Limited Ageing Analysis.</u>

Reference: A-053 [IAEA-EBP-LTO-25]

For long term operation, once a TLAA is identified, an evaluation will be performed with the new assumed time of plant operation to demonstrate that the component will maintain its safety margin at the end of the extended plant life, and that at least one of the following criteria is applicable:

1. The analysis remains valid for the period of long term operation,
2. The analysis has been projected to the end of the period of long term operation, or
3. The effects of ageing on the intended function(s) will be adequately managed for the period of long term operation.

TLAA and the revalidation, including reanalysis requirements have been reviewed as part of WG.4 (Ref. A-052, Section 6).

General Recommendations.

1. Requirements for long term operation of existing nuclear power plants should be specified within their regulatory framework and a technical basis justifying the period of operation beyond design life of the facilities should be provided.
2. A set of preconditions containing plant specific programmes for LTO as defined in this report should be implemented and appropriately documented.
3. The FSAR and its updates or other licensing documents should clearly and adequately describe the current licensing basis or the current design basis requirements for current plant operation. It is recommended that the implementation of plant activities for LTO should be properly documented in updating FSAR or other licensing documents that integrates the results of the LTO engineering process and constitutes the basis documents for LTO application and approval.
4. Existing NPP programmes may be credited with some modifications or enhancements upon evaluation/assessment for use in LTO. The evaluation criteria for existing NPP programmes are provided in Section 3.2. Ageing management programmes (AMPs) may be needed (or need to be modified) for those structures and components that were not in the scope for the current plant programme, but are in the scope for LTO for reasons such as operating experience, or PSA.

Section 2 General Framework for LTO.

This section gives a brief description of the processes, regulations and requirements for the implementation of LTO. The definition of LTO agreed by the member states is included (this is given in the programme overview at the beginning of this document) along with some recommendations regarding the documentation for justification of LTO.

2.2 Laws and Regulations Relevant to LTO; refers to the laws and regulations within the member states. The report considers the varying degrees with which the member states utilise the IAEA recommendations stating that "With respect to long term operation, the laws and regulations in Member States range from a general decree to a very prescriptive law of technical requirements".

2.3 Current Design Basis Requirements and Plant Practices; contains information on current design basis requirements and plant practices within the member states. In this part, the report lists these requirements and activities it deems significant for LTO and gives a brief description of each.

These are;

Reference: A-053 [IAEA-EBP-LTO-25]

1. General design codes and standards
2. Equipment qualification
3. Maintenance practices
4. In-service inspection, testing, surveillance and monitoring
5. Time limited ageing analysis
6. Quality assurance and configuration management

2.4 Description of LTO Process; lists the approaches to LTO and the principles on which this approach should be based, the SSCs within the scope of LTO and their functions and the LTO engineering evaluation process.

The LTO principles are:

1. Current operational practices meet national regulations and international guidelines and are adequate to ensure safe operation of the NPP during the current period of operation.
2. The existing regulatory process is adequate to maintain safe operation of the NPP and should be carried over the period of LTO provided the effects of ageing are managed.
3. The current licensing basis provides an acceptable level of safety and should be carried over the LTO in the same manner to the same extent, with the exception of any changes specific to LTO.
4. NPP programmes may be credited for use in LTO provided that they have the nine attributes. (The nine attributes referenced here are listed in the document summary above).

The SSC functions are:

1. All SSCs important to safety that ensure the integrity of the reactor coolant pressure boundary.
2. All SSCs important to safety that ensure the capability to shut down the reactor and maintain it in a safe shut down condition.
3. All SSCs important to safety that ensure the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the limits specified in the regulations of individual Member States.
4. All SSCs not important to safety but whose failure could prevent satisfactory accomplishment of, or initiate challenges to, any of the safety functions defined above.

In addition to these it was noted that some member states may *"require that all SSCs that are credited in safety analysis to perform a function that mitigates the following events are also in the scope of LTO":*

1. Fires and floods
2. Pressurized thermal shock
3. Anticipated transient without scram (ATWS)
4. Station blackout.

Reference: A-053 [IAEA-EBP-LTO-25]
The engineering evaluation has been noted in the summary section above. 2.6 Preconditions for LTO; As listed in the summary there are existing plant programmes which can considered preconditions for LTO. Some LTO experience taken from the member states recommend the following activities prior to LTO implementation: 1. Technical assessment of LTO feasibility; including compliance with regulatory safety requirements; 2. Economical assessment of LTO feasibility; including the cost of any safety upgrades necessary for LTO; 3. Detailed plant programmes for LTO implementation. 2.8 Recommendations; states *"Requirements for long term operation of existing nuclear power plants should be specified within their regulatory framework and a technical basis justifying the period of operation beyond design life of the plants should be provided".* Additional recommendations regarding the documentation for justification, these include documented LTO plant activities, updating the licence documents with any changes and including the results from the engineering evaluation to form the licence application for LTO. Section 3 Plant Activities for LTO. This section refers back to the plant programmes that are considered preconditions for LTO, each of these programmes are described in more detail along with some recommendations for each regarding LTO. Also included in this section are the nine attributes for the AMP and more detail on the TLAA required for LTO. Many of the statements within this section are similar to those found in the SSG-48 document which has also been reviewed as part of this phase. 3.1.1 In-service Inspection; describes the basic methods of in-service inspection (ISI) used by most NPPs and recommends the implementation of a risk informed (RI) approach. The RI would look at the scope of ISI (RI-ISI), the periods required and the consequences of a failure to determine these. Recommendations include; 1. the methodology, personnel and equipment used for ISI should be qualified as per national standards and regulatory requirements. 2. the development of ISI reviews for ascertaining the effectiveness of the inspections for the detection of ageing mechanisms. The report states "The review process should provide a technical basis that justifies that the ageing phenomena will be adequately detected with the proposed inspection or monitoring activities". 3. a living database should be used for documenting the effectiveness of the ISI and to "provide technical references to support findings and conclusions". *"If RI-ISI programmes are to be used during the period of LTO, consideration should be given to 1) developing comprehensive regulatory requirements for implementation of RI-ISI and 2) the effectiveness of RI-ISI should be evaluated as recommended under attribute 7".* (The reference here is to the nine attributes of the AMP which have been listed in the document summary above). 3.1.2 Maintenance; refers to the ISI paragraphs regarding the activities and evaluations, it states here that *"Maintenance programmes for LTO should clearly identify the type of maintenance (preventive, predictive*

Reference: A-053 [IAEA-EBP-LTO-25]

and corrective), the links with ageing management programmes, the frequency and tasks, the records, their evaluation and storage for optimization".

To continue the link with suggestions in the above ISI paragraphs the report states that the maintenance programme should be reviewed for its effectiveness in detecting the ageing mechanisms.

Further recommendations include;

1. considering short-comings in the current programme and technical developments.
2. a living database (as above)
3. *"organizations should consider applying destructive testing methods using specimens of electrical cables that were exposed actual environmental conditions during operation to monitor material degradation of during LTO"*.

There are further, more detailed descriptions, of ISI and maintenance for SSCs within the WG.4 document (A-052, Section 5, Operational Programmes).

3.1.3 Equipment Qualification; considers the assurances that, over the period of LTO;

1. the equipment will continue to fulfil its function throughout the intended period of operation,
2. the ageing effects would be managed effectively,
3. if required, the equipment would be replaced in order to fulfil its intended function.

The report also states, *"Equipment designed according to earlier standards should be requalified under a comprehensive programme that is focused to ensure that the equipment can perform its design function under current design basis accident conditions"*.

Regarding the documentation for equipment qualification the report states that it *"should be stored in auditable form during the entire installed life of equipment including LTO"*.

3.1.5 Surveillance and Monitoring Programmes; The results from this type of programme can be used to confirm the components current operational state and to predict the performance of the component, making judgements based on operating experience and trending to prevent any future failures. The report states, *"surveillance programmes using representative material samples addressing time limiting mechanisms should be extended or supplemented for LTO, if necessary"*.

3.2 Ageing Management Programmes for LTO; states, *"Ageing is the continuous time degradation of materials due to normal service conditions which include normal operation and transient conditions. The ageing management is combination of engineering, operations and maintenance actions to control ageing degradation and wear out of structures, systems or components remains within acceptable limits"*.

This part of section 3 lists the nine attributes previously stated in this review and gives a brief description of each. Also included in this part are 3 steps of an ageing management review for the SSCs identified in the LTO scoping and screening process.

Step 1: An engineering assessment of the current status of SSCs within the scope, and a confirmation of the ageing effects and degradation mechanisms of these SSCs.

Step 2: An evaluation process involving a review of the existing programmes and a review of the proposed ageing management programmes.

Reference: A-053 [IAEA-EBP-LTO-25]

Step 3: The documentation of *"the technical justification demonstrating that the structures and components within the scope of LTO, identified in Step 1 will fulfil their safety related functions during the proposed period of LTO"*.

3.3 Identification and Revalidation of Time limited Ageing Analysis; This area is covered in WG.4 and some relevant statements can be found in the review which has been conducted as part of this phase. (Ref: A-052, Section 6). In addition to the area covered in WG.4 this report lists some common TLAAs, these are:

1. Reactor pressure vessel irradiation embrittlement
2. Metal fatigue
3. Fracture mechanics analysis
4. Thermal ageing
5. Loss of preload
6. Loss of material

The final section of this report (Section 4) looks at the research programmes and operating experiences. This section concludes that member states do not currently share analysis and research results and suggests that a process for this needs to be created.

The report lists some objectives/considerations for a collaborative project like this, the objectives are:

1. Identification of degradation mechanisms and their effects on long term functionality of safety related SSCs;
2. Development of databases on ageing management assessment;
3. Design of upgraded monitoring system to ensure accurate monitoring of all significant degradation effects;
4. Analysis and trending of data for the evolution of SSCs degradation processes;
5. Development of ageing management programs to minimize ageing degradation processes including the corrective measures of their effects.

Document Relationships & Referencing

This programme was carried out between 2003 and 2006, many of the themes here have been developed further and documented in the 2009 publication NS-G-2.12 which has since been superseded by SSG-48 in 2018. There are several themes within this document which have some additional detail within the individual Working Group final reports.

Applicability to Beyond Design Life Expectations

N/A

Applicability to the ONR SAPs

N/A

Reference: A-053 [IAEA-EBP-LTO-25]
Future Considerations The Working Group 2 Final Report would be a worthwhile consideration as part of this phase of the project.
Additional Notes N/A

Reference: A-054 [IAEA-INSAG-14]
Document Title/Version Number: Safe Management of the Operating Lifetimes of Nuclear Power Plants.
Date of Issue: November 1999
Summary: This report by INSAG deals with a general approach to the safe management of the operating lifetimes of nuclear power plants. It responds to the concerns about maintaining adequate safety levels at ageing plants, even beyond their design lifetimes. The objectives of this report were to: 1. suggest a general safety objective for safe management of the operating lifetimes of nuclear power plants; 2. reflect on the ageing processes that can degrade the integrity of structures and components over time; 3. present some considerations about ageing that should be taken into consideration at the design and construction stages for new plants; 4. present principles related to the treatment of physical ageing of structures and components, in order to maintain operating plants consistent with their initial design basis; 5. emphasise the need to check whether the safety levels of operating plants are still acceptable, or whether they may possibly have to be upgraded; 6. promote safety reviews as a good means of dealing with these issues; 7. draw attention to infrastructural issues that may influence the capability to provide adequate means for safe management of the operating lifetimes of nuclear power plants, and underlines that these areas have also to be properly managed; 8. emphasise the distinct yet interdependent roles of both the operating organization and the regulator in the safe management of the operating lifetimes of nuclear power plants. *"The general objective for safe management of the operating lifetimes of nuclear power plants is to maintain the safety level of each plant at all times higher than its reference level defined by the corresponding safety case, which is the basis for safe operation and which is at the same time consistent with the regulator's requirements". This general objective covers two issues. Firstly, the characteristics of the various structures and components related to the safety of a nuclear power plant should not degrade below the values considered in the design, which incorporates provisions for ageing effects. Secondly, the expected and acceptable safety level at the time of the design may later come to be regarded as insufficient and its continued acceptability for further operation has to be assessed".*
Key Themes <u>Design Stage Considerations</u>. Degradation mechanisms that could be detrimental to structures, systems and components related to the safety of a nuclear power plant are taken into account from the design stage. Design provisions are made to permit appropriate surveillance activities throughout the operating lifetime of the plant in order to verify

Reference: A-054 [IAEA-INSAG-14]
the continued acceptability of operation at an adequate safety level. Consideration is also given to potential future requirements for repair or replacement of structures, systems and components. At the design stage recognition is also given to the potential increase in the probability of common cause failures due to the degradation of redundant components. Consideration of ageing processes may therefore lead to the introduction of diversity into the design to ensure that an adequate level of reliability can be maintained. The actual evolution of equipment may differ considerably from the expectations at the time of the design, with either beneficial or harmful effects on safety. <u>Lifetime Management/Obsolescence</u>. Particular attention is paid to the reliability of equipment which is required to perform a safety function under accident conditions. Such equipment is qualified taking into account not only the potential ambient accident conditions but also ageing effects. Qualification has to be maintained throughout the operating lifetime of the plant and can give rise to the need for periodic replacement of equipment. The potential operating lifetimes for components considered not to be replaceable are assessed and periodically updated, enabling a prediction of the plant's potential operating lifetime to be made. Checks are also made to confirm that not too many components would have to be replaced over a short period of time, thus creating a further possible limit to future economic operation. Particular difficulties arise if an item is no longer available, whether because it has been technically superseded or because the supplier no longer exists or no longer manufactures the item. Comprehensive and systematic studies should be conducted over the entire operating lifetimes of the plants in order to: 1. enhance or refine understanding of significant ageing mechanisms; 2. determine the cause of any failure or unexpected degradation experienced during operation; 3. develop existing and new techniques to improve the prospects of timely detection of ageing degradation; 4. seek to control the rates of the ageing processes or to mitigate their effects. <u>Ageing of SSCs</u>. Physical ageing involves changes (often degradation) in the characteristics of structures and components arising from their service or storage conditions; however, the rates of these changes vary considerably. The time dependent degradations can impact significantly on the safety, reliability, operating efficiency and cost effectiveness of industrial facilities. It is normal industrial practice therefore to repair, refurbish or replace plant equipment that has failed and, in some cases, plant items the reliability of which has been called into question. Some items are, in fact, replaced in advance of failure on a schedule that takes account of the failure history of the item or similar items. Ageing of structures, systems and components begins with the construction stage. Mistakes or oversights at this stage in equipment related to the safety of a plant can induce life limiting consequences for the plant.

Reference: A-054 [IAEA-INSAG-14]

Regarding maintaining safety margins/levels a principle is stated as:

"In order to meet the general objective for safe management of the operating lifetimes of nuclear power plants, adequate provision is made to confirm that the characteristics of the various structures, systems and components related to the safety of each plant remain better than the limiting characteristics considered at the design stage".

The effective application of this principle implies that:

1. the limiting functional characteristics of the various items of equipment related to the safety of the plant are defined and reviewed;
2. the degradation mechanisms for these items of equipment are identified and provisions such as adequate operating procedures and technical specifications are implemented to minimize the expected degradations; the effects of ageing are monitored and the results are used to predict the residual potential lifetime of the plant;
3. a maintenance policy is in place, so that appropriate decisions are taken in a timely manner to maintain the safety characteristics within allowable ranges, by repair, replacement or adjustment of operating conditions.

<u>OPEX</u>.

"The identification of possible degradation mechanisms takes into account operating experience and the results of research it is therefore essential that links among operating organizations are developed and maintained to exchange information on operating experience and to optimize research". Over the last two decades since this document was written, the IGALL database and the Extra Budgetary Programmes have been introduced to allow for the exchange of OPEX and good practice. These sorts of initiatives and reports have been instrumental in the creation of SSG-48.

Surveillance/monitoring activities can be enhanced or modified during the operating lifetime of a nuclear power plant, depending on advancements in knowledge, in connection notably with operating experience and the results of research.

<u>Programmes</u>.

For many degradation mechanisms that are gradual, appropriate monitoring can provide adequate time to predict the rate of degradation and to implement corrective actions, as necessary. The scope and the frequency of surveillance activities depend on the safety importance of the corresponding structures, systems and components as well as on the knowledge of degradation mechanisms.

A recommendation of surveillance activities generally corresponds to the 'second level of defence in depth' as stated in 75-INSAG-3 and INSAG-10.

To obtain data, taking samples from equipment in operating nuclear power plants at different ages may be beneficial.

The implementation of large scale inspection programmes to identify unexpected degradation, or to determine the evolution of degradation, could be limited by the capabilities of the available techniques, notably of non-destructive examination techniques. This calls for the implementation of research programmes and development activities relating to diagnostic techniques to improve the ability to assess the real condition of ageing nuclear power plants.

Reference: A-054 [IAEA-INSAG-14]
The benefit of a good ageing management programme is that the operating lifetime of a nuclear power plant would in practice be limited only by the degradation of: 1. items that could not be realistically replaced because of the technical complexity of the replacement and of the associated cost (e.g. reactor pressure vessel, containment building, large parts of electrical, instrumentation and control cables); 2. items that could not be economically replaced after 'failure', owing to the limited expected residual operating lifetime of the plant (e.g. steam generators that would 'fail' a few years before the end of the expected operating lifetime of the reactor pressure vessel). This document dates back to the early days of ageing management and LTO, in the years that have followed significant work has been undertaken in the development of ageing management and LTO processes. The collation of different experiences from across the industry to distil common approaches has contributed to the development of many documents including the current approaches outlined in SSG-48. This document represents the start of this journey and as such does not add any new or additional themes or considerations.
Document Relationships & Referencing This document looks at ageing management from the perspective of development of techniques that have since been developed further it, and the documents it references (INSAG-10 &12), were a part of the development of NS-G-2.12, which has been superseded by SSG-48 (reviewed as part of this phase, Ref: A-069).
Applicability to Beyond Design Life Expectations Other than showing the early stages of ageing management approaches and some considerations for LTO, this does not give anything of significance beyond that of SSG-48.
Applicability to the ONR SAPs The contents of this document could be relevant to a wide range of SAPs, it refers to the need for equipment qualification, additional activities such as monitoring, considerations for the maintenance of the safety margins and the ageing and degradation mechanisms of SSCs. This document has also been reviewed as part of the ONR376 task (Ageing and Degradation).
Future Considerations N/A
Additional Notes N/A

Reference: A-055 [IAEA-INSAG-19]
Document Title/Version Number: Maintaining the Design Integrity of Nuclear Installations throughout their Operating Life.
Date of Issue: December 2003
Summary: This INSAG report discusses the problem of maintaining the integrity of design of a nuclear power plant over its entire lifetime in order to achieve a continuous high level of safety. As the title states, this document concentrates on design and how the organisation responsible for the plant retains the design knowledge and maintains the impact of design changes over the lifetime of the plant. The challenges faced can span *"several working lifetimes of the staff"* and the length of time the plant is required to operate has specific challenges to its safety. This report is aimed at senior executives responsible for: 1. The overall safety of nuclear installations 2. The operation, maintenance and modification of nuclear installations 3. The original design of nuclear installations, including the nuclear steam supply, the balance of plant and major components 4. Regulatory supervision of licence activities Due to the age of this document some of the references have been superseded and the ideas developed further. The design themes within this document are included as part of SSG-48 (Review Ref: A-069), this document adds to that with a description of the design authorities' responsibilities within the operating organisation.
Key Themes <ins>Design Life.</ins> For organisations, when taking control of the plant, they suggest that a *"formally designated entity"* (the design authority) within the organisation should take responsibility for the approval of design changes and the maintenance of design integrity. Regarding the knowledge of the design and its impact on the operation it states here that "*the operating company is frequently the only organisation that has an overview of the design as a whole*". It also states that due to the specialised knowledge of the SSCs required, the organisation may assign responsibilities to other entities with that specialised knowledge. The knowledge that should be available includes: 1. A detailed understanding of why the design is as it is. 2. The experimental and research knowledge on which the design is based.

Reference: A-055 [IAEA-INSAG-19]

3. The design inputs such as basic functional requirements, performance requirements, safety goals and safety principles, applicable codes, standards and regulatory requirements, design conditions, loads such as seismic loads, interface requirements, etc.
4. The design outputs such as specifications, design limits, operating limits, safety limits, failure or fitness for service criteria.
5. A detailed knowledge of the design calculations which demonstrate the adequacy of the design and the ability to reproduce the design calculations if needed.
6. An understanding of the inspections, analysis, testing, computer code validation and acceptance criteria used by participating design organizations to verify that the design output meets the design requirements.
7. The assumptions made in all the steps above, including assumptions related to operating modes or procedures, expected life history such as changes in fluence, expected transients, etc.
8. The implications of operating experience on the design.

The design authority is responsible for:

1. Assigning a specialised entity with its responsibilities
2. Ensuring the knowledge base is maintained and expanded with experience
3. Ensuring the availability of the knowledge to all parts of the organisation
4. The review, verification and approval or rejection of design changes
5. Design configuration control by maintaining up to date records
6. Controlling interfaces with the specialised entity or other suppliers involved in design work.

Even with the establishment of a design authority or another entity responsible for areas of design the operating organisation will still have the overall responsibility for the maintenance and safe operation of the plant. The tasks and functions will need to be clearly established in formal documentation.

Regulatory Oversight.

"Given that the inadequate management of design integrity can lead to a significant increase in risk, INSAG recommends that regulatory bodies verify that appropriate programmes are established and that the design authority and any responsible designers are identified, together with the boundaries of their functions. Regulatory bodies also need to ascertain that design integrity maintenance programmes are effective, that adequate arrangements exist to ensure that design knowledge is used appropriately in the process for controlling design change over the operating lifetime of plants and that the safety impacts of multiple changes have been properly analysed and understood".

Document Relationships & Referencing

The document refers to two other documents, Safety of Nuclear Power Plants: Design, Safety Standards Series No. NS-R-1 (superseded by SSR 2/1) and Quality Assurance for

Reference: A-055 [IAEA-INSAG-19]
Safety in Nuclear Power Plants and other Nuclear Installations, Code and Safety Guides Q1–Q14, Safety Series No. 50-C/SG-Q. (1996). These however, these date back to the late 90's or early 2000's and most of this information has been superseded over the last 20 years and overtaken by more recent experiences.
Applicability to Beyond Design Life Expectations This document adds to the information provided in SSG-48 (Section 4) by listing the knowledge and responsibilities of a design authority within the operating organisation.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-060 [IAEA-NP-T-3.20]
Document Title/Version Number: Buried and Underground Piping and Tank Ageing Management for Nuclear Power Plants.
Date of Issue: October 2018
Summary: This publication is one in a series of reports on the assessment and management of ageing of major nuclear power plant components. Current practices for the assessment of safety margins (fitness for service) and the inspection, monitoring and mitigation of ageing degradation of underground piping related to Canada deuterium–uranium (CANDU) reactor plants, boiling water reactor plants, pressurized water reactor plants and water moderated, water cooled power reactor plants are documented. This information is intended to help all those involved directly or indirectly in ensuring the safe operation of nuclear power plants and to provide a common technical basis for dialogue between plant operators and regulators when dealing with age related licensing issues. <u>Section 1</u> considers the objectives and background. The objectives of this document are: 1. State of the art information regarding ageing management of underground piping in nuclear power plants throughout their entire service life, including the after service period; 2. Background material indicating the importance of ageing management programmes (AMPs); 3. Practices and techniques for assessing fitness for service and for inspection, monitoring and mitigation of ageing related degradation of underground piping important for the safe, reliable and environmentally acceptable operation of nuclear power plants; 4. A technical basis for developing and implementing a systematic ageing management programme; 5. Guidelines that can be used to ensure that ageing management is taken into account during different phases of a nuclear power plant's life cycle (i.e. design, fabrication and construction, commissioning, operation (including long term operation and extended shutdown) and decommissioning); 6. Research materials related to ageing and lessons learned. This report deals with underground piping systems that are part of a nuclear power plant. It addresses potential ageing mechanisms, age-related degradation and ageing management as well as condition assessments for the materials and components of underground piping systems. Regarding Ageing management, this document refers back to the 2009 NS-G-2.12 IAEA document, this has since been superseded by SSG-48. <u>Section 2</u> describes the approach to developing an AMP and lists five components of an AMP for underground piping and tanks. <u>Section 3</u> describes the types of underground Piping and Tanks and the associated systems. <u>Section 4</u> looks at the material properties, their ageing mechanisms and the consequences of the degradation of these materials. Included in this section is a 'bathtub curve' used to describe failure rates

Reference: A-060 [IAEA-NP-T-3.20]
over time and a table (Table 5) containing degradation mechanisms for buried pipework and tanks. A list of degradation mechanisms is given, these are described in more detail throughout this section: 1. Corrosion; 2. Droplet impingement; 3. Fatigue; 4. Tuberculation or occlusion; 5. Freeze–thaw cycling; 6. Settlement and soil displacements; 7. Wear. Section 5 considers the development and optimisation of activities for ageing management. In this section it refers to some specific underground/buried pipeline and tank guidelines and recommendations which include some relevant information regarding the implementation of a programme and refers to the NS-G-2.12 IAEA document (superseded by SSG-48) regarding the scoping/screening process and the staff training. Section 6 looks at the effects of managing the ageing mechanisms during operation. 6.1 states, *"Plant operation has a significant influence on the degradation rates of nuclear power plant SSCs. Accordingly, operational staff should maintain operating conditions within prescribed design limits to ensure that the effects of any associated degradation mechanisms are minimized. For buried piping this is normally achieved through adhering to technical specifications, chemistry control and system monitoring procedures and processes".* The remainder of this section looks at the specific effects on piping with regards to flow, water treatment and environmental controls. Section 7 describes the inspection, monitoring and assessment of the underground piping and tanks. The following topics are covered: 1. Background 2. Testing and Calibration 3. Pre-service and in-service inspection (a table with the list of NDT technologies is included) 4. Surveillance 5. Leak detection 6. Assessment of piping 7. Record keeping Section 8 considers the types of maintenance strategies such as run to failure, preventative and planned. This section also describes parts management, replacements and maintenance history.
Key Themes Ageing Management Programmes.

Reference: A-060 [IAEA-NP-T-3.20]
The five components listed in section 2 are as follows: 1. Understanding of structure/component ageing; 2. Development and optimization of activities for ageing management; 3. Operation of a plant within design limits to minimize age related degradation (in particular, error-induced accelerated degradation); 4. Inspection, monitoring and assessment to detect and characterize significant component degradation before fitness for service is compromised; 5. Maintenance to manage ageing effects. The National Association of Corrosion Engineers (NACE) has developed its own version of an AM framework specifically for buried piping management which is listed in section 2 this is compared to the IAEA ageing management framework in the form of a table (Table 1). 4.7; looks at the research and development related to buried pipework and tanks and suggests that this should be an important part of an NPPs AMP. A list of current (2017) research being conducted is given. It also states here that *"research developments may contradict assumptions made during a plant's design stage and new techniques may be available to investigate and analyse plant systems".* 4.10; considers the mitigation of the ageing degradation, referring again to NS-G-2.12, states that an "*effective AMPs should include the mitigating methods for the effects of ageing degradation mechanisms"*. This section continues with a list of the measures specific to underground pipework and tanks. 5.2; refers to guidelines from NEI 09-14 (Guidelines for the management of underground piping and tank integrity) listing five steps for setting up and implementing a programme, these are as follows: 1. Procedures and oversight 2. Prioritisation 3. Condition assessment plans 4. Plan implementation 5. Asset management plan 5.3; looks at the sources of data required; some examples are listed below: 8. Station drawings 9. Design manuals 10. Technical standards 11. Specifications 12. Surveillance procedures 13. Quality control records

Reference: A-060 [IAEA-NP-T-3.20]

14. Plant OPEX
15. Maintenance procedure and history
16. Root cause reports

5.7; states *"Experts from operations, engineering, equipment qualification, design and research and development should be participants in the ageing management team".*

7.6.1; states, *"An AMP applies acceptance criteria to results from routine inspections to confirm that the current plant condition is acceptable and, through historical trending of results (plus other data when available), to estimate future performance. Utilities should document and store all inspection results (direct and indirect) in a controlled database. This documentation should include as-found and as-left data. Inspection data should be evaluated to determine 'wear rate', 'remaining life', and 'time to next inspection or repair/replacement'."*

7.7; describes the record keeping requirements, it continues on from the wording in 7.6.1 and adds to this by stating, *"Records should be readily retrievable and contribute to a repair/replacement strategy. They should be regarded as permanent records and should be stored appropriately for the life of the station. When defects are detected, their location, size and orientation should be reported, photographed or videoed, if practicable, and recorded. Where it is judged that defects could pose a potential risk to plant integrity, appropriate additional inspections should be carried out and repairs/replacements undertaken as required. Results of these additional inspections, assessments and repairs/replacements should be recorded. Furthermore, these locations should be considered under an ongoing inspection regime to identify whether further degradation or damage is taking place. Once a defect has been found, the implications of the discovery on other system components should be assessed to determine whether similar components/locations/systems should also be inspected. OPEX should be recorded and shared with stations having similar equipment".*

8.5; suggests that as part of the formal AMP, areas where repairs have been done should be considered for additional surveillance. Referring back to the record keeping section it states that maintaining good maintenance records is an important element of an AMP. By maintaining a database and good record keeping plants are able to identify problem areas and provide OPEX for other areas and plants.

<u>Ageing/Degradation Mechanisms.</u>

It states in section 4 that *"Developing the appropriate level of understanding is a continuous process and builds on plant experience. The basis of these judgements is often a review of a generic body of knowledge, supported by a detailed understanding of the mechanisms involved, all put into a plant specific context".*

4.3.1 states, *"Understanding ageing mechanism fundamentals is necessary for preventing these mechanisms from degrading by using appropriate protection means. It is also necessary for predicting buried pipe behaviour in service conditions.*

The degradation of buried pipework may be linked to poor design, construction or maintenance, or the internal or external environment of the buried pipework.

4.6; considers the consequences of ageing degradation and the effects it can have, it states, *"Depending on the systems affected, pipe or tank failures can have safety related or economic impacts in that they might remove important systems from service or otherwise degrade their function. Unplanned shutdowns or outages may be needed to implement repairs, and compensatory measures may be needed during interim periods. Flood control measures can be compromised. For systems containing tritium or other*

Reference: A-060 [IAEA-NP-T-3.20]

radionuclides, leakages into groundwater can generate substantial public or regulator concern even where there are few or no environmental or health impacts. These can require substantial resources to address".

4.11; states that the *"Knowledge of the current status of underground piping and tanks is essential for nuclear power plants. This is typically via assessments against documented condition indicators. Condition indicators can be established for detecting, monitoring and trending ageing degradation of applicable structures"*. Although this relates directly to underground piping and tanks, this method should be considered for all SSCs. The monitoring and understanding of the SSCs current conditions are vital to the maintenance of the SSC in question, especially if this SSC is considered in the scope of a long-term operation application.

<u>OPEX.</u>

4.8.1; *"An effective operating experience (OPEX) review programme is essential to effective ageing management. OPEX should be actively sought from the nuclear industry. This includes sources internal to the operating organization, external operating organizations, plant owner groups, international collaboration programmes (Institute of Nuclear Power Operations (INPO), World Association of Nuclear Operators (WANO), Organisation for Economic Co-operation and Development (OECD), IAEA, etc.), as well as sources external to the nuclear industry (various associations engaged in piping technology and research). Internal company OPEX should be shared externally"*.

Regarding degradation assessments this document considers the benefit of having access to a database of material performance within certain environments. They do however recognise that the sharing of this information may be difficult due to databases such as this containing proprietary information.

"Regulators typically require an effective OPEX programme to be in place in the context of normal operation or for lifetime extensions. The US Nuclear Regulatory Commission (USNRC), for example, issued LR-ISG-2011-05 [135], which provides guidelines on how the ongoing review of plant specific and industry wide OPEX should be used to ensure the effectiveness of the licence renewal ageing management programmes used at nuclear power plants".

Some OPEX industry examples are given in section 4.8.

4.8.5; decommissioning experience is considered here; they refer to an IAEA document on decommissioning of underground SSCs (Technical Report Series No.439). The most common causes of problems during the decommissioning of underground SSCs were those listed:

17. Facility layout — Narrow spaces between pipes, no access foreseen for inspections or maintenance, no use of double walled piping or drip pans, etc.;
18. Material selection — Construction material of piping or tankage exceeding design life and insufficient inspection of its state to verify its continued proper functioning;
19. Lack of records — Insufficient records available on the exact location and dimensions of embedded parts;
20. Unverified records — Incorrect interpretation or verification of available information;
21. Characterization programmes — Insufficient characterization data available;
22. Lack of a decommissioning strategy — Lack of a clear project strategy for how to reach the final decommissioning end point;

Reference: A-060 [IAEA-NP-T-3.20]
23. Waste management — Waste disposition routes not defined from the start of the project (including waste conditioning, packaging and storage/disposal); 24. Deactivation of utility services — Incidents resulting from poor deactivation practices. Maintenance. 8.1; states, *"Preventive maintenance may be seen as a proactive intervention where some form of activity is applied prior to damage becoming visible. Proactive condition control is well suited for nuclear facilities since it is important to keep performance above a certain safety function and to minimize lifetime costs"*. This part of section 8 considers the differences between maintenance practices and where they work together. *"Predictive maintenance is a form of preventive maintenance performed continuously or at regular intervals as governed by observed conditions (i.e. condition based maintenance). The results of such activities may generate required planned maintenance activities. Planned maintenance is refurbishment or replacement of a system, structure or component that is scheduled prior to its unacceptable degradation"*. The remaining part of 8.1 describes condition based and time based strategies for piping. 8.2; regarding corrective maintenance they state, *"The replacement or repair decision following an inspection should be determined based on projected and needed design life"*. Obsolescence. 8.3; "*Materials or components may become obsolete when a product gets discontinued, a manufacturer or supplier goes out of business, or applicable standards change, requiring the new product/material to be qualified to more stringent requirements"*. *"To avoid interference with operations, it is important to ensure that qualified materials and/or components exist and are readily available when the need for repair or replacement arises. Although it may be considered prudent to keep some spare parts and repair materials available at all times, it may not necessarily be economical to do so as some parts and materials have a relatively short shelf life (e.g. elastomers, coatings, some repair materials). Facility purchasing and stocking procedures need to account for parts shelf life issues to ensure availability of usable (i.e. non-life-expired) material when needed"*. References are made here to NS-G-2.12 (SSG-48) for different types of obsolescence and section 5.3 of IAEA Nuclear Energy Series No. NP-T-3.21 for strategies related to procurement in general and obsolescence in particular.
Document Relationships & Referencing References are made to the IAEA IGALL project on AMPs, the Technical Report Series No. 439 and NP-T-3.21 (specifically section 5 containing obsolescence). Several references are made to NS-G-2.12 which in 2018 was superseded by SSG-48 (Review Ref: A-069). Most of the details regarding AMPs and OPEX have been taken from NS-G-2.12.
Applicability to Beyond Design Life Expectations Although this document is specific to buried/underground piping and tank degradation, it includes some considerations regarding the importance of OPEX and understanding the degradation mechanisms and how to counteract these. Most of the AMP information however has been taken from IAEA documents which have since been superseded.

Reference: A-060 [IAEA-NP-T-3.20]
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes The IAEA document on decommissioning of underground SSCs (Technical Report Series No.439) may be worth reviewing, this document considers the preparation for the later stages of plant life.

Reference: A-065 [IAEA-SRS-82]
Document Title/Version Number: Ageing Management for Nuclear Power Plants: International Generic Ageing Lessons Learned (IGALL)
Date of Issue: April 2015
Summary: This Safety Report provides detailed information on specific programmes to manage existing and potential ageing and degradation of systems, structures and components (SSCs) that will assist operating organisations and regulatory bodies by specifying a technical basis and practical guidance on managing ageing of mechanical, electric and instrumentation and control components, and civil structures of nuclear power plants important to safety. It also provides a common, internationally recognized basis on what constitutes an effective ageing management programme; a knowledge base on ageing management for design of new plants, design reviews, evaluations of safety analyses and time limits assumed; and a roadmap to available information on ageing management. There are 5 sections to this report: Section 1: Background, Objective, Scope and Structure Section 2: Ageing Management Review Section 3: Ageing management Programmes (AMPs) Section 4: Time Limited Ageing Analysis (TLAA) Section 5: Definitions In addition to these sections there are 4 appendixes which contain the following; 1. A list of IGALL AMPs 2. A list of IGALL TLAA 3. Definitions of SSCs, materials, environments and ageing and degradation mechanisms 4. Civil structure except of containment This report was created in addition to the EBP SALTO report (Review Ref: A-053) and NS-G-2.12, superseded by SSG-48 (Review Ref: A-069), to concentrate on the ageing and degradation mechanisms and give guidance to the member states on the Ageing Management Programmes (AMP) acceptable for certain SSCs. <u>Objective</u>; *"This Safety Report provides a common, internationally agreed basis on what constitutes an acceptable AMP, as well as a knowledge base on ageing management for design of new plants, design reviews, safety reviews (such as periodic safety review), etc., and serves as a roadmap to available information on ageing management"*. Scope; "This Safety Report addresses ageing management of passive and active structures and components for water moderated reactors that can have an impact, directly or indirectly, on the safe operation of the plant and that are susceptible to ageing degradation". This part refers to the obsolescence of SSCs, referencing the NS-G-2.12 (SSG-48) and TOP401 documents. The report states here that "Although this publication is focused on management of physical ageing, obsolescence of SSCs important to safety has to be managed proactively throughout their service life.

Reference: A-065 [IAEA-SRS-82]

Aspects of technological obsolescence, such as insights into individual degradation mechanisms, have already been taken into consideration in the AMPs, i.e. the AMPs provided in this publication reflect the current state of the art in managing these mechanisms. However, new insights have to be addressed in future updates of the AMPs".

Key Themes

Ageing Management Review considers the scoping process and refers to SSR-2/2 and SRS-57. The scope and screening of SSCs has also been covered within the EBP SALTO review (A-053).

The AMR process involves, but is not limited to, the identification of the following elements:

1. System;
2. Structure/component;
3. Ageing effect/degradation mechanism;
4. Critical location/part;
5. Material;
6. Environment;
7. AMP;
8. TLAA(s).

There are three tables included in this section which refer to the numbering of an AMR table, the column designations and an example of the AMR table.

Ageing management Programmes (AMPs).

As well as referencing the SSG-48 predecessor (NS-G-2.12) regarding the AMP and what it should identify, it also lists the nine attributes which were reviewed as part of the EBP SALTO review (A-053).

An irregularity has been noticed between the two documents regarding the nine attributes, this document lists them as follows;

1. Scope of the AMP based on understanding ageing
2. Preventive actions to minimize and control ageing degradation
3. Detection of ageing effects
4. Monitoring and trending of ageing effects
5. Mitigating ageing effects
6. Acceptance criteria
7. Corrective actions
8. Operating experience feedback and feedback of research and development results

Reference: A-065 [IAEA-SRS-82]
9. Quality management. <u>Time Limited Ageing Analysis</u>. Section 4 states that TLAAs should meet the following 6 criteria; 1. Involve SSCs within the scope of LTO 2. Consider the effects of ageing degradation 3. Involve time limited assumptions defined by the current operating term 4. Were determined to be relevant by the plant in making a safety determination as required by national regulations 5. Involve conclusions or provide the basis for conclusions related to the capability of the system, structure, or component to perform its intended function(s) 6. Are contained or incorporated by reference in the CLB (current licencing basis) An example of TLAA statements and disposition is given in Table 4. In addition, *“a TLAA is acceptable if it meets one of the following;* – *The analysis remains valid for the intended period of operation* – *The analysis has been projected to the end of the intended period of operation* – *The effects of ageing on the intended function(s) of the structure or component will be adequately managed for the intended period of operation”*.
Document Relationships & Referencing As stated in the summary, this document covers the same themes that are in both the EBP SALTO report (Review Ref: A-053) and SSG-48 (Review Ref: A-069). SSR-2/2, SRS-57 and Technological Obsolescence Programme (TOP401) (Not reviewed as part of this phase) are also referenced.
Applicability to Beyond Design Life Expectations N/A
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-066 [IAEA-SVS-26]

Document Title/Version Number: SALTO Peer Review Guidelines; Guidelines for Peer Review of Safety Aspects of Long Term Operation of Nuclear Power Plants

Date of Issue: January 2014

Summary:

The guidelines in this publication are primarily intended for members of a SALTO review team and provide a basic structure and common reference for peer reviews of LTO. Additionally, the guidelines also provide useful information to the operating organizations of NPPs (or technical support organizations) for carrying out their own self-assessments or comprehensive programme reviews. The guidelines are intended to be generic, as there are differences between utilities and NPPs.

This document contains 3 sections covering the following topics:

1. Introduction
2. Methodology
3. Practical guidance

Section 1 describes the purpose, scope and objectives of the SALTO review and looks at the organisation, schedule and composition of the review team and their responsibilities to the requesting organisation as well as the final mission report and the definitions of the content.

Section 2 refers to the areas addressed and the techniques used by the review team. Also discussed in this section are the requirements of the 'counterpart' (the organisations representative to the SALTO review team) and what information is expected to be provided by them.

Section 3 concentrates on the guidance for the review team, which is broken down into 6 parts, each of these is broken down further into different elements which make up each part (labelled A-F).

Also included in this document are 8 Annexes which include the review timetables, steps, report contents and a list of publications used as a basis of the SALTO review.

Key Themes

Section 3 contains parts A-F headed as follows:

Part A; *Organization and functions, current licensing basis (CLB), configuration/ modification management.*

Par B; *Scoping and screening and plant programmes relevant to LTO.*

Part C; *Ageing management review, review of ageing management programmes and revalidation of time limited ageing analyses for mechanical components.*

Part D; *Ageing management review, review of ageing management programmes and revalidation of time limited ageing analyses for electrical and I&C components.*

Part E; *Ageing management review, review of ageing management programmes and revalidation of time limited ageing analyses for civil structures.*

Reference: A-066 [IAEA-SVS-26]
Part F; *Human resources, competence and knowledge management for LTO.* Each of the elements has a description containing the expectations, an example of the documents required and the evaluation process. The expectations for each section describe the role of the organisation and the requirements of them for the review process. Part A; Related regulatory requirements, codes and standards states, *"The operating organization should identify, from the existing national legal framework, a consistent and complete set of regulatory requirements, codes and standards, related to long term operation and ageing management. The identified set of regulatory requirements, codes and standards should provide a basis for developing the LTO programme"*. Organizational structure for LTO states, *"The plan should indicate the general policies, lines of responsibility and authority, lines of communication, duties and number of staff and their required qualifications needed to conduct the necessary activities. The plant should adopt a suitable organizational structure and dedicate the necessary resources for preparation and implementation of the LTO programme. A special LTO oriented project team or similar organizational arrangement should be established"*. Plant policy for LTO states, *"The plant should have plant level documentation describing the general concepts and approach for preparation and implementation of the LTO programme. Responsibilities in development, updating and implementing the LTO programme should be described in plant procedures"*. LTO implementation programme states, *"The plant should have a programme of actions/measures identified on the basis of review of AMPs and revalidation of time limited ageing analyses. This programme should cover modifications, major reconstructions and scheduled replacements, and other plant commitments needed for assuring necessary safety margins during the LTO period. This programme should be supported by safety analyses, and it can be part of the PLiM programme"*. Current safety analyses report and other current licensing basis documents states, *"Justification of LTO should be properly documented in the CLB, in particular in documents like FSAR, PSR report or in other licensing basis documents"*. Configuration/modification management including design basis documentation states, *"The plant should have a configuration management and modification management programme encompassing the status of the plant and all modifications of SSCs, releases of process software, operational limits and conditions, set-points, instructions and procedures. Management/QA systems should contain the processes and activities related to the configuration management and modification management programme. The plant should also have adequate design basis documentation reflecting all the design changes and planned LTO"*. Part B; Methodology and criteria for scoping and screening of SSCs for LTO states, *"The processes for scoping and screening should ensure that SSCs that perform required safety functions are identified for evaluation of their suitability for LTO. The scoping process is carried out at the structure, system and component level, and the screening process at the structure and component level. Those processes should be carried out specifically for mechanical, electrical and I&C and civil SCs. The plant should demonstrate that the effects*

Reference: A-066 [IAEA-SVS-26]
of ageing on all SCs within the scope of LTO are covered by plant programmes, newly established ageing management programmes or revalidation of time limited ageing analyses". Plant programmes relevant to LTO is broken down into 5 sections, each of these have the expectations, document examples and evaluation descriptions as above, these are: 1. Maintenance; "Actual and potential ageing mechanisms should be taken into account in preventive and predictive maintenance programmes for SCs important to safety to determine a suitable maintenance method, e.g. overhaul maintenance and condition based maintenance, and an appropriate maintenance frequency". 2. Equipment Qualification; "Equipment qualification establishes that equipment, while being subject to environmental conditions, is capable of performing its intended safety function or that it will be replaced or repaired so that its intended design functions will not be compromised during the planned period of LTO". 3. In-service Inspection; "ISI programme should be available and properly implemented for applicable SSCs in the scope of LTO (including SCs not important to safety within the scope of LTO)". "ISI results should be correctly documented, e.g. in a database, starting from the baseline data from pre-service inspection. The database should provide the technical basis to support findings and conclusions necessary for LTO (evaluation of effectiveness, trending, etc.)". 4. Surveillance and monitoring; "The surveillance and monitoring programmes should be available and properly implemented for the applicable SSCs in the scope of LTO. Surveillance programmes using representative material samples should address degradation mechanisms relevant for LTO". 5. Chemical Regimes; "The chemistry programme should specify scheduling, analytic methods used to monitor chemistry and verification of the effectiveness of the chemistry programme. The chemistry programme should also provide the necessary chemical and radiochemical assistance to ensure safe operation, the integrity of SCs during the original design lifetime and planned period of LTO, and control and reduction of radiation levels in working areas". Part C, D and E; Area specific scoping and screening of SSCs for LTO states, *"The plant should establish specific screening methods for mechanical components, electrical and I&C components and civil structures. A complete list of SCs in the scope of LTO should exist and determine boundaries between mechanical, electrical, I&C components and civil structures"*. Ageing management review states, "The plant ageing management review should identify for each SC in scope of LTO possible ageing effects and degradation mechanisms, critical locations/ parts, material, environment and ageing management programmes", *"If some SSCs cannot be inspected (e.g. due to inaccessibility) or assessed, justification for such SSCs to continue in service is necessary"*. Review of ageing management programmes states, *"Ageing management programmes should be evaluated against the nine attributes"* (these attributes have been referenced in the review of the EBP SALTO (A-053)). *"Existing programmes and newly developed ageing management programmes should incorporate insights and results of ageing management review"*. Obsolescence management programme lists the expectations as: 1. The plant should demonstrate that technological obsolescence is properly managed;

Reference: A-066 [IAEA-SVS-26]

2. Management of obsolescence should be a continuous activity addressing both the maintenance and performance of SSCs;
3. A programme to address obsolescence could be a part of normal plant programmes (e.g. maintenance);
4. Responsibility for programme implementation should be clearly assigned within the organization of the plant.

Existing time limited ageing analyses states, *"The plant should identify existing time limited ageing analyses regarding period of operation and design considerations or licence terms"*.

Revalidation of time limited ageing analyses states, *"The capability of some SCs within the scope of LTO to accomplish intended function should be verified by plant specific time limited ageing analyses". "The revalidation of these analyses should be done with respect to the assumed period of LTO. The revalidation should confirm function and safety margins necessary for the whole period of LTO"*.

Part F;

Human resources policy and strategy to support LTO states, *"The plant should be staffed with an adequate number of qualified and experienced personnel and competent managers who are duly aware of the technical and administrative requirements for LTO. The plant should provide reasonable amount of time overlap when personnel are to be replaced, so that replacement personnel can acquire an understanding of their new duties and responsibilities as well as knowledge and experience prior to assuming their positions"*.

Competence management for LTO and recruitment and training/qualification processes for personnel involved in LTO states, *"Plant should consider enhancement of training programmes for staff at ageing plants to compensate for losses of personnel due to retirement or job changes and for other reasons. Training programmes should also be adapted to accommodate the special technical, administrative and operational needs for LTO. The recruitment and selection policy at the plant should be aimed at retaining a pool of experienced staff for LTO. A broad distribution of both age and experience should be established to ensure that the necessary pool of knowledge, skills and safety expertise is sustained and that long term objectives of human resources policy are met. Suitably qualified personnel should be selected and recruited in accordance with needs of LTO"*.

Knowledge management and knowledge transfer for LTO states, *"A knowledge management (KM) plan and processes should be in place to support the LTO activities. KM needs to be a part of the long term strategy of the operating organization. Especially when considering LTO of NPP's, the plant should include knowledge-loss risk management in its KM practices". "The plant should identify the organization's knowledge needs (i.e. internal and external knowledge sources, utilization of knowledge, knowledge sharing, and preservation of organizational knowledge and capture of tacit knowledge)"*.

Document Relationships & Referencing

This document is based on NS-G-2.12 Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants (superseded by SSG-48) and SSR-2/2 Safety of Nuclear Power Plants, Commissioning and Operation.

Applicability to Beyond Design Life Expectations

The expectations on the organisations from the peer review teams (section 3) show the preparations and justifications required to consider the long term operation of an NPP.

Reference: A-066 [IAEA-SVS-26]
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-069 [IAEA-SSG-48]
Document Title/Version Number: Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants
Date of Issue: November 2018
Summary: "This Safety Guide supplements and provides recommendations on meeting the requirements relating to ageing management and long term operation that are established in SSR-2/1 (Rev. 1) and SSR-2/2 (Rev. 1). It identifies key elements of effective ageing management for nuclear power plants. This publication revises and supersedes the Safety Guide on Ageing Management for Nuclear Power Plants (NS-G-2.12) issued in 2009, and also supersedes two Safety Reports issued by the IAEA in 1999 (SRS No.15) and 2007 (SRS No.57). This revision takes into account developments in the ageing management of nuclear power plants worldwide and expands the scope to include provisions for maintaining the safety of nuclear power plants during Long Term Operation."
Key Themes: <u>Section 2; Basic Concepts.</u> Para 2.7 refers to the understanding of ageing effects on SSCs and states that this "is the key to effective ageing management. This understanding is derived from knowledge of: 1. *The current licensing basis and anticipated updates to the licensing basis, where relevant (including regulatory requirements, codes and standards);* 2. *The safety functions and other intended functions of the SSCs;* 3. *The design and fabrication processes used (including the material, the material properties, adverse residual effects from fabrication methods, such as cold work or residual stresses in welds, specific service conditions, results from inspections and examinations, and testing in manufacturing);* 4. *Equipment qualification (where applicable);* 5. *The environmental conditions of the SSCs during any delayed construction period, as these may affect the ageing performance of the SSCs;* 6. *The environmental conditions of the SSCs during operation and shutdown conditions, including, at a minimum, temperatures, humidity levels, aqueous parameters (e.g. water quality and levels of deleterious constituents) and neutron or gamma radiation fields;* 7. *The operation, irradiation and maintenance histories of SSCs, including their commissioning, repair, modification and surveillance histories;* 8. *Operating experience at the plant or at other nuclear power plants;* 9. *Relevant research results;* 10. *Data and data trends from condition monitoring, inspection and maintenance".* Para 2.30 refers to the long term operation (LTO) as *"operation beyond an established time frame defined by the licence term, the original plant design, relevant standards or national regulations"* It states that long term operation should be justified by a safety assessment, a licence renewal or a periodic safety review (PSR) (PSR Ref: IAEA SSG-25). Para 2.30 also refers to the specific consideration that should be

Reference: A-069 [IAEA-SSG-48]
given to the managing of the ageing processes that affect SSC's and to ensure *"that those SSCs will retain their capability to perform their intended safety functions throughout the planned period of long term operation"*. Para 2.32 states that should LTO be pursued, justification should be provided in the form of an adequate ageing management plan for the period of LTO. The plan should be *"based on the results of the periodic safety reviews or the results of an adequate evaluation process (that includes scope setting, ageing management review, and revalidation of time limited ageing analyses, as described in this Safety Guide), and this justification should be evaluated for adequacy by the regulatory body"*. <u>Section 3; Ageing management throughout lifetime of NPPs.</u> Para 3.3 suggests that the use of operating experience and results from research and development should focus on: 1. Ensuring that all levels of the analysis are either performed, or are specified and accepted, by qualified experts within the operating organization to ensure that specific aspects relating to ageing management and long term operation are taken into account; 2. Improving the understanding of ageing effects for all in-scope SSCs by analysis of operating experience from the nuclear power plant, from other nuclear power plants and from other industries, when relevant, and by analysis of results from research and development; 3. Applying lessons identified in order to update and improve the ageing management. Para 3.18 sates *"the operating organization should collect baseline data and should also confirm that critical service conditions (as used in equipment qualification) are in compliance with the design. Analyses of such data should be subject to review by the regulatory body.* Para 3.26 refers to events or changes in conditions, it states *"in the event of operational changes or modifications to SSCs, the operating organization should ensure that a review is performed of possible changes in environmental or process conditions (e.g. temperature, flow pattern, velocity, vibration, radiation and hot spots) that could affect ageing or lead to the failure of SSCs. If necessary, an ageing management review should be completed for the affected SSCs.* Para 3.31 considers the preparation phase of the LTO and what should be considered *"well before the plant enters into long term operation"*. These considerations include establishing policy documents, organisational structures and action plans. It also states that *"the operating organization should specify subjects for evaluation for long term operation and should assess the current physical status of relevant SSCs"*. Para 3.32 states *"the operating organization should detail how the physical status of structures or components will be managed consistent with the current licensing basis for the planned period of long term operation"*. Para 3.34 looks at the in-scope structures and components that should be identified by the operating organisation and states that the time limited ageing analysis *"should demonstrate either that all these analyses will remain valid for the planned period of long term operation, or that the structures or components will be replaced, or that further operation, maintenance or ageing management actions will be implemented"*.

Reference: A-069 [IAEA-SSG-48]

Para 3.35 provides a list of suggested activities that an operating organisation should periodically perform to *"validate or correct the ageing related assumptions so that plant safety during long term operation is ensured and improved".* These are:

1. Evaluation of operating experience at the plant or at other nuclear power plants, after entering long term operation;
2. Analysis of trends in ageing effects;
3. Review of the effectiveness of the ageing management programmes and existing plant programmes for long term operation;
4. Incorporation of relevant research and development results;
5. Evaluation of the need for new research and development.

Para 3.36 states that *"decisions concerning ageing management and long term operation should take due account of the potential implications for the subsequent decommissioning stage".* This links to the following paragraphs (3.41 & 3.42) which refer to the possible transitional period between operations at the reactor and the implementation of the decommissioning plan.

3.41 states that, *"appropriate ageing management arrangements should be put in place to ensure that required SSCs remain available and functional. This may necessitate the implementation of relatively long term ageing management provisions for certain SSCs, such as containment and spent fuel pool systems, fire protection systems, lifting equipment and monitoring equipment".*

3.42 shows some examples of plans and procedures to put in place for SSCs, these include, *"ensuring the long term integrity of SSCs to prevent their deterioration and to allow the safe dismantling, handling and transport of components until the completion of decommissioning"* and *"monitoring SSCs to ensure the integrity of the containment and to ensure that there are no significant radioactive releases during the transition period until completion of decommissioning".*

<u>Section 4; Relevant plant documentation and programmes.</u>

Para 4.3 states, *"The policy on ageing management and the justification for long term operation should be properly documented in the current licensing basis, in particular in documents such as the safety analysis report, reports of periodic safety reviews (if applicable) or other licensing basis documents".*

Para 4.6 refers to the PSR and states, *"A periodic safety review is a systematic, comprehensive assessment of the plant's safety".* It refers to the Safety Factors listed in SSG-25 and suggests considerations for the operating organisation, specifically:

1. The adequacy of the design of the nuclear power plant (safety factor 1) and its documentation, by assessment against the current licensing basis and national and international standards, requirements and practices.
2. Thorough documentation of the actual condition of each SSC important to safety (safety factor 2). Knowledge of any existing or anticipated obsolescence of plant systems and equipment should be considered part of this safety factor.
3. Whether qualification of equipment important to safety (safety factor 3) is being maintained through an adequate programme that includes maintenance, inspection and testing and that provides assurance that safety functions will be maintained at least until the next periodic safety review.

Reference: A-069 [IAEA-SSG-48]
4. The effects of ageing on nuclear power plant safety, the effectiveness of ageing management programmes and the need for improvements to ageing management programmes, as well as the obsolescence of technology used in the nuclear power plant (safety factor 4). The following paragraphs refer to the equipment qualification programme which includes environmental qualification. These are also referred to in the above para (4.6). Para 4.23 states *"an equipment qualification programme should be in place to ensure that the qualified status of in-scope SSCs is achieved and maintained in order to meet Requirement 30 of SSR-2/1 (Rev. 1) and Requirement 13 of SSR-2/2 (Rev. 1)".* Para 4.25 states *"environmental qualification should demonstrate that, at the end of its qualified life, the equipment will still be capable of performing its intended function(s) under the full range of specified service conditions".* Para 4.26 states *"environmental qualification should establish the qualified life of the equipment, within which ageing effects would not prevent satisfactory performance of the equipment if a postulated accident were to occur within the established operating period (possibly including long term operation).* Para 4.27 states that *"monitoring of actual environmental conditions should be implemented in order to get additional information necessary for the assessment of ageing effects on the equipment in its actual operating environment".* Para 4.28 states *"the qualified life of equipment should be reassessed during its lifetime, taking into account progress in the knowledge and understanding of degradation mechanisms and the actual operating environment of the equipment. If the qualified life is to be extended, a thorough safety demonstration should be provided by the operating organization".* Para 4.29 refers to the equipment qualification and how this should be documented. It states that the documentation should include: 1. A master list of qualified equipment; 2. Results of temperature monitoring and radiation monitoring in the plant; 3. The evaluation report for equipment qualification; 4. Test reports relating to equipment qualification; 5. Reports of time limited ageing analyses relating to equipment qualification (for the evaluation for long term operation) or reports of another suitable equivalent analysis. Para 4.32 refers to in-service inspections and references NS-G-2.6 (Maintenance, Surveillance and In-service Inspection in Nuclear Power plants). 4.32 states that in-service inspection programmes *"should be in place and properly implemented for ageing management and for evaluations for the long term operation of applicable in-scope SSCs, including consideration of baseline data".* Para 4.36 states *"a list or database should be developed and maintained to document the adequacy of non-destructive examination in detecting, characterizing and trending the degradation of structures or components. The database should provide the technical bases to support the findings and the conclusions necessary to support ageing management decisions".* Section 5; Management of Ageing.

Reference: A-069 [IAEA-SSG-48]

Para 5.10 refers to the data collection and record keeping which should have been established (ideally) from construction onwards. 5.10 states that this data should be used to provide the information for the following:

1. Identification of fabrication, construction and environmental conditions that could adversely affect the ageing of SSCs, including any periods of delayed construction or suspended operation;
2. Identification of relevant fabrication records, such as heat treatment history and certified reports on material tests;
3. Identification and evaluation of degradation, failures and malfunctions of components caused by ageing effects;
4. Decisions on the type and timing of maintenance actions, including calibration, repair, refurbishment and replacement;
5. Optimization of operating conditions and practices that prevent or minimize ageing effects;
6. Identification of all ageing effects before they jeopardize plant safety or reduce the service life of SSCs;
7. Records of configuration and modification management, maintenance, surveillance and in-service inspection results, as well as chemistry control records.

Para 5.16 looks at the types of SSCs which are considered to be in-scope and therefore included in ageing management. These are:

1. SSCs important to safety that are necessary to fulfil the fundamental safety functions:
   - Control of reactivity;
   - Removal of heat from the reactor and from the fuel store;
   - Confinement of radioactive material, shielding against radiation and control of planned radioactive releases, and limitation of accidental radioactive releases.
2. Other SSCs whose failure may prevent SSCs important to safety from fulfilling their intended functions. Examples of such potential failures are:
   - Missile impact from rotating machines;
   - Failures of lifting equipment;
   - Flooding;
   - High energy line break;
   - Leakage of liquids (e.g. from piping or other pressure boundary components).
3. Other SSCs that are credited in the safety analyses (deterministic and probabilistic) as performing the function of coping with certain types of event, consistent with national regulatory requirements, such as:
   - SSCs needed to cope with internal events (e.g. internal fire and internal flooding);

Reference: A-069 [IAEA-SSG-48]

- SSCs needed to cope with external hazards (e.g. extreme weather conditions, earthquakes, tsunamis, external flooding, tornados and external fire);
- SSCs needed to cope with specific regulated events (e.g. pressurized thermal shock, anticipated transient without scram and station blackout);
- SSCs needed to cope with design extension conditions [1] or to mitigate the consequences of severe accidents.

Para 5.28 refers to the ageing effects and degradation mechanisms of SSCs and how these can affect the SSCs capabilities to perform its intended function. It states that there should be a comprehensive understanding of these effects and this understanding should be based on the following:

1. The design, including the SSC's intended function(s) and applicable regulatory requirements, codes and standards, the design basis and design documents, including safety analyses;
2. The fabrication of the SSC, including material properties, manufacturing conditions that may affect ageing and service conditions;
3. The operation and maintenance history of the SSC, including commissioning, operational transients and events, power uprating, modifications and replacements;
4. Stressors on the structure or component (including loads on the structure or component and the environmental conditions inside and outside the structure or component);
5. Results of in-service inspections and surveillance;
6. Operating experience, results of research and development, and any post-service examinations;
7. Results from walkdowns, inspections and condition assessments, if available;
8. Results of the evaluation of time limited ageing analyses.

Para 5.30 *"Appropriate methods to detect, monitor, prevent and mitigate ageing effects and degradation mechanisms for each structure or component should be specified".*

Para 5.31 suggests that any existing ageing management or plant programmes should be assessed to ensure that they are *"effective in detecting, monitoring and preventing or mitigating ageing effects and degradation mechanisms in the structures or components for which the programme is credited".*

Para 5.32 states *"if existing ageing management programmes and other plant programmes are not sufficiently effective, the existing programme should be improved or modified or a new programme should be developed".*

Both Para 5.31 and 5.32 refer to a table (Table 2) of attributes which should be included in an effective ageing management programme. These nine attributes are:

1. Scope of the ageing management programme based on understanding ageing
2. Preventive actions to minimize and control ageing effects
3. Detection of ageing effects
4. Monitoring and trending of ageing effects

Reference: A-069 [IAEA-SSG-48]

5. Mitigation of ageing effects
6. Acceptance criteria
7. Corrective actions
8. Operating experience feedback and feedback of research and development results
9. Quality Management

Para 5.39 states "*Plant programmes or processes used to manage ageing effects and ageing management programmes should include one or more of four types of activity:*

1. *Prevention activities, which preclude the ageing effect from occurring;*
2. *Mitigation activities, which attempt to slow the ageing effects;*
3. *Condition monitoring activities, including inspection and examination for the presence and extent of ageing effects, or surveillance using test samples or coupons intended to mimic the performance of the structure or component;*
4. *Performance monitoring activities, which test the capability of a structure or component to perform its intended function(s)".*

Para's 5.64 and 5.67 are referred to in many of the LTO (Section 7) paragraphs, these two paragraphs are related to time limited ageing. Para 5.64 lists six criteria for time limited ageing analysis, these are:

1. Time limited ageing analyses should involve SSCs within the scope for ageing management.
2. Time limited ageing analyses should consider ageing effects. Ageing effects include, but are not limited to loss of material, changes in dimension, changes in material properties, loss of toughness, loss of pre-stress, settlement, cracking, and loss of dielectric properties.
3. Time limited ageing analyses should involve time limited assumptions defined by the current operating term. The specified operating term should be explicit in the analysis. Simple assertion that a component is designed for a particular service life or for the lifetime of the plant is not sufficient. Any such assertion should be supported by calculations or other analyses that explicitly include a time limit or a time based assumption.
4. Time limited ageing analysis should have been determined to be relevant by the operating organization in making a safety determination as required by national regulations. Relevancy is a determination that the operating organization makes on the basis of a review of the information available. A calculation or analysis is relevant if it can be shown to have a direct bearing on the action taken as a result of the analysis performed. Analyses are also relevant if they provide the basis for the safety determination for the plant when, in the absence of the analyses, the operating organization might have reached a different safety conclusion or taken a different safety action.
5. Time limited ageing analyses should involve conclusions or provide the basis for conclusions relating to the capability of SSCs to perform their intended functions.
6. Time limited ageing analyses should be contained or incorporated by reference in the current licensing basis. The current licensing basis includes the technical specifications and the design basis information, or the commitments of the operating organization documented in the plant specific documents contained or incorporated by reference in the current licensing basis, including, but not

Reference: A-069 [IAEA-SSG-48]

limited to: safety analysis reports, regulatory safety evaluation reports, the fire protection plan or hazard analysis, correspondence with the regulatory body, the documentation of the management system, and topical reports included as references in the safety analysis reports. If a code of record is in the safety analysis report for a particular group of structures or components, the reference material should include all the calculations called for by that code of record for those structures or components.

Para 5.67 lists three criteria to which the time limited analysis should satisfy, these criteria are listed below:

1. The analysis should remain valid for the intended period of operation. The time dependent parameter value for the intended operating period should not exceed the time dependent parameter value used in the existing analysis.
2. The analysis should have been projected to the end of the intended period of operation. The value of the analysis parameter value should be changed on the basis of the time dependent parameter projected for the intended operating period, and the value of the analysis parameter should continue to meet the regulatory limit or criterion.
3. The effects of ageing on the intended function(s) of the structure or component should be adequately managed for the intended period of operation. The value of the analysis parameter should be managed (using an ageing management programme) to ensure that ageing effects are adequately managed and that the value of the analysis parameter will continue to meet the regulatory limit or criterion throughout the intended period of operation.

Section 6; Management of Technological Obsolescence.

Para's 6.2 and 6.6 refer to an obsolescence programme, specifically looking at SSCs important to safety. 6.2 states *"A technological obsolescence programme should be prepared and implemented to address all SSCs important to safety and the spare parts required to maintain those SSCs"*. 6.6 refers to three basic steps which should be included in an obsolescence programme, these are:

1. The operating organization should identify the installed SSCs important to safety that are technologically obsolete or will become obsolete in the upcoming years.
2. The identified equipment should be prioritized on the basis of the safety and criticality significance of the obsolete equipment (i.e. its impact on the plant safety).
3. The operating organization should develop and implement effective replacement solutions in a timely manner.

Section 7 (Programme for Long Term Operation) of this document refers specifically to LTO and how this should be prepared and implemented, referring back to many of the previous paragraphs noted above. This section considers the feasibility study and the principles with which this LTO programme should be based upon.

Para 7.6 lists the items which should be addressed in a feasibility study prior to the decision of LTO:

1. Strategic elements, such as the need for electrical power, an economic assessment and issues concerning diversity in supply, with due consideration that safety takes precedence over electricity production;
2. Compliance with current codes, standards and regulations;

Reference: A-069 [IAEA-SSG-48]

3. The most recent relevant international standards and guidance;
4. A technical assessment of the physical condition of the plant;
5. An evaluation of past operating experience at the plant relating to ageing, obsolescence and other safety issues;
6. Storage of spent nuclear fuel for long term operation;
7. Radioactive waste management for long term operation;
8. An assessment of the environmental impact of long term operation as required by national regulations.

Para 7.8 suggests the principles on which the LTO programme should be based:

1. Operational practices should meet national regulations, should follow international guidelines, as applicable, and should be adequate to ensure safe operation of the plant.
2. The regulatory process should be adequate to ensure that safe operation of the nuclear power plant is maintained and should focus on ageing effects that need to be properly managed for the planned period of long term operation.
3. The current licensing basis should provide an acceptable level of safety and should be carried over to the planned period of long term operation in the same manner and to the same extent, with the exception of any changes specific to long term operation.

Para 7.14 refers to a Figure 8 which shows the major steps and considerations for the operating organisation, prior to, during and on approval of the LTO assessment. It also states *“the major steps of the programme for long term operation should involve the following”:*

1. Demonstration that ageing effects will continue to be identified and managed for each structure or component in the scope of long term operation for the planned period of long term operation (including feedback on operating experience and research and development findings).
2. Review of time limited ageing analyses to ensure that the analyses continue to meet the criteria specified in para. 5.67.

Para 7.18 suggests the inclusion of the following in an LTO programme:

1. The method of scope setting, the results obtained (structures or components within the scope and out of the scope of long term operation), and supporting technical justifications
2. Demonstration that the programmes credited for long term operation support the conclusion that the intended functions of the SSCs and the required safety margins will be maintained. This demonstration should address the following topics:
   - *A description of the intended functions of the structures or components;*
   - *Identification of applicable ageing effects and degradation mechanisms based on, for example, the materials used, the environment and operating experience;*
   - *Specification and description of operational programmes and ageing management programmes that manage the identified ageing effects;*

Reference: A-069 [IAEA-SSG-48]
– *Demonstration that these operational programmes and ageing management programmes (including new programmes) are effective.* 3. Demonstration that the review performed for the SSCs within the scope of long term operation is consistent with the ageing management programme. A technical justification should be provided that: – *Demonstrates that ageing effects will be adequately managed for each structure or component in such a way that the intended function(s) of the structure or component will be maintained throughout the planned period of long term operation in a manner that is consistent with the current licensing basis;* – *Ensures that operating experience and research findings are adequately reflected in assessing the ageing effects of structures or components that are in scope for long term operation and will continue to be taken into account during the entire period of long term operation.* 4. Demonstration that the time limited ageing analyses have been revalidated and that the evaluation includes: – *Identification of time limited ageing analyses in accordance with the definition specified in para. 5.64;* – *Revalidation of each identified time limited ageing analysis in accordance with the recommendations provided in para. 7.28 to demonstrate that the intended function(s) of the structure or component will be maintained throughout the planned period of long term operation in a manner that is consistent with the current licensing basis.* 5. The implementation of the programme for long term operation, specifying the corrective actions for safe long term operation, and the schedule and commitments of the operating organization relating to long term operation. The following paragraphs refer to the review of the current ageing management programme, if in place, specifically looking at long term operation. Para 7.23 states that *"the ageing management review for long term operation should focus on the following issues:* 1. Whether any new ageing effect or degradation mechanism is anticipated in the course of the planned period of long term operation; 2. Whether the significance, degradation rate or susceptible sites of degradation mechanisms are expected to change during the planned period of long term operation; 3. Whether current relevant operating experience and research findings have been incorporated into ageing management programmes. Para 7.24 suggests that if a review of ageing management has not been completed then the results from this recommended review for long term operation should be used to develop an ageing management programme *"in order to detect and mitigate those ageing effects identified in the ageing management review before the integrity and the functional capability of the SSCs are compromised".*

Reference: A-069 [IAEA-SSG-48]
Para 7.25 states that "*The ageing management review should provide a clear demonstration that ageing effects will continue to be identified and managed for each structure or component in the scope of long term operation for the planned period of long term operation"*. Para 7.26 refers to the results of current plant and ageing management programmes and ensuring the reviews show that these existing programmes effectively manage the effects identified for the period of LTO. It also states that *"This review should identify programme modifications and/or new programmes necessary to ensure that the structures or components will be able to perform their intended functions for the planned period of long term operation"*. Para 7.28 refers back to para 5.67 regarding the review of time limited ageing analysis on any specific SSC and its applicability to the LTO period planned. It states, *"The time dependent parameter should be determined from a re-evaluation or analysis of the operating history of the plant (including its projection to the end of the planned period of long term operation) to define a value of the parameter that applies to or bounds the expected value of the parameter at the end of the planned period of long term operation"*. The following paragraphs refer to the documentation of plant programmes and ageing management regarding long term operation. Para 7.29 refers to the documentation of the plant programme for LTO. It states that it should be documented by the operating organisation in accordance with national regulatory requirements and *"be developed and retained in an auditable and retrievable form so that it provides a part of the technical basis for approval of long term operation"*. Para 7.31 states *"with regard to ageing management, the documentation should also include the following to demonstrate that ageing effects will be managed throughout the planned period of long term operation:* *1. A description of plant programmes and documentation relevant to ageing management throughout the planned period of long term operation;* *2. A list of commitments for the improvement or development of plant programmes and documentation relevant to ageing management throughout the period of long term operation, and information on the implementation of new ageing management programmes"*. Para 7.33 refers to the ageing management review and the type of information it should contain. It suggests three which should be considered: 1. identification and listing of SSCs subject to an ageing management review and their intended functions 2. a description and justification of the methods used to determine the structures or components that are subject to an ageing management review 3. the information sources used to accomplish the above, and any description necessary to clarify their use Para 7.34 refers to an ageing management review report which should *"address the understanding of ageing, the monitoring of ageing and the prevention and mitigation of ageing effects"*. Para 7.35 states that *"documentation of the demonstration that ageing effects will be adequately managed during long term operation should include the following:*

Reference: A-069 [IAEA-SSG-48]
1. *Identification of the ageing effects and degradation mechanisms requiring management;* 2. *Identification of the specific programmes or activities that will manage the ageing effects and degradation mechanisms for each structure, component or commodity grouping listed;* 3. *A description of how the programmes and activities will manage the ageing effects and degradation mechanisms".* Para 7.36 states that the documents required for the licencing process should be updated to reflect the *"assumptions, activities and results of the plant programme for long term operation".* Para 7.38 refers to SSG-25 and the safety factors contained within (specifically 2-5). This paragraph suggests that if a PSR is used as a licencing tool then the safety assessment performed for these safety factors should consider the entire LTO period. Paras 7.39 and 7.40 conclude Section 7 with short statements regarding the regulatory review and approval of LTO. 7.39 states that the operating organisation should demonstrate that the safety of the NPP will be maintained over the LTO period and that the regulatory body should oversee this. 7.40 refers to the organisation's demonstration of safety and states that *"the demonstration of safety for long term operation should be provided to the regulatory body for review and approval at a level of detail, and in a manner, defined by national regulatory requirements".* Examples of justifications are listed and suggested for inclusion in the demonstration by the operating organisation.
Document Relationships & Referencing: This document makes reference to other guides such as SSG-25 (Periodic Safety Review for Nuclear Power Plants) which states relevant safety factors applicable to BDL, SSR-2/2 (Safety of Nuclear power Plants: Commissioning and Operation) which has a requirement (Requirement 16) specific to programmes of LTO, SSR-2/1 (Rev. 1) Safety of Nuclear Power Plant Design; Requirement 30 (Qualification of items important to safety), NS-G-2.6 Maintenance, Surveillance and In-service Inspection in Nuclear Power plants and its predecessor NS-G-2.12 Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants.
Applicability to Beyond Design Life Expectations This document outlines the qualification of equipment, makes recommendations for the implementation and improvement of ageing management programmes and more specifically to this review, the implementation of long term operation. Included in this document are OPEX from previous IAEA member state projects, it refers to the IGALL documents for this, a list of attributes important to an ageing management programme and several figures and tables which can be used to aid organisations and regulatory bodies when justifying long term operation.
Applicability to the ONR SAPs IAEA SSG-48 covers many topics regarding SSCs, Ageing Management and Long Term Operation. Many of the aspects quoted above relate both directly and indirectly to several SAPs which were reviewed as part of phase 1 of this project. This document was also reviewed as part of the Ageing and Degradation task (ONR376), within this document additional SAPs were recommended for consideration.
Future Considerations Further in depth reviews of supporting documentation such as SSG-25, SSR-2/1 & 2/2.

Reference: A-069 [IAEA-SSG-48]
Additional Notes N/A

Reference: A-077 [IAEA-TECDOC-1305]
Document Title/Version Number: Safe and Effective Nuclear Power Plant Life Cycle Management towards Decommissioning
Date of Issue: August 2002
Summary: This document considers the consequences of the strategies and decisions made during the lifetime of the plant and the implications of management decisions which could affect it. The document considers the current published lifecycle guidance from various bodies and notes that this has not been collected into one document on the subject. This document contains the following 2 relevant sections; Section 2; Life Cycle Management Section 3; Decommissioning Planning *"The objective of this publication is to promote and communicate the need for a longer-term perspective among senior managers and policy or strategy makers for decisions that have the potential to affect the life cycle management of a nuclear power plant including decommissioning. The following sections provide practical guidance in the subject areas that might have the potential to have such an impact. The publication should be used as an aid to help strategic planning take place in an informed way through the proper consideration of any longer-term decisions to enforce recognition of the point that decommissioning is a part of the whole life cycle of a nuclear power plant"*.
Key Themes Section 2; Life Cycle Management. *"Life cycle management is the integration of safety management, ageing management and business management decisions, together with economic considerations over the life of the nuclear power plant in order to:* 1. Maintain an acceptable level of performance including safety. Optimize the operation, maintenance and service life of structures, systems and components (SSCs). 2. Maximize returns on investment over the operational life of the nuclear power plant. 3. Take account of national strategies for life cycle funding (including decommissioning), fuel management and waste management". There are two figures shown at the end of the introduction and page 2 of section 2. These figures show the life cycle as the full life of the plant from design through to decommissioning. It states here that, *"the period of nuclear power plant life cycle encompasses the early conceptual phase through approval, financing, construction, operation (including periodic safety reviews supporting plant life extensions), shutdown, and decommissioning to the eventual recovery of the site and includes the eventual disposal or re-accountability of responsibility for the fuel and waste. Therefore, in economic terms the full scope of the "life cycle" of a nuclear power plant describes that period when financial charges can be made against the nuclear power plant"*.

Reference: A-077 [IAEA-TECDOC-1305]

This section mainly considers the economic concerns of member states to cover the cost of the whole plant life through the revenue generated by operation. It also refers to changes which may affect the ability to fund their decommissioning and safety obligations.

"Life cycle management should enable utilities to be able to demonstrate their commitment to safe operation, their long-term plans and strategies for the plant including the financial provisions being made to cover the cost of safe operation and decommissioning".

Here the document refers to the attributes for an ageing management programme (AMP), these have been reviewed as part of this phase within SSG-48 (A-069) and the EBP SALTO review (A-053).

Regarding safety management the document states that it *"is a term that encompasses:*

1. The achievement of proper operating conditions,
2. The prevention of accidents or mitigation of accident consequences, resulting in the protection of workers, the public,
3. The establishment and maintenance of an appropriate safety culture".

This continues with a short statement regarding the business management part of the plant and states that *"The integration of activities for ageing management, safety management and business management of a nuclear power plant are an essential element of "life cycle management".*

"Information must be captured and recorded progressively through the life cycle to inform and facilitate socio-economic decision making. Analysis of information should ensure that proper attention is given to the factors forming the basis for the decision.

2.1, <u>Safety Management</u>.

"The objective of safety management within life cycle management is to maintain the safety level of the nuclear power plant higher than the reference level defined in the corresponding safety case".

This general objective of safety management covers two issues:

1. The characteristics of the various systems, structures and components (SSCs) related to the safety of a nuclear power plant should not degrade below the values considered in the design, which incorporates provisions for ageing effects.
2. The expected and acceptable safety level at the time of design may later come to be regarded as insufficient and its continued acceptability for further operation has to be assessed.

"It should be recognized within life cycle management that some SSCs are needed for, or would assist in, maintaining safety during decommissioning. Life cycle management should ensure these SSCs are maintained and remain capable of meeting their design intent until they are no longer required".

2.2 <u>Asset Management</u>.

"A utility should adopt a clear asset management programme to achieve real and lasting improvements with the objective of longer-term decisions supporting plant life management".

Some asset management activities are listed in this section, some relevant ones are;

Reference: A-077 [IAEA-TECDOC-1305]

1. Regular physical inspections of SSCs in order to become thoroughly knowledgeable about every aspect of their condition and operation.
2. Implementing improvements through a structured and practical approach to change management.
3. Operating and maintaining the plant equipment in order to sustain long term availability and reliability.
4. Offsetting plant-ageing impacts.
5. Staff development to ensure the 'people' asset remains effective.
6. Alignment with the human resource strategy to ensure there is succession management for key posts.

The staff development and alignment to the human resource strategy was eluded to in the SALTO guidance document review (A-066). In that document it listed some key points regarding the strategy to support LTO, competency management and knowledge transfer for LTO.

2.5 Ageing Management.

"Ageing management, as a part of its input to life cycle management, should consider the benefits to the plant of maintaining SSCs in good working order if they would aid decommissioning, rather than taking the short-term view and withholding funding for maintenance during the operational stage. Such SSCs include the fuel route, the active effluent treatment plant and the change room facilities".

"The recommendations and actions identified by the ageing management programme provide a major input to nuclear power plant life cycle management. Implementing these recommendations and actions will enable the plant to continue operation or alternatively could indicate when a plant is no longer economically viable to operate".

2.6 Preventative/Predictive Maintenance.

"Having a well-developed and properly resourced preventative maintenance programme is an essential part of life cycle management, as it will extend the operability of the SSCs".

Condition based maintenance (CBM) is described here along with Probabilistic Risk Analysis (PRA) and Probabilistic Safety Analysis (PSA). These predictive maintenance measures provide the means to identify maintenance frequency and schedule planned maintenance/replacements based on condition. It states, *"Predictive maintenance (or condition-based maintenance) is maintenance performed continuously or at intervals governed by observed conditions, which are used to monitor, to diagnose or trend an SSCs condition indicators to identify current and future ability or to identify the nature and schedule of planned maintenance".*

Regarding the life cycle of the plant the document recognises that the requirements of the SSCs will change, it states, *"The high risk SSCs within the operational stage may differ from those within the decommissioning stage. In order to ensure that appropriate maintenance and controls are implemented the concept of a graded approach to quality assurance should be used to determine significance, recognizing that the graded approach will itself differ from operations to decommissioning".*

2.8 Knowledge Management.

It states here that the methodology of capturing the knowledge regarding decisions and strategies, whether implemented or not, would *"ultimately be one of the most important sources of information for life management activities".*

Reference: A-077 [IAEA-TECDOC-1305]

"Establishing and maintaining an effective records management system is essential to aid decommissioning and to enable the organization to be able to provide the information to demonstrate or support options or strategies chosen, decisions taken and claims made".

"The need to capture corporate memory is particularly important during the longer stages such as the operational and decommissioning NPP life cycle phases. It is also important to understand the reasoning and issues for major technical activities such as periodic safety reviews or lifetime extension programmes".

2.9 Performance Management.

Similar to knowledge management this brief section refers to the recording and storage of performance data, trend analysis and monitoring programmes to *"aid plant life management".*

2.11 Fuel Cycle/Waste Management.

"It is imperative that strategic decisions regarding fuel and waste management are properly considered in the context of the life cycle management of the nuclear power plant. It is often the case that strategic decisions taken during operations do not consider the implications on the longer-term decommissioning activities".

2.12 Licence Management.

"The license management programme should be in place from the outset of a proposal to locate a nuclear power plant through all subsequent periods of the nuclear power plant life cycle, including de-licensing. The status of commitments made on behalf of the nuclear power plant should be tracked through to completion".

"Many Member States have no absolute limit on the life of a nuclear power plant, and as long as the nuclear power plant can demonstrate that it is safe to operate, they can continue operating beyond the original design life".

"Proactively managing licensing activities should result in periodic reviews being part of ongoing activities rather than a large single project. This continuous approach is more cost effective when implemented as an element of plant life cycle management".

"License commitments, having been recognized and identified, should be integrated with supporting objective information and known status into any cost/benefit analysis for future decisions. The output from this activity is naturally an input to strategy and life cycle management and will form the basis for many lifetime extension decisions".

2.13 Periodic Safety Reviews.

"The results of periodic safety reviews are effectively an input to plant life management as they aid plant life extension studies and the decision making regarding the investments required to secure an extended operating life".

"The decision to proceed with any plant life extension must be based on:

1. A good safety performance record,
2. The capability to operate the plant safely during the proposed extension,
3. Sound economic assessment showing benefits from the investment, Public confidence".

Reference: A-077 [IAEA-TECDOC-1305]
"Periodic safety reviews are also utilized during the decommissioning stage. In such cases, they are used as a justification to support the decommissioning strategy that take into account the changes in plant configuration and continued availability of SSCs to ensure decommissioning is carried out safely". The following statements are based around plant life extension and the requirements and considerations of the organisation. These aren't just the technical considerations but also the economic and business decisions which affect the feasibility of the extension. *"For a plant seeking life extension, the assessment has to be started in advance of the end of the design life. This is necessary so that the main issues for life extension can be identified early enough to enable an engineering programme to be deployed so that any necessary modifications are completed before life extension begins".* Also stated here is the need to consider the sequence of modifications carefully, ensuring that the overall plant can be modified as required to sustain safe LTO. Regarding Obsolescence; *"Plant life extension should also consider the question of spare parts: do they have to be designed and built according to current rules when they have to fit in a mature plant? As we are dealing with single components, the applicable rules are generally not the general safety requirements given by regulatory texts, but the codes and standards established by industry"*. *"The original suppliers can no longer provide major components for many older plants because some manufacturers are no longer in that business, the manufacturing methods have been substantially changed, the current material choice, and specifications are significantly different to those in older components".* 2.14, <u>Economic Optimisation</u>. *"This optimization must take place in the full knowledge of potential effects on many other factors, such as safety, plant degradation, accumulation of wastes and liabilities".* *"The criteria governing economic optimization should be:* 1. Safe and economic plant operation to the original design period and beyond if necessary, 2. Safe and economic decommissioning to an acceptable condition, 3. Enhancements to plant safety to enable long-term sustainability and performance". *"Economic optimization should take place from a basis of informed knowledge of the risk environment affecting the nuclear power plant both currently and in future life cycle stages".* <u>Section 3, Decommissioning Planning</u>. The decommissioning section considers the end of lifecycle processes, the options for decommissioning (immediate/deferred dismantlement), the human resource strategy as well as the waste disposal and social/environmental implications.

Reference: A-077 [IAEA-TECDOC-1305]
Document Relationships & Referencing This document covers the full lifecycle of NPPs and considers the economic and business management side of the operation. Due to the age of this document (2002) many of the themes within this document have been developed further and included in SSG-48 (Review Ref: A-069).
Applicability to Beyond Design Life Expectations Of the current phase reviews of IAEA documents, this has been the only document to consider the business and financial implications of the plant lifecycle. There are some insights into the operational business mindset which suggest that the longer term operation or decommissioning are not always considered until further down the line.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-083 [IAEA-TECDOC-1736]	
Document Title/Version Number: Approaches to Ageing Management for Nuclear Power Plants.	
Date of Issue: April 2014	

Summary: The main deliverable of the International Generic Ageing Lessons Learned for Nuclear Power Plants (IGALL) Extra budgetary Programme (EBP), the IGALL Safety Report, provides an internationally recognized basis for an acceptable ageing management programme, as well as a knowledge base on ageing management to aid in the design of new power plants, design reviews, modifications and upgrades, and to serve as a source of information on ageing management.

"This publication is a summary of the national approaches taken by Member States participating in the IGALL programme. This information was collected during the first phase of the IGALL programme between 2010 and 2013 and explains different national practices in the area of ageing management and the preparation for long term operation".

The document is closely linked to the Ageing Management for Nuclear Power Plants IGALL Safety Report (SRS-82, review Ref: A-065), both of these publications use the information from the US-NRC GALL (NUREG-1801) report. It also refers to the previously reviewed EBP for SALTO of water moderated reactors (Review Ref: A-053).

This document is broken down into country related sections;

- Argentina
- Belgium
- Brazil
- Canada
- Czech Republic
- France
- Germany
- Hungary
- India
- Japan
- Mexico
- Russia
- Slovakia
- Spain
- Sweden
- Switzerland
- Ukraine
- USA

Within each of the country sections many of the approaches/procedures for scoping and screening, ageing management and the application for LTO are similar due to the use of the same RGP or regulatory body documents. There are some slight differences in reporting procedures and some have a more in depth approach to LTO than others.

Reference: A-141 [IAEA-EBP-LTO-21]
Document Title/Version Number: Final report from Working Group 2 on the Long Term Operation of Mechanical Components and Material Issues.
Date of Issue: September 2006
Summary: The Extrabudgetary Programme on Safety Aspects of Long Term Operation (SALTO) of Water Moderated Reactors contains 4 working groups (WGs) lead by a steering committee. Each working group produced a final report based on their findings in the area allocated. The programme also contained a final report which summarises the results, conclusions and recommendations of the programme with regards to long term operation, mechanical components and materials, E/I&C and SSCs. More detailed information is included in the 4 working group reports prepared in the framework of this Programme. <u>Programme overview</u>. Increasing numbers of IAEA member states are looking into the long term operation (LTO) of existing Nuclear Power Plants (NPPs), this programme was devised after the IAEA recognised that *"internationally agreed-upon, comprehensive guidance was needed to assist regulators and operators in dealing with the unique challenges associated with the LTO"*. The report defines long term operation as *"operation beyond an initial time frame set forth by licence term, design limits, standards, and/or regulations etc., which has been justified by safety assessment considering life limiting processes and features for systems, structures and components (SSCs)"*. (Definition reference; Final report [25] Section 2 'General Framework'). *"The Programme was carried out by means of exchange of experience and formulation of guidance, which will assist regulators and plant operators considering long term operation"*. The programme uses the IAEA Safety Guide for PSRs (NS-G-2.10) as a reference, this document is also referred to in the review of SSG-48 (Ref; A-069). The Safety Guide contains Safety Factors which each of the Working Groups identified as part of their objectives. The scope: *"The scope of the Programme included general long term operation framework, mechanical components and materials, electrical components and instrumentation and control, and structural components and structures"*. The program's objectives were to *"assist those Member States considering LTO of water moderated reactors in how best to reconcile the related processes and practices; how to establish a general LTO framework; and finally, it provides a forum in which Member States can freely exchange information"*. A steering committee was set up to guide the programme through 4 working groups and one final report, these groups were: • Working Group 1: General Long Term Operation Framework (IAEA-EBP-LTO-20) • Working Group 2: Mechanical Components and Materials (IAEA-EBP-LTO-21) • Working Group 3: Electrical Components and I&C (IAEA-EBP-LTO-22)

Reference: A-141 [IAEA-EBP-LTO-21]
• Working Group 4: Structures and Structural Components (IAEA-EBP-LTO-23) – Reviewed as part of this project. • Final report of the programme on S.A.L.T.O. of water moderated reactors (IAEA-EBP-LTO-25) – Reviewed as part of this project. The activities of Working Group 2 evaluated Member State management processes and practices for the mechanical components and materials of Systems, Structures and Components (SSCs) relevant to LTO whose function belonged in the following 4 categories: 1. All safety related SSC that ensure the integrity of the reactor coolant pressure boundary 2. All safety related SSC that ensure the capability to shut down the reactor and maintain it in a safe shut down condition 3. All safety related SSC that ensure the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure. 4. All non–safety related systems, structures, and components whose failure could prevent satisfactory accomplishment of, or initiate challenges to, any of the safety functions defined above.
Key Themes Plan Section 4 refers to the ageing management programmes, splits the programmes into 4 major phases, describes some mitigation methods, considers future challenges and gives a short statement of recommendations. 4.1 splits the programmes into 4 major phases: Phase 1: *"involves carrying out an engineering assessment of the current status of SSCs within the scope of LTO and identifying potential ageing mechanisms or degradation mechanisms"*. Phase 2: *"involves evaluating maintenance programmes and plant operational practices (including in–service inspection and in–service testing programmes) to ensure that the impact of the ageing mechanisms will be detected and characterized"*. Phase 3: *"requires an evaluation to ensure that the safety margins of SSCs identified in phase 1 are adequate to ensure safe operation for the proposed period of LTO"*. Phase 4: *"defines the necessary preventive measures, additional inspections, repair and replacement work, and systems engineering activities, or any modification of operating modes which are required either individually or collectively to prevent accelerated degradation by the identified ageing and wear mechanisms and to ensure that the structures, systems and components can reach their design service life"*. Regarding mitigation measures, Para 4.1.2 states, *"Identification and early implementation of mitigation measures is critical to developing adequate ageing management programmes"*. Examples of mitigation measures are: 1. Reduction or reversal of residual stresses in weldments (reduction in stresses, vibration, etc)

Reference: A-141 [IAEA-EBP-LTO-21]

2. Corrective maintenance including repair or replacement of components on a schedule that prevents failure

A list of IAEA TECDOCs are provided as references for mitigation guidance for specific critical components (listed in the Document relationships and referencing section of this review).

"The following challenges have been identified for AMPs:

1. The need for harmonization of industrial standards and regulatory requirements applicable to AMP

2. Gaps in the knowledge that need to be covered in future research

3. Gaps in the feedback of experience on making allowances for ageing at the design stage and monitoring ageing"

Para 4.4 gives two short statements of recommendation, both around collaboration and OPEX sharing. WG2 members recommended developing a database of known degradation mechanisms and an exchange of experiences through workshops and seminars.

<u>Do</u>

Section 3 covers the scoping and screening of SSCs. It was found during this programme that the scoping and screening process varied greatly among member states. The working group members from all 4 WGs recognised this issue, a recommended practice was developed from this (Appendix 2). Para 3.1 states, *"The differences in details for determining the SSCs subject to the engineering reviews and detailed fitness for service evaluations required by LTO resulted in significant technical differences and potential safety issues among Member States"*.

Three examples of different country methods are given to show the differences in methods and depth of the scoping and screening process.

Section 5 describes the operational programmes; these are broken down into the following sections:

5.1 In-Service Inspection (ISI) Practices for Passive Components

5.2 Maintenance Codes or Practices for Active Components

5.3 Equipment Qualification (EQ) Practices

5.4 Component Functional Tests

5.5 Applied Diagnostic Systems (including load monitoring systems)

5.6 Surveillance Programmes

5.7 Non Destructive Testing Materials Properties Testing

5.8 Destructive Tests and Material Research Carried Out During NPP Operation

5.9 Chemical Regimes Monitoring

Each of the above sections contains a background statement, a comparison of member states, future challenges and some recommendations.

Some recommendations from each section are:

Reference: A-141 [IAEA-EBP-LTO-21]
5.1 In-Service Inspection (ISI) Practices for Passive Components: 1. ISI should be a pre-condition for LTO 2. Development of a review process for evaluating maintenance for effectiveness in detecting ageing mechanisms 3. A living database for the effectiveness of NDE in detecting degradation mechanisms 5.2 Maintenance Codes or Practices for Active Components: 1. A process for developing maintenance programmes should be a pre-condition for LTO 2. Monitoring of the effectiveness of maintenance for addressing optimisation 3. International cooperation should be encouraged to promote advanced methods and tools for predictive maintenance. 5.3 Equipment Qualification (EQ) Practices: 1. Qualification programmes should be a pre-condition for LTO 2. The programme for the qualification of equipment should be approved by the regulatory body 3. EQ should be demonstrated by tests, analysis and OPEX 5.4 Component Functional Tests: 1. Development of minimum standards for functional tests such as: a. The scope and scheduling b. Acceptance criteria c. Criteria for monitoring and trending of results 2. Tests should be clearly tied with the operational requirements of the component 5.5 Applied Diagnostic Systems (including load monitoring systems): 1. Development of a minimum evaluation criteria for the use of diagnostic technology 2. Diagnostic systems should be reviewed through a scoping and screening process 5.6 Surveillance Programmes: 1. Early consideration is required to prepare background, operational aspects and consider supplementary surveillance programmes 2. Supplementary RPV surveillance programmes should be pre-conditions for LTO 3. Existing surveillance using representative samples should be extended or supplemented for LTO 5.7 Non Destructive Testing Materials Properties Testing: 1. Technical exchange meeting on NDE material property measurements

Reference: A-141 [IAEA-EBP-LTO-21]

2. A benchmarking protocol for measuring the capability of NDE methods
3. Development of criteria that regulators may use for evaluating NDE measurements

5.8 Destructive Tests and Material Research Carried Out During NPP Operation:

1. International guidance be developed for application of destructive measurements in evaluations for LTO
2. An internationally agreed upon methodology for application of miniature specimens to determine material properties be evaluated
3. Databases be developed (similar to that of RPV surveillance specimens)

5.9 Chemical regimes Monitoring:

1. Water chemistry programmes should be a pre-condition for LTO.

Check

Section 6 contains information on Time Limited Ageing Analysis (TLAA).

Examples of TLAAs are those calculations and analyses used by the plant operator that:

1. Involve systems, structures, and components within the scope of LTO
2. Consider the effects of ageing
3. Involve time–limited assumptions defined by the current operating term—for example, 40 years
4. Were determined to be relevant by the plant operator in making a safety determination as required by national regulations
5. Involve conclusions or provide the basis for conclusions related to the capability of the system, structure, or component to perform its intended function(s)
6. Are contained or incorporated by reference in the current licensing basis.

Para 6.2.1 through 6.2.6 gives examples of types of TLAAs used by member states.

Para 6.3 states that uncertainties in the material properties of the SSCs and the development of analytic techniques for new technologies are the challenges for TLAAs.

"Working Group 2 members believe that the major challenge in the area of TLAAs involves developing minimum standards for methodology and acceptance criteria".

Para 6.4 give the following list of recommendations to improve TLAAs:

1. Sharing international experience on material properties for SSCs in the scope of LTO; this could be in the form of a database of material property measurements
2. Development of minimum standards specific applicable to LTO for TLAA
3. In order to improve the accuracy of TLAAs, research/development and codification of advanced analytic methods should continue

Reference: A-141 [IAEA-EBP-LTO-21]

4. Workshops and training on developing TLAAs with respect to LTO should be carried out.

Document Relationships & Referencing

This programme was carried out between 2003 and 2006, many of the themes here have been developed further and documented in the 2009 publication NS-G-2.12 which has since been superseded by SSG-48 in 2018.

Additional references found in this document include:

- Assessment and Management of Ageing of Major Nuclear Power Plant Components important to Safety:
  - *IAEA-TECDOC-1120 (PWR Pressure Vessels)*
  - *IAEA-TECDOC-1119 (PWR Vessel Internals)*
  - *IAEA-TECDOC-981 (Steam Generators)*
  - *IAEA-TECDOC-1361 (Primary Piping in PWRs)*
  - *IAEA-TECDOC-1470 (BWR Pressure Vessels).*

Applicability to Beyond Design Life Expectations

The themes from this document list some of the key issues/requirements recognised by the SALTO group 2. These could aid the creation of questions to gain insight into or evidence of, the preparation for LTO for a specific materials or mechanical components. Section 5 of this document contains the operational programmes considered to be a 'pre-condition' for Long Term Operation.

Applicability to the ONR SAPs

N/A

Future Considerations

N/A

Additional Notes

Appendix 2 contains the scoping and screening process, including two figures, one of which contains a flow for the TLAA.

Appendix 3 contains a table of examples of SSCs, their materials, environments/stressors and ageing and degradation mechanisms.

Reference: A-142 [IAEA-TOP401]
Document Title/Version Number: Technical Obsolescence Programme
Date of Issue: Date modified (IAEA IGALL database) December 2019
Summary: The purpose of this programme is to provide operating organizations with a general format for development and implementation of a proactive obsolescence programme to manage the impact of obsolescence on the availability and reliability of systems, structures and components (SSCs). This document has been labelled as modified in December 2019, however the content contains references to NS-G-2.12 (2009) which has been superseded by SSG-48 (2018). The TOP document contains the following sections: 1. Scope of the technological obsolescence programme 2. Proactive technological obsolescence actions to minimize and control obsolescence 3. Detection of technological obsolescence indicators 4. Monitoring and trending of technological obsolescence 5. Mitigating technological obsolescence 6. Acceptance criteria 7. Corrective actions 8. Operating experience feedback 9. Quality management The definition given in this document for technical obsolescence is the one used in NS-G-2.12: *"Lack of spare parts and technical support; lack of suppliers and/or industrial capabilities"*
Key Themes <u>Section 1: Scope of the technological obsolescence programme</u> This section focuses on the part and component obsolescence in nuclear power plants (NPPs). This refers to items which may be replaced over the period of operation of an NPP. A list of consideration descriptions are given: 1. If an item is no longer supported by the manufacturer to maintain an item or model, or is otherwise difficult to procure and qualify, the original item needs to be replaced and the item is considered obsolete. 2. If an item is obsolete but it is in stock, it remains obsolete. This means that technological obsolescence does not depend on stock, but on the ability to acquire the item in market.

Reference: A-142 [IAEA-TOP401]

3. If the manufacturer changes only the model or commercial denomination of an item, the original item is considered obsolete.

4. If a manufacturer no longer provides the model with adequate qualification documentation, the item is considered obsolete.

5. If a manufacturer no longer provides the model with the same specifications (dimensions, material, footprints, etc.), the item is considered obsolete.

<u>Section 2: Proactive technological obsolescence actions to minimize and control obsolescence</u>

This section is broken down into parts A and B and includes three basic elements required for a proactive approach to obsolescence, these are Identification, Prioritisation and Solution development.

Part A, Organisation.

This part refers to the organisation's responsibilities to technical obsolescence, here the document refers to the EPRI 1016692 document (see Documents and referencing below) regarding the specific roles and responsibilities.

TOP401 describes three roles responsible for obsolescence:

1. Obsolescence Owner

2. Obsolescence Committee

3. Obsolescence Specialists

The owner coordinates the activities across the organisation and is responsible for the management, governance and obsolescence programs. The owner is also involved in the assessment of the overall effectiveness of the programs, processes and alignment to equipment reliability programmes.

The committee contains *"experts among key departments such as operations, maintenance, engineering, and procurement"*. The committee is responsible for the review of unsolved obsolescence issues.

Obsolescence specialists are those who are involved in regular obsolescence related task such as the identification and resolution of obsolete parts.

Part B, Methodology.

"The first step in establishing a proactive obsolescence programme is to develop a baseline listing of equipment and associated items in the plant".

This baselining is a way of mitigating the potential pitfalls of incomplete data, which could lead to availability issues. In order to achieve this the identification of missing data can be achieved by:

1. A document review and data capture using existing data sources

2. A physical walk-downs of the equipment

3. The use of available industry software tools

Part B describes in more detail the three elements of Identification, Prioritisation and Solution.

Reference: A-142 [IAEA-TOP401]
Identification of the equipment which no longer have the support of the original manufacturers, some examples of sources to aid the identification of these items are: 1. System, programme, and/or component health reports and assessments 2. Proactive vulnerability reviews 3. Industry obsolescence databases Prioritise by obsolescence vulnerability: 1. The importance of the component 2. The demand for the part 3. Spare part availability Implement solutions, *"The types of solutions can vary from minor design changes and equivalency evaluations to reverse engineering and major design modifications".* <u>Section 3: Detection of technological obsolescence indicators</u> Examples of early warning indicators are given, such as: 1. Changes in the suppliers' owner structure, e.g. brands that are bought or sold to another company 2. Outsourcing of manufacturing 3. Long lead times and high price <u>Section 4: Monitoring and trending of technological obsolescence</u> *"It is important to monitor the effectiveness of the obsolescence programme and continuously seek to improve performance and efficiency. Two types of activities are recommended":* 1. Periodical obsolescence programme assessment; and 2. Development and monitoring of meaningful performance indicators on a periodic basis (e.g. quarterly). A list of obsolescence questions are provided to aid the development of the obsolescence scope. 1. Is there an obsolescence programme or process description or guideline describing implementation? 2. Does it include roles and responsibilities? 3. Is there a designated obsolescence owner? 4. Is there an obsolescence committee involving key departments such as operations, maintenance, engineering, procurement? 5. Are obsolescence vulnerability reviews performed to identify critical obsolescence issues? 6. Are there tools being utilized to support identification, prioritization, and research of solution for obsolete components? 7. Are there information exchanges or collaboration initiatives with other operating organization?

Reference: A-142 [IAEA-TOP401]

8. Do system and/or component health reports contain a section on obsolescence vulnerabilities?
9. Are metrics used to monitor the programme and process health?
10. Has the programme proactively resolved any obsolescence challenges?
11. What lessons have been learned (what could have been done better) from the obsolescence programme development and implementation?
12. How the plant measures success? What are the key performance indicators?

Another list containing metrics for site v industry are given as examples of performance indicators.

"Technological obsolescence is an important parameter that is usually considered upon evaluating the cause of the plant disturbance. The number of identified "obsolescence events" can be monitored as a plant performance indicator".

Section 5: Mitigating technological obsolescence

"Reactive or proactive obsolescence issues can be added to the plant's corrective action programme with action plans and due dates. Codes are available for events that are caused by obsolescence or have obsolescence issues that result in an extension of outage so that the impact of technological obsolescence on plant availability can be fully understood".

The document considers the solution paths and the responsibilities for each of these paths, a table is provided showing the solution path, the responsible organisation and the priority order of least to most complex. A description of each path is also provided.

Some examples of considerations are given in this section to mitigate obsolescence problems:

1. Training and qualifying workers to perform the repair/service on obsolete items or to consider contracting a specialised company to conduct the repair/service
2. Keeping a database with information about which, where and how many parts are obsolete which is constantly updated
3. Improving maintenance to allow the lifetime extension of obsolete components
4. Using a standard equipment rather than customized or unique designs
5. Identifying key components which are likely to become obsolete before the end of SSC lifetime and procurement of sufficient spare parts

Section 6: Acceptance criteria

"The obsolescence programme acceptance criteria are:

1. No failure to identify and address the adverse effect on SSCs in a scope caused by obsolescence

2. The unavailability of these components will not exceed acceptable limits

3. The reliability of these components is not degraded because of obsolescence"

Section 8: Operating experience feedback

Reference: A-142 [IAEA-TOP401]
This section considers the value of collaboration between plant areas and organisations. Industry databases are an effective tool to aid the discovery and prevention of obsolescence. A reference to the Nuclear Utility Obsolescence Group (NUOG) is given, this website gives information and tools relating to obsolescence. This section also directs you to the EPRI 1019161 document (Proactive Obsolescence Management: Program Implementation and Lessons Learned). The document contains a benchmarking questionnaire which will help perform a self-assessment, which can be compared to the information within this referenced document.
Document Relationships & Referencing Three documents from EPRI and one from the INPO were used as a reference when developing the Technical Obsolescence Programme, these are: • EPRI 1015391, Obsolescence Management: A Proactive Approach • EPRI 1016692, Obsolescence Management: Program Ownership and Development • EPRI 1019161, Proactive Obsolescence Management: Program Implementation and Lessons Learned • INPO, Nuclear Utility Obsolescence Group (NUOG) Obsolescence Guideline
Applicability to Beyond Design Life Expectations This document contains obsolescence questions which could be used in conjunction with a site assessment for long term operation. The documents referenced within TOP401 also contain some useful guides and OPEX which may be of use to an organisation when planning for LTO.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes EPRI 1019161 (Proactive Obsolescence Management: Program Implementation and Lessons Learned) may be a useful document to refer to as part of this review process.

Appendix C. Output of Nuclear Industry Codes & Standards and Other RGP

Reference: A-006 [ASME XI Div 2]
Document Title/Version Number: 2019 ASME Boiler and Pressure Vessel Code, SECTION XI – Rules for Inservice Inspection of Nuclear Power Plant Components, Division 2 – Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Power Plants
Date of Issue: July 2019
Summary: Section XI, Division 2, Requirements for Reliability and Integrity Management (RIM) Programs for Nuclear Power Plants, is a technology-neutral standard of the ASME Boiler and Pressure Vessel Code. It provides requirements for protecting pressure integrity of structures, systems, and components (SSCs) that affect reliability. Application of Division 2 begins when the requirements of the Construction Code have been satisfied. It is applicable regardless of the Construction Code classification used for an SSC if the SSC is designated as important to the safety and reliability of an operating plant. The rules of this Section constitute requirements to maintain the nuclear power plant and to return the plant to service, following plant outages, in a safe and expeditious manner. Division 2 rules require the development of a Reliability and Integrity Management (RIM) Program that considers the combination of design, fabrication, degradation mechanisms, inspection, examination, monitoring, operation, and maintenance of SSCs to ensure they will meet their required reliability target values. The rules also stipulate duties of the Authorized Nuclear Inservice Inspector to verify that the program has been completed, implemented, and updated in accordance with the requirements of Division 2. The RIM Program addresses a plant's entire life cycle. It is applicable over the entire life of the plant and each passive Structure, System, and Component (SSC) that is in scope. It requires a combination of monitoring, examination, tests, operation, and maintenance requirements that ensure SSCs meet the plant risk and reliability goals (i.e., Reliability Targets) that are selected for the RIM Program. The RIM process consists of the following steps: 1. RIM Program scope definition 2. Degradation mechanism assessment 3. Plant and SSC Reliability Target allocations originating from the probabilistic risk assessment (PRA) 4. Identification and evaluation of RIM strategies 5. Evaluation of uncertainties 6. RIM Program implementation 7. Performance monitoring and RIM Program updates This Division identifies the areas subject to inspection, monitoring, responsibilities, provisions for accessibility and inspectability, examination methods and procedures, personnel qualifications, frequency of inspection, record keeping and report requirements, procedures for evaluation of inspection and monitoring results and subsequent disposition of results of evaluations, and repair/replacement activity requirements, including

Reference: A-006 [ASME XI Div 2]
procurement, design, welding, brazing, defect removal, fabrication, installation, examination, and leak testing. The objective of the RIM Program is to define, evaluate, and implement strategies to ensure that Reliability Targets for SSCs are defined, achieved, and maintained throughout the plant lifetime. The RIM Program shall select the combination of inspection, monitoring, operation, examinations, tests and maintenance requirements that enable the SSCs to meet its Reliability Target in an efficient and cost effective manner.
Key Themes <u>Identification of SSCs to be Covered by the RIM Program</u> The scope shall include SSCs whose failure could adversely affect plant safety and reliability. The Owner shall also document the basis for the exclusion of any SSC considered to be outside the scope of the RIM Program. <u>Identification of Degradation Mechanisms</u> The potential active degradation mechanisms for the SSCs within the RIM Program scope shall be identified and evaluated, this may include: • Design characteristics; • Fabrication practices; • Operating and transient conditions; • Plant-specific, industry-wide service experience and research experience; • Results of preservice, in-service, and augmented examinations; • Applicable degradation mechanisms; • Recommendations by SSC vendors. <u>Identification of Reliability Targets</u> The PSA should be used to derive the reliability targets for the applicable SSCs. <u>Identification and Evaluation of RIM Strategies</u> The RIM Expert Panel (RIMEP) shall identify the RIM strategies that are available to meet the Reliability Targets and evaluate & select combinations of strategies that will meet and maintain the Reliability Targets. The strategies shall account for all factors that contribute to reliability. The evaluated RIM strategies shall account for the potential for specific degradation mechanisms applicable to each SSC. The RIMEP shall select the RIM strategies or combinations of strategies that are necessary and sufficient to achieve and maintain SSC reliability consistent with SSC Reliability Targets. <u>Evaluation of Uncertainties</u> The RIMEP shall identify additional RIM strategies over and above those determined previously that are necessary to provide additional assurance that the Reliability Targets will be achieved and maintained during the SSC service lifetime in order to address uncertainties in predicting SSC reliability performance. Specific RIM strategies that are included to address these uncertainties shall be documented.

Reference: A-006 [ASME XI Div 2]

RIM Implementation & Documentation

The Owner shall document the RIM strategies that are selected for inclusion into the RIM Program as part of the RIM Program documentation. This documentation shall include the following:

1. The scope of SSCs selected for inclusion in the RIM Program;
2. The results of the degradation mechanism assessment evaluation for the SSCs in the RIM Program;
3. The plant level risk and reliability goals;
4. SSC Reliability Targets derived from the plant level risk and reliability goals;
5. The technical adequacy of the PSA and risk information used to derive the SSC Reliability Target;
6. The specific RIM strategies selected for the RIM Program for each SSC including associated performance parameters that are required to achieve Reliability Targets, (e.g., probability of detection, inspection intervals);
7. The evaluation of the impact of RIM strategies and combination of RIM strategies on the SSC reliability performance;
8. The quantification of uncertainties and evaluation of additional RIM strategies selected to address uncertainties.

The RIM Program documentation shall be updated periodically to evaluate changes to any of the technical inputs.

Performance Monitoring & RIM Updates

The affected portions of the RIM Program shall be re-evaluated to incorporate results from SSC performance Monitoring And NDE (MANDE) and new information affecting implementation of the program as it becomes available. New information may include the following:

- Changes to plant design;
- Changes to plant procedures;
- Changes in SSC performance;
- MANDE results that indicate service-related degradation;
- Industry or research experience.

RIM Program updates may include adjustment of SSC Reliability Targets based on new information.

Document Relationships & Referencing

N/A

Applicability to Beyond Design Life Expectations

The requirements of this document broadly follow the requirements of an Ageing Management Plan for SSCs, (as described in IAEA SSG-48), with the level of detail of the AMP reflective of the safety significance of the item. For those SSCs that have be designed in line with the ASME codes, then the level of detail required by the RIM Programme would be consistent with the AMP for applicable SSCs. However, the requirements of

Reference: A-006 [ASME XI Div 2]
this document are applicable through the whole lifecycle of an SSC and not specifically supporting extended operation. There are similarities in the key themes outlined above that fit with the Plan => Do => Check => Act and Understanding activities identified in the Systematic Approach to Ageing Management, which provides further support to establishing Ageing Management and using the collated information to support operation beyond the original design life for SSCs. To support the justification/substantiation of SSCs beyond the original design life a requirement to have an AMP in place for safety significant SSCs would be considered good practice. The AMPs should be suitably and sufficiently detailed to demonstrate the degradation mechanisms are understood and that there is appropriate management of the SSCs during the extended operation. If no AMP exists then generation of one to support the BDL submission would demonstrate a level of understanding around the SSC and ensure visibility of the information. Where an AMP may already exist then demonstration that the AMP is reviewed/updated to support the BDL submission or this is undertaken as part on-going operations could form an additional leg of the BDL justification.
Applicability to the ONR SAPs Aspects of the Ageing & Degradation SAPs would be applicable including EAD.2 to EAD.4 and additional Ageing Management Principles identified as part of task ONR376.
Future Considerations N/A
Additional Notes N/A

Reference: A-014 [EPRI-TR-106109]	
Document Title/Version Number: Nuclear Plant Life Cycle Management Implementation Guide	
Date of Issue: November 1998	
Summary: The objective of this document is to provide background information and guidance to those NPPs beginning to implement dedicated LCM plant programmes and to others desiring to improve existing LCM programmes. This document introduces the LCM concept, gives an overview of asset & ageing Management; describes activities, staffing needs, and long-term benefits of LCM plant programmes; and provides key references related to LCM. It also presents major elements of LCM required for licence renewal. The document notes that to support licence renewal the application should include: • An integrated plant assessment (IPA), which should identify: – A list of SSCs subject to AM reviews; – Methodology & justification for selection; – Demonstration that the effects of ageing are adequately managed. • An evaluation of TLAAs, which should demonstrate: – The analyses remain valid for the period of extended operation; – The analyses have been projected to the end of operation – The effects of ageing on the intended function(s) will be adequately managed for the period of extended operation. A list of any exemptions must also be included, including justification for why the exemption remains valid for the period of extended operation. • Any changes to the licencing basis that may have occurred during the NRC review period. • An FSAR supplement covering the elements above. The document identifies that the fundamental steps of the IPA process as: • Scoping; • Screening; • Identification of Applicable Ageing Effects; • Significant Ageing Effects (that need active management during extended operation); • Ageing Management Demonstration.	

Reference: A-014 [EPRI-TR-106109]

The report notes that the purpose of a TLAA review is to determine what design analyses needs to be addressed for extended operation. The steps of the TLAA include:
 	
• Identify the TLAA, which are typically either calculations or analyses which are:
  – A time dependant parameter, or;
  – A time dependant measure of material condition.
• Resolve the TLAAs by showing:
  – The initial analysis is valid for the extended period;
  – Re-analysis completed for extended operation, or;
  – Covered by aging management programme (e.g. replacement, inspections, etc.)
• Identification of any exemptions and justification over the extended period.
 	
The report also identifies that the environmental impact of the extended operation should also be evaluated as part of the licence renewal.
 	
To support the development and implementation of an LCM programme the document includes a number of self-assessment questionnaires that focus on the identification of long-term financial risk/vulnerabilities, Asset Management and Plan Condition & Ageing Management. While the first two questionnaires are not directly applicable to this research task the third one has some relevance.
 	
In addition to presenting information around LCM and the activities for licence renewal, the document also includes information on generic ageing mechanisms and the identification mechanisms applicable to common LWR SSCs.

Key Themes <u>General Note</u> This document dates back to the early days of ageing management, Life Cycle Management and licence renewal for extended operation, in the years that have followed significant work has been undertaken in the development of requirements for extended operation. The collation of different experiences from across the industry to distil common approaches has contributed to the development of many documents including the current approaches outlined in SSG-48. This document represents the start of this journey and as such does not add any new or additional themes or considerations.
Document Relationships & Referencing N/A
Applicability to Beyond Design Life Expectations <u>BDL Questions/Challenges</u> The list of questions identified in the third part of the self-assessment questionnaire are summarised below: • What is general level of health (material condition) of the plant? • Are there any current critical degradation problems with major components?

Reference: A-014 [EPRI-TR-106109]
• How does the plant valuation model address the relationship between plant condition, planned & unplanned outages in projections for planning purposes? • To what extent are environmental conditions, which lead to adverse ageing stressors, being measured and documented? • What processes are being used to minimise the potential failure of active components due to ageing degradation of passive parts (e.g. valve bodies or pump supports)? • Does the maintenance programme cover monitoring and control of degradation in passive items? • How is long-term degradation being monitored and trended? • Are procedures in place to enable advantage being taken for inspecting inaccessible SSCs during other plant activities? • What systematic procedure ensures that the results of long-term degradation monitoring are documented and are readily retrievable? • How are lesson learned from older plants being used to address plant ageing? Although the questions are generally aimed at considering what is being done at a facility level to help support LCM implementation, it is not difficult to see how these could be adapted to develop a list of questions used to challenge BDL substantiation. As noted above this document dates back to early-on in the development of Ageing Management and much of the information presented has either been incorporated into or superseded by SSG-48.
Applicability to the ONR SAPs The document does not identify anything that is related to a specific SAP or TAG, but instead challenges regulators to ensure their requirements are suitable for extended operation. This research task, to a certain extent, is that check and is actively looking at BDL or LTO RGP to determine if the ONR Guidance (through the SAPs & TAGs) support LTO and developing the expectations for BDL substantiation, mapping these to the SAPS & TAGs.
Future Considerations Consideration of developing a series of questions that challenge the BDL justification to ensure key elements have been considered for the SSC and the potential impact on the facility as a whole to be included in any potential TAG that addresses BDL.
Additional Notes The document contains some OPEX around degradation mechanisms and monitoring methods. The information is all focussed on LWRs and reflects understanding over 15 years ago; as such, it may have limited use in the UK.

Reference: A-024 [ENSREG-SW2017]
Document Title/Version Number: Topical Peer Review 2017 Ageing Management - Swedish National Assessment Report
Date of Issue: 2017
Summary: This report issued by the Swedish Radiation Safety Authority (SSM), is based on the licensee's assessment of the aging management programmes and the results of SSMs review. Based on the SSMs performance based regulatory philosophy Swedish licensees have pursued slightly different paths to develop the respective overall ageing management programmes, all with the goal to ensure the availability of required safety functions throughout the service life of the plant. The Swedish licensee's use the key elements of ageing management as listed in the IAEA document NS-G-2.12, which has been superseded by SSG-48. This document contains the following sections: 1. General information 2. Overall ageing management programme requirements and implementation 3. Electrical cables 4. Concealed pipework 5. Reactor pressure vessels 6. CANDU – (No info or data included) 7. Concreate containment structures 8. AGRs - (No info or data included) 9. Overall assessments and general conclusions Also included in this document are two annexes: 1. Drawings of RPVs 2. Concreate containment structures There are three licensees in Sweden: 1. Forsmark 2. Oskarshamm 3. Ringhals The ageing management programmes used by the Swedish licensees are based on the IAEA guidance from NS-G-2.12 and SRS 57. Both of these earlier documents (2007 & 2009) have since been superseded by SSG

Reference: A-024 [ENSREG-SW2017]
48. The licensees have also used SRS 82 and NUREG 1801 to aid the development of the ageing management programmes.
Key Themes <u>Plan</u> Regarding ageing programmes, section 2 states that there should be a programme for ageing degradation and damage in place. This programme should contain the following concerning ageing mechanisms: 1. Identification 2. Monitoring 3. Handling 4. Documentation This programme should be updated when technological and scientific developments are recognised and on the emergence of new OPEX. The three reactors in Sweden approach ageing management in different ways. Oskarshamm: Overall ageing management is split among 6 teams: 1. Construction 2. Mechanics 3. Electricity 4. I&C 5. Vessel and pipe components 6. Obsolescence These make up a coordinating group for ageing management. The AMP responsibilities for this group are: 1. Documentation of the overall programme 2. Developing new AMPs 3. Evaluation and optimisation of existing programmes 4. Holding meetings every quarter 5. Assessment of work orders, licence event reports and serve as expert support 6. OPEX and R&D Ringhals:

Reference: A-024 [ENSREG-SW2017]
As above, there are 6 technical areas which are responsible for ageing management, these are: 1. Primary system 2. Mechanical systems 3. Electrical systems 4. I&C systems 5. Civil structures 6. Fuel The AMP group responsibilities are: 1. Documentation of the overall programme 2. Ensuring the programme is complete 3. Coordinate activities 4. Evaluation and optimisation of existing programmes 5. OPEX exchange with external organisations 6. Disseminate R&D results related to ageing management within Ringhals 7. Ensure that information is available and training is provided 8. Report to management Forsmark have allocated responsibilities differently, the departments involved and their individual responsibilities are: 1. Engineering a. Time limited Ageing Analysis b. Sustainable and long term plant development c. Technical support for refurbs and equipment renewals 2. Maintenance a. OPEX information for optimising maintenance b. Review of maintenance programmes and AM activities c. Management of obsolescence 3. Production a. Safety related system performance testing b. Results trending/monitoring, looking for effects of ageing

Reference: A-024 [ENSREG-SW2017]

c. Environmental condition monitoring & mitigation of ageing stressors

4. Human Resources

a. Skill development and training

5. Planning

a. Production and availability reporting in support of goals regarding Nuclear safety

The methodology for evaluating current AMPs varies across the 3 licensees:

Forsmark carryout analysis of the SSCs within each of the commodity groups, the analysis covers the material, function, medium, surrounding environment, experiences, current maintenance programmes and maintenance actions. *"All existing programmes for the different component groups should further be fully evaluated based on whether they meet the ten criteria described in the USNRC NUREG-1801. These ten criteria have been evaluated and been found to correspond to the nine criteria described in the IAEA NS-G-2.12".*

Ringhals relies on the EPRI Preventative Maintenance Basis Database (PMBD). *"For components covered by EPRI PMBD the specified degradation mechanisms should be used".*

Oskarshamn develops the AMP from the commodity group stage by forwarding the SSCs with stated ageing mechanisms to an Ageing Management Review (AMR). For this process they use a specific AMR Tool. All existing programmes are reviewed in relation to the IAEA NS-G-2.12 document.

Section 2.4 looks at the ways in which the review and update of the AMPs are carried out by each of the three licensees. This section also mentions that internal and external OPEX is used as part of this process along with evaluations of plant modifications and Time Limited Ageing Analysis (TLAA). Examinations, maintenance, Inspection and Testing (EMIT) results are also considered as part of the review of the AMPs. These task reports are *"of central importance for an effective ageing management process".*

<u>Do</u>

Scoping and screening of all SSCs generally follow the SSG 48 classifications based on importance to safety.

Forsmark groups the SSCs into the following groups:

1. Mechanical components

2. Civil structures

3. I&C components

4. Electrical components

The SSCs are further sorted by role, type, design and operating conditions. These are then placed in commodity groups.

Ringhals follows the IAEA SRS 57 (SSG 48) example. Each of the technical areas of responsibility group SSCs slightly differently based on the component type.

When grouping the following is considered:

Reference: A-024 [ENSREG-SW2017]
1. SCs material 2. Operating environment 3. Degradation mechanism 4. Type of maintenance Oskarshamn groups components by using a plant specific identification based on the component type, environment, material and ageing mechanism. These are collected together in a database. Where components have no plant identification new areas are created, a few examples are given such as cables and lifting equipment. The assessments of ageing effects on SSCs are done by assessing the following key elements: 1. Material used in the SSC 2. Media acting on the SSC e.g. substances/temperature etc. 3. The environment the SSC is in 4. Experience from both internal and external sources All three licensees use these key elements. <u>Check</u> Page 18 refers to the inspection programmes. Here it states that the ISI is a support to the ageing management programme. It also states that there are risk informed inspection programmes in place which are categorised as A-C. In the case of A-B categories, these must be "*performed by qualified personnel with qualified procedures and equipment*". The ISI should be approved by an accredited body. <u>Understanding</u> Forsmark and Ringhals use NORDERF for recording their experiences as well as using the NRC and IAEA databases and internal status reports. A joint forum for ageing issues (FORSAMP) involves all three licensees, Swedish Nuclear Fuel and Waste Management Co. Within this forum framework a common list of degradation mechanisms has been created. This list was created following the studies of IGALL, IAEA SRS 82, NUREG 1801, NOG SEP 04-120 and various EPRI documents. Regarding R&D there are some common activities which are coordinated by the NOG and Swedish Energy Research Center. The FORSAMP group are developing "*common metrics*" to measure individual AMPs. An R&D example given from Ringhals states, *"R&D is performed in different areas where there are appointed specialists"*. It also describes the goal of R&D as, *"to strive for preparedness for future demands, to build competence, to develop methods and tools for safety analysis, severe accident handling, human factor engineering and to follow research in the field and participate in joint projects between other nuclear operators and the authority"*. <u>Section 2.7: Regulators conclusions.</u> This document compares the AMPs of the three licensees. As part of the AMP assessment and conclusions (Section 2.7) the SSM believe the Forsmark and Ringhals approach to be more robust. These two licensees

Reference: A-024 [ENSREG-SW2017]
focus their attention on the internal and external experiences rather than the acquired databases of adapted information used by Oskarshamn. The SSM believes that the high level acceptance criteria used by the licensees should be more specific to the intended function of the SSC. The results from international reviews of AMPs should be handed into the regulator by the licensees as part of the PSR documentation. Also recognised by this review was how the SSMs expectation differed from that of the licensees view of the AMPs. *"The performance/goal based regulatory philosophy used by SSM has so far resulted in too wide interpretations by the licensees of the requirement concerning programme for ageing management."* <u>Section 9: Overall assessments and general conclusions.</u> This section breaks down the discussions from each section (2 to 7) and gives a short statement on findings and good practice. Most of the thoughts recorded here reflect the uses of IAEA, NUREG and other national and international experiences.
Document Relationships & Referencing The three licensees base their AMPs on the following documents: • IAEA documents NS-G-2.12, SRS 57 and SRS 82 • NUREG 1801 Other documents referenced in this review are the Swedish Radiation Authorities Regulations SSMFS 2008:17, which have been superseded by SSMFS 2018:12. The following document is related to the list of degradation mechanisms created as part of the FORSAMP forum, this is the Nordic Owners Group report (NOG SEP04-120).
Applicability to Beyond Design Life Expectations Section 2.7 contains the views of the SSM from inspections and reviews of the AMPs across the three licensees. These regulatory experiences may add some value to the ONR. Most of this review contains information from SSG 48's predecessor NS-G-2.12.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-025 [ENSREG-GER17]
Document Title/Version Number: Report by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) on Topical Peer Review Ageing Management of Nuclear Power Plants and Research Reactors.
Date of Issue: December 2017
Summary: Through the European Nuclear Safety Regulators Group (ENSREG), the Member States of the European Union have selected the topic of 'ageing management' for the first peer review. This is to be carried out for all nuclear power plants that will be operating on 31 December 2017, as well as research reactors with a power equal to 1 MWth or more. In addition to general aspects of ageing management, the assessment report also has to address specific topics. These are • electrical cables • concealed pipework, • reactor pressure vessels, and • concrete containment structures. To ensure the most uniform structure possible of all national reports, WENRA developed the technical specification for the peer review at the request of ENSREG /WEN 16/. Structure and contents of the German national assessment report are based on the technical specification /WEN 16/. This document is broken down into the following sections: 1. General Information 2. Overall ageing management programme requirements and their implementation 3. Electrical cables 4. Concealed pipework 5. Reactor pressure vessels 6. Calandria/pressure tubes (CANDU) 7. Concrete containment structures 8. Prestressed concrete reactor pressure vessels (AGR) 9. Overall assessment and general conclusions Each section follows the format of: 1. Description of ageing management programmes a. Scope of ageing management b. Ageing assessment

Reference: A-025 [ENSREG-GER17]
c. Monitoring and testing d. Preventative and remedial actions 2. Licensees experience of the application of AMPs 3. Regulatory assessment and conclusions on ageing management Sections 3, 4, 5 and 7 relate to specific areas of concern within LWRs, PWRs and BWRs and contain some examples of degradation mechanisms relevant to each area. Each of these follow the format as stated above. Sections 6 (CANDU) and 8 (AGR) do not contain any information. The German national framework uses the Plan Do Check Act (PDCA) cycle to feed into the general knowledge base for ageing management. A version of this is shown on page 11 (Section 2.1). This document relies heavily on the safety standard KTA 1403 (Ageing Management in nuclear power plants). *"Overall, KTA 1403 represents a catalogue of requirements that enables and ensures a continuous assessment of the functional features of the SSCs and their ageing-related degradation mechanisms in a closed cycle. All measures are implemented in a process-oriented manner and are organisationally integrated into the operational procedures"*.
Key Themes Plan. As part of the German national regulatory framework (section 2.1) a safety standard is identified (KTA 1403) which applies to safety related SSCs and the physical ageing of plant items and the procedures for ageing management. From this safety standard the licensees have set up a *"systematic and knowledge-based ageing management system as part of the integrated management system"* which can be assessed and updated. Section 2.1 states, *"Ageing management shall be implemented in a process-oriented manner and integrated into the operational processes. For this purpose, the following basic requirements shall be implemented by the operator:* *1. The extent of ageing-related observations shall be defined and documented. The observations shall include* *a. ageing of the auxiliary and operating supplies of the respective SSCs* *b. ageing-related influences on the data from information and operation management systems including documentation.* *2. The procedures of ageing management shall ensure that safety-related degradation mechanisms are identified. The causes and/or consequences of these degradation mechanisms shall be controlled by appropriate measures.* *3. The further development of the state of the art in science and technology shall be monitored and assessed.* *4. The measures taken with respect to ageing management and the results achieved shall be documented and assessed. Corresponding reports shall be drawn up at regular intervals. Ageing-management shall be continuously optimised based on the assessments carried out. Impermissible deviations from the required quality shall be eliminated.*

Reference: A-025 [ENSREG-GER17]
5. *Ageing management is part of an integrated management system. It shall be implemented in a process-oriented manner and integrated into the operational processes. The processes involved (e.g. servicing, maintenance), the interrelated activities as well as their interactions shall be identified, directed and controlled. This overall process shall be designed according to the principles of a PDCA cycle.* 6. *Ageing management shall be performed on the basis of a structured knowledge base. In particular, this knowledge base shall contain sufficient information on the respective design concept, ageing-related requirements from the rules and regulations, on the design and manufacture as well as the operating history of the SSCs, on the potential degradation mechanisms and, with respect to the relevant degradation mechanisms, the designated and possible monitoring, testing and corrective measures, including assessment of the results".* Section 2.3.1a considers nuclear power plants and refers to KTA 1403, its implementation and uses within the German nuclear power plants. This section also refers briefly to the PSR, basic reports for the scope of SSCs and the recording of maintenance measures in an operation management system. Regarding knowledge management 2.3.2a refers to the ageing assessments and how these add to the knowledge base. The degradation mechanisms and operational histories of the SSCs must be included in the knowledge base. From this information the monitoring and ISI schedules are created. A list of sources of information are given ranging from ISI results to event reports from other NPPs. *"Working panels within the VGB deal with issues relating to degradation mechanisms in the context of SSCs of mechanical engineering, electrical and I&C systems as well as civil engineering. The aim of these operator activities is to integrate the existing information in a common database, which comprises the known degradation mechanisms and serves to identify the degradation mechanisms that are relevant during operation and potentially effective. This database is part of the knowledge base for ageing management".* Sections 2.3.1b and 2.3.2b looks at research reactors, this differs from 2.3.1a and 2.3.2a (nuclear power plants) respectively, by not having an ageing management programme. The research reactors use the maintenance and In Service Inspection (ISI) programmes for the monitoring and trending of age related issues. These aspects of ageing are then considered for modification or replacement based on the findings. Section 2.4a refers to the reviews and updates for the ageing management programmes. *"The entire ageing management process, including the evaluation of experience feedback, repairs and ISIs of safety-related SSCs, is carried out, reviewed and adapted on the basis of a structured process".* As stated previously these programmes use the PDCA cycle which is continuously improved as part of the process. Annual status reports and self-assessments are used and the findings from these are reintegrated back into the process to improve them. Here, the document refers to another safety standard, KTA 1402 (Integrated Management System for the Safe Operation of Nuclear Power Plants). Regular reviews of ageing management are carried out with the inclusion of operators, this aids the understanding of known degradation mechanisms and the testing and control measures required for those. *"Due to the participation of the operators in the KTA working panels, necessary modifications to the ageing management are incorporated into the regulations also from the point of view of the operators".* <u>Check.</u> Section 2.3.3a gives an overview of the types of monitoring and ISIs carried out on the nuclear power plants. Some examples of these are: 1. long-term monitoring systems (e.g. fatigue monitoring system FAMOS and integrity management system IMAS)

Reference: A-025 [ENSREG-GER17]

2. structure-borne noise monitoring system of the reactor pressure vessel
3. vibration monitoring system of the primary circuit
4. walkdowns
5. NDT

"For the implementation of the above-mentioned measures of monitoring of SSCs in the context of ageing management, which are subject to regulatory supervision, there are corresponding clear instructions in the German plants. The basic requirements to carry out maintenance measures and ISIs are specified in the operating licences of the plant, the operating manual and the testing manual. The boundary conditions both in terms of the technical issues and the procedures for an effective ageing management are thus clearly laid down in the licensing documents of the plants".

2.3.3b, Research reactors have comprehensive monitoring and inspection processes in place. Evaluations of results from the ISI programme are trended to allow for the identification of long term effects. *"Unexpected mechanisms are taken into account by the redundant and diverse design of SSCs, by the great care taken in the procurement and installation of such components…"*

<u>Act.</u>

2.3.4a gives several examples of preventative and remedial actions on German plants. An example of this is the use of shared fatigue analysis experiences from other local plants and those abroad.

<u>Understanding.</u>

Section 2.3.1a refers to a central incident reporting and evaluation office (ZMA) which is part of VGB PowerTech. The ZMA organises the exchange of information across the German plants and those abroad. Regarding any ageing management events, the ZMA distributes manufacturers information to the operators who can then take any necessary actions.

"Overall, the German operators have a comprehensive system for the exchange of experience. In combination with the process of national and international exchange of experience of the nuclear regulatory authorities, this leads to an intensive exchange of experience on ageing-related degradation mechanisms and their assessment".

Section 2.5 considers the licensees experiences with ageing management, this section refers to the KTA 1403 document, stating, *"The introduction of KTA 1403 formalised the processes and contents of ageing management. Recent years have shown that the ageing management of KTA 1403, based on the already proven processes and measures of the operators of the nuclear power plants for controlling ageing degradation mechanisms, is suitable for maintaining the required quality of the SSCs and thus for making an important contribution to plant safety".*

Section 2.6 looks at the regulatory oversight process, provides a diagram of the structure of the *'Lander'* (collection of the 16 federal states within Germany) and provides a list of tasks performed by the *Lander*. These tasks are:

1. evaluation of the annual status reports of the nuclear power plant operators on ageing management, also taking into account opinions of nuclear experts consulted (e.g. TÜV or for special issues in the field of materials science e.g. the MPA)
2. review of the procedure and regulations of the operator's ageing monitoring in the different organisational areas (electrical and I&C systems, mechanical engineering, civil engineering, auxiliary

Reference: A-025 [ENSREG-GER17]
materials) on the basis of presentations and explanations provided by the heads of department or heads of section. 3. examination of documents and records, e.g. in the context of ISIs and maintenance or factory acceptance tests, 4. interviewing the persons who implement ageing management measures (status meetings, accompanying supervisions) 5. random review of individual measures of ageing management, e.g. in the context of ISIs, maintenance and, plant modifications, if any, or factory acceptance tests 6. discussion with the power plant management about objectives, strategies, major projects etc. 7. evaluation and discussion of the results of the entire ageing management process, in particular the annual status reports <u>Section 9, General conclusions.</u> This section gives a list of short statements based on the main document. Some examples of these are: *1. "In Germany, consideration of ageing effects of safety-related SSCs already began with the design/layout of the nuclear power plants still in operation today. By appropriate design and construction as well as the operation of the nuclear power plants, precautions against undue impairment from ageing effects known at that time have been taken, which were also laid down plant-specifically in the construction and operating licences.* *2. Identification, documentation and consideration of ageing effects has been continuously expanded based on the progressing state of knowledge. For this purpose, various sources were used and, where necessary, appropriate measures have been implemented for the control of ageing phenomena, including the replacement of affected parts and various constructive improvements.* *3. The knowledge required for effective ageing management is summarised in a knowledge base and regularly updated so that the identification of safety-related degradation mechanisms is ensured and appropriate measures are derived.* 4. *In summary, it can be concluded that the ageing management practised in German nuclear power plants provides an effective instrument for the detection and monitoring of ageing-related phenomena. The measures are suitable for identifying and controlling ageing-related mechanisms and thus maintaining the condition of the SSCs meeting the requirements".*
Document Relationships & Referencing Two safety standards are referenced in this document: 1. KTA 1403 (Nuclear Safety Standards Commission), Ageing Management in nuclear power plants. 2. KTA 1402, Integrated Management System for the Safe Operation of Nuclear Power Plants. This document is a summary of the KTA documents and the processes and procedures in place at German power plants. The KTA documents referenced above provide information on the processes and procedures, maintenance, personnel knowledge and the data and documentation systems required for ageing management

Reference: A-025 [ENSREG-GER17]
Applicability to Beyond Design Life Expectations This document summarises the actions carried out by the regulatory body and the operator's responsibilities, not just directly on the plant, but also their involvement in the KTA panels. This document shows how the German plants integrate their ageing management programmes with the operational management systems.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes KTA 1403, Ageing Management in nuclear power plants, within this document there is a section on Ageing of Mechanical Systems and Components which may prove useful.

Reference: A-026 [ENSREG-FR2017]
Document Title/Version Number: Safety Assessment of Nuclear Facilities in France Ageing Management National Report
Date of Issue: December 2017
Summary: *"This report was drawn up by the French nuclear safety regulator (ASN), which acted as coordinator, with contributions from the French Institute for Radiation Protection and Nuclear Safety (IRSN), the nuclear reactor licensees: Électricité de France (EDF), the French Alternative Energies and Atomic Energy commission (CEA) and the Laue-Langevin Institute (ILL). The national report drafting process began in February 2017 when ASN sent the licensees (EDF, CEA, ILL) official notification of initiation of the assessment. The contributions from the licensees were sent to ASN in mid-2017 and were reviewed by it over the summer of 2017. The draft report was validated by ASN as of November 2017."* This ENSREG document contains 9 sections, listed below, and 13 appendices. 1. General information 2. Overall ageing management programme requirements and implementation 3. Electrical cables 4. Concealed pipework 5. Reactor pressure vessels 6. CANDU 7. Concrete containment structures 8. AGRs 9. Overall assessment and general conclusions
Key Themes <u>Plan</u> Within the summary of Section 2 the report describes the ageing management approach, this is shown in 4 steps: 1. SSC selection process 2. Individual analysis of ageing mechanisms 3. Additional actions and studies 4. Drafting of an ageing analysis report specific to the reactor ASN state that although EDF do not follow the formal layout of the IAEA documents, they do incorporate the OPEX and an R&D programme. *"In the context of a continued operation of the NPPs, EDF proposes reusing*

Reference: A-026 [ENSREG-FR2017]
this approach for the fourth ten-yearly outage inspections (VD4). This approach will be extended to all SSCs important for the management not only of radiological risks, but also conventional risks".   Para 2.1.4.2 refers to the life extension of EDFs reactors. ASN have noted that EDF have set up an organisation to look into equipment degradation and stated that *"it considers that the programme of work relating to ageing management of this equipment needs to be supplemented by additional studies and inspections, more particularly with regard to the mechanical strength of the vessels, the consideration of environmental effects on the mechanical fatigue phenomenon and changing material properties".*   Para 2.3.1.1, Structure of the process, states *"To demonstrate ageing management of the Systems, Structures and Components (SSC) whose ageing can affect reactor safety and thus determine their operating lifetime, a 4-step approach has been adopted:*   *1. selection of the SSC potentially susceptible to ageing and whose failure can have an impact on safety;*   *2. drafting of the list of pertinent SSC/ageing mechanism combinations. Each pertinent SSC/ageing mechanism combination is analysed as shown by an AAS (Ageing Analysis Sheet) the aim of which is to verify the degree of ageing management in the light of the operating and maintenance provisions in force, along with the repairability and replaceability conditions;*   *3. for each component or structure potentially susceptible to ageing, the failure of which could have an impact on safety and for which ageing management cannot in principle be demonstrated by routine operating provisions, the production of a component Detailed Ageing Analysis Report (DAAR), comprising the analysis of the ongoing or scheduled actions, designed to manage ageing and define the additional actions or studies to be carried out to this end;*   *4. for each reactor undergoing VD3 (third ten-yearly outage inspection) and the subsequent ten-yearly outage inspection (VD), drafting of an ageing analysis report specific to the reactor, known as the UAAR, based on the AASs and component DAARs. This UAAR comprises the Local Ageing Management Programme which is to be implemented during the ten-year period following the VD".*   This is further broken down into sub-processes, SP1 through to SP4.   2.3.1.4, Inventory of the SSC to be considered (SP1). This part looks at the identification of components which can affect a safety function, these are list as: *1. "SSCs important for safety (EIPS),*   *2. non-EIPS SSCs, for which ageing could lead to failures liable to compromise the design hypotheses adopted in the safety case;*   *3. non-EIPS SSCs which, with respect to the PSA (Probabilistic Safety Assessments) make a significant contribution to limiting the core melt risk.*   *With regard to preparation for VD4-900 and the subsequent VDs, the scope of the SSCs is expanded:*   *1. to all the SSC which are elements important for the protection of interests (EIP);*   *2. to the other SSCs considered for the seismic, fire and internal flooding hazard PSAs".*   2.3.2.1, Drafting and review of AAS (SP2). Based on the materials making up SSCs of PWRs a list of mechanisms is put together. This list is based on lists in the IAEA NS-G-2.12 document (superseded by SSG 48) and the US-IGALL. Further, this para states, *"Each AAS is the subject of a "status" classification, used to*

Reference: A-026 [ENSREG-FR2017]
judge the ability of the existing provisions to ensure long-term ageing management. It shall in particular consider: *1. the potential or confirmed nature of the ageing mechanism;* *2. the suitability of the operating and maintenance actions currently implemented: monitoring, testing, inspection and maintenance;* *3. the difficulty of repairing and replacing the SSC".* Para 2.3.2.2 considers SP3, the drafting and review of the Detailed Ageing Analysis Report (DAAR). "*Each DAAR precisely indicates the scope covered and its limits:* *1. a component or a structure;* *2. a group of components or structures; certain groups broader than those of the selection table can be envisaged at this level;* *3. the operating lifetime considered".* DAARs for components have a 5 yearly update, these updates include the results from any work done. They are reviewed/validated by the *"operations engineering decision-making body"* before being sent to ASN. Para 2.3.2.3 describes the Ageing Analysis Report for each reactor (UAAR). This report supplements the analysis carried out by the engineering centres. *"The drafting of the UAARs is part of the periodic safety review. This analysis is carried out for each reactor in preparation for each VD as of the third VD. The UAARs are sent to ASN and their conclusions are incorporated into the RCRP (periodic safety review conclusion reports)".* The approach to drafting a UAAR is given: 1. Incorporation of the DAARs, completed by the NPPs 2. Incorporation of the Ageing Analysis Sheets by the NPPs 3. Joint analysis with the UNIE and SEPTEN 4. Draft of UAAR by the NPP 5. Validation prior to ASN *"In its UAAR, the NPP takes account of the actual condition of the facilities and local ageing* (Operating Experience Feedback) *OEF".* *"An initial version (revision index 0) of the UAAR is drawn up in preparation for the reactor ten-yearly outage. Subsequent to this ten-yearly outage (VD), this version is supplemented (revision index 1) to take account of:* *1. the results of the checks and inspections performed during the VD; the summary of modifications and renovations performed during the VD and with an impact on ageing management* *2. the analysis of fleet ageing OEF since the previous UAAR revision, based on the new AASs issued and the AASs whose status has been upgraded".*

Reference: A-026 [ENSREG-FR2017]
Para 2.3.2.4 and 2.2.3.5 given some information on the R&D activities of EDF, including a description of the ageing knowledge database. Para 2.3.4.4 states *"In the case of the Flamanville 3 EPR, design measures to mitigate the effects of ageing were taken with the goal of achieving a reactor service life of 60 years. They apply in particular to non-replaceable components such as the reactor pressure vessel and the containment…The inventory of design transients (DDS) describes these loadings for a service life of 60 years and the situations during operation are counted, as with the previous plant series".* Section 2.4 discusses the assessment and update of the AMP. This section gives an example of external assessments carried out by ASN and the IAEA. The findings from these assessments are incorporated into the Ageing Analysis Sheets (AAS). Also mentioned here are the internal reviews which take into consideration the external assessments, reviews of the AAS/DAARs/UAARs and a comparison with international standards from the IAEA. These reviews were due to become periodic as of 2017. *"For the EDF fleet in service, the activities relating to understanding of the ageing mechanisms are:* *1. R&D described in reports produced for each mechanism, on which the AAS and component DAARs are based;* *2. analyses, assessments or tests carried out for maintained qualification after the VD4 described in the NSQP (gradual qualification strategy reports) for equipment qualified for accident conditions.* *The other actions are part of reactor operation and maintenance. They concern the following fields:* *1. chemical conditioning of the systems* *2. the implementation of low flux fuel loading plans* *3. certain modifications* *4. situations accounting* *5. operating provisions to avoid or mitigate the situations* *6. NDT* *7. in-service monitoring (field inspections, periodic testing, MEEI evaluations, etc.)* *8. assessments during intrusive or condition-based maintenance work* *9. preventive, remedial and exceptional maintenance* *10. assurance files* *11. operating experience feedback.* *These actions are mentioned in the component DAARs, the AASs and the UAARs. They are generally produced within routine and exceptional maintenance prescriptions".* <u>Check</u> Paras 2.3.3 onwards discuss the monitoring, inspection and testing activities.

Reference: A-026 [ENSREG-FR2017]
Para 2.3.3.2 refers to the NDT qualification on the primary and secondary systems of the PWRs. Here it states that "*the NDT processes must be qualified prior to implementation on the site by an independent, recognised organisation".* EDF have a designated commission for NDT whose role is to provide independent confirmation of the NDT processes compliance. This para refers to an Article 8 of the Order of 10 November 1999. Para 2.3.3.4 describes the type of inspections carried out during a shift by the operational staff, referring to the as local/field inspections and start up pre-use checks. This para also discusses the use of periodic technical inspections, these are used to confirm: 1. the absence of any unfavourable trend with respect to the design baseline requirements, 2. compliance with the hypotheses of the accident studies, 3. monitoring of the availability criteria for equipment and the associated fluids constituting the required safety functions, 4. monitoring of the operability of the incident and accident operating procedures. These types of inspections are used to aid understanding of the state and availability of equipment and plan any corrective actions as required. Para 2.3.4.1 states *"The maintenance policy is structured in such a way as to guarantee the required reliability level for equipment and systems, by anticipating the maintenance of equipment with a view to extending the operating lifetime of the reactor fleet up to VD4+20 years".* The para describes the development over time of this maintenance policy from EDF OPEX based to Other country/operators OPEX, RCM, condition based maintenance (CBM) and *"by gradual implementation of AP913 as of 2009".* Para 2.3.4.2 considers the routine maintenance and gives further information on the RCM and CBM. EDF decided to implement the INPO AP913 method which allows *"a more pragmatic and systematic approach to be developed to the maintenance of components and systems, by combining monitoring and maintenance of these items. Consequently, it makes it possible to define maintenance and monitoring programmes depending on the functional importance of the equipment".* <u>Understanding</u> Para 2.1 gives regulatory framework and references to several different Orders and Articles such as: 1. Environmental code, specifically L.593-18 and 19 2. Orders, such as 30 December 2015 3. Article 2.5.1 of order 7 February 2012 Regarding the orders (2) its states *"the regulations make provision for partial requalification of the* (Nuclear Pressure Equipment) *NPE every 5 years, as of the third ten-yearly outage".* *"French regulations set no time limit on the operation of the facilities".* 2.1.2.1 considers the PSRs, here it states that the 10 yearly inspections are ideal time to implement modifications resulting from the PSR. *"Following the ten-yearly outage inspection of each reactor, the licensee sends ASN a periodic safety review conclusions report. In this report, the licensee states its position on the regulatory compliance of its facility as well as on the modifications made to remedy deviations observed or to improve the safety of the facility".*

Reference: A-026 [ENSREG-FR2017]
Para 2.1.3.1 refers to the Order of 30 December 2015 (NPEs). It states here that, *"as early as the design stage, the NPE manufacturer must take account of alteration of the materials over time and of the ageing phenomenon, in particular irradiation-induced ageing".* Also contained within this section are references to several appendices, specifically 5 & 6 which determine the in-service monitoring of NPE. Here three principles are given: 1. *"for each equipment item, the licensee must draft a programme of maintenance and monitoring operations, the aim of which is to manage the possible deterioration of the equipment considered in order to prevent it from failing; the licensee is required to keep this programme up to date;* 2. *the equipment with the highest risk in terms of fluid contained and fluid pressure must systematically be periodically inspected by the licensee (every 40 months) with periodic requalification by an independent organisation (every ten years):* a. *the periodic inspections consist of an examination of the outer and inner walls of the pressurised compartments and verification of the operation of valves;* b. *the periodic requalifications consist of the same checks as the periodic inspections, plus containment pressure tests of the pressurised compartments;* 3. *equipment repairs and modifications are carried out in accordance with the rules in force for the design and manufacture of new equipment".* The order of 10 November 1999 is discussed in Para 2.1.3.2, where it states that monitoring comprises of: 1. *periodic equipment monitoring programmes to verify the absence of defects or, if manufacturing defects are indeed found, to check that they do not develop;* 2. *a programme to monitor the degradation modes of the properties of the materials;* 3. *a precise documentary system precisely identifying the actions to which the equipment has been subjected and indicating all the observations liable to affect its maintained integrity.* Para 2.7.1 describes the inspections carried out by ASN. *"With regard to EDF NPP reactors, ASN carries out inspections in the NPPs on the topic of ageing management, to coincide with the progress of the VD3 900 and VD3 1300. These inspections more specifically constitute an opportunity for ASN to verify how the NPPs have assimilated the process defined by the EDF national engineering centres, notably with regard to taking account of any specific aspects of their facilities in their local ageing management programme".* Para 2.72 refers to the record keeping of the licensee, ASN check the completeness of files provided and may ask for further demonstrations or studies to be conducted. Para 2.7.3 refers to the outage oversight. Regarding outages and restarts it states *"the licensee must send ASN an approval request for the approach to criticality and then criticality operations after an outage during which some or all of the fuel present in the vessel has been renewed. The reactor criticality approval request includes a demonstration by the licensee that the installation is capable of functioning over the forthcoming cycle in conditions that suitably protect the interests mentioned in Article L. 593-1 of the Environment Code and in compliance with the baseline requirements applicable to the installation".* <u>Other</u> Para 2.6.1.2 gives a list of priority levels used by the Research Reactors Operations Division.

Reference: A-026 [ENSREG-FR2017]

1. Priority 1: obsolete equipment for which spares are no longer available and requiring complete replacement and major work, or a system with no equivalent nor possibility of upgrade, significant or penalising impact on the facility
2. Priority 2: obsolete equipment for which spares can still be bought, although with an average procurement lead-time, or a more widely commercially available system for which continued operation requires work or modifications limited impact on the facility
3. Priority 3: obsolete equipment that is easily replaced by a recent and rapidly available equivalent, low impact on the facility
4. Priority 4: no obsolescence (equipment or parts still commercially available).

Regarding obsolescence management the research reactors have a contract in place with Rolls Royce to provide a guarantee of spare parts. *"This service, which has been covered by contracts with the system designer company since 2005, is a means of ensuring:*

1. *obsolescence monitoring of the hardware and software in order to maintain the ability to ensure corrective maintenance of the hardware, boards and subassemblies, by guaranteeing the availability of the various components*
2. *obsolescence processing through CEA proposals for preventive measures, which can more particularly be:*
   i. *stock-piling of components by the contract-holder before they disappear from the market,*
   ii. *replacement by a compatible component,*
   iii. *"complex" processing if it becomes impossible to find an equivalent component*
3. *compilation and processing of operating experience feedback. Using all the data collected by the contract-holder (assessment report for equipment repaired in the factory, information sheets forwarded by the sites), the contract-holder is asked to create and update a database for:*
   i. *monitoring the specific configurations of each facility,*
   ii. *ensuring the traceability of failures on each board and each rack specific to each facility,*
   iii. *compiling OEF and extracting summaries and recommendations,*
   iv. *ensuring a monitoring and alert function for problems which are occurring and which could require in-depth analysis*
4. *the provision of technical assistance to the manufacturer in looking for causes of malfunctions*
5. *the performance of occasional services such as corrective maintenance, preventive maintenance, specific studies and training".*

<u>Section 9, Overall conclusions.</u>

Section 9 gives an overview of the types of issues identified by both the peer review and ASN.

A list of the 4 steps are given, on which the approach to Ageing Management has been based. These are:

1. selection of the SSCs potentially susceptible to ageing and whose failure can have an impact on safety,

Reference: A-026 [ENSREG-FR2017]
2. establishing and analysing the SSC/ageing mechanism combinations to verify the ageing management in the light of the operating and maintenance provisions in force, along with the reparability and replaceability conditions (materialised by an Ageing Analysis Sheet (AAS) 3. defining, if applicable, the additional ageing management actions or studies to carry out (materialised by a component Detailed Ageing Analysis Report (DAAR)), 4. drawing up an ageing analysis specific to each reactor, called an UAAR, using the generic AASs and the component DAARs for each reactor reaching its third ten-yearly outage (VD3) and the subsequent ten-yearly outages.
Document Relationships & Referencing Various Articles and Orders are referenced within this report. The main document which aligns with this report is the IAEA NS.G.2.12 which has since been superseded by SSG48.
Applicability to Beyond Design Life Expectations This document summarises the actions carried out by the regulatory body and the operator's responsibilities. As part of the plant life extension requests EDF suggest that the fourth 10 yearly outage (VD4) be approached in the same manner with the additional scope of all SSCs, not only those of radiological risk but conventional risks also. The addition of an AMP for buried pipework has also be added by EDF, this will help define a programme for VD4 giving an understanding of the buried pipework condition and whether its fit for continued operation.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-028 [EUR 22483 EN]
Document Title/Version Number: Models and data used for assessing the ageing of systems, structures and components (European Network on Use of Probabilistic Safety Assessment (PSA) for Evaluation of Ageing Effects to the Safety of Energy Facilities)
Date of Issue: 2007
Summary: This report summarizes and presents the results of the studies conducted in the frame of European Network on Use of Probabilistic Safety Assessment (PSA) for Evaluation of Ageing Effects to the Safety of Energy Facilities (EC JRC IE Ageing PSA Network). The Network was initiated and will be operated within the framework of the JRC FP-6/7 Institutional Action "Analysis and Management of Nuclear Accidents" (AMA). The report is focussed on the reliability models and data that could be used for assessing the ageing of systems, structures and components including statistical and physical ones. The report looks at approaches for incorporating ageing effects into a PSA model for the evaluation of the impact of plant ageing. The report notes that there are three qualitatively different settings for data collection and analysis, 1. Frequent or periodic data collection over time. The purpose of the analysis is to discover the existence and magnitude of a trend. 2. Single data collection under current conditions. The obtained measurement data are included in the input data of physics based ageing analysis, performed with a suitable analysis code. The purpose of the analysis is to estimate the probability of failure in the future. 3. Infrequent data collection, such as non-destructive testing of materials. The analysis can have two purposes. It may be intended to characterize the current state of the material, or, as in setting (1), the analysis may be intended to discover and quantify the existence of a trend. The discussion in the document emphasizes the first setting because some general analysis methods can be given. For the second setting, every type of ageing requires a major effort to develop an effective mechanistic model; by comparison, the effort of data collection is relatively minor. The third setting was considered relatively new at the time of writing and (at the time) required further development and application. The document notes that the issue of 'how to use the data in a PSA' would be developed in the future stages of the project. However, the report identifies that evidence of ageing may require the following: • As a minimum, the basic event probabilities must be modified in a PSA. • More changes may also be needed in the PSA, such as – new initiating events – new basic events – new common cause initiators

Reference: A-028 [EUR 22483 EN]
• Cut-sets that were truncated from the original PSA because of their low probabilities may now need to be restored. • Finally, one must be wary of extrapolation into the future if the fitted trend model was chosen primarily for simplicity and mathematical convenience. It is safer to let evidence of a trend alert the analysts and decisionmakers to the need for frequent reassessment of the initiating event frequencies and basic event probabilities.
Key Themes The document appears to be the start of a larger project looking at how the ageing of SSC can be modelled in the PSA and focuses on data collection and analysis. It provides discussion that focuses on frequent or periodic data collection over time because some general analysis methods can be given. Further work around the overall objective for modelling ageing in the PSA may appear in documentation developed for later stages of the task, but these were not identified.
Document Relationships & Referencing The document states that '*how to use the data in a PSA will be developed in the future stages of the project*'; however, the searches done as part of Phase 1 of the task did not identify and documents that appear to correlate with future stages of the work. Further searches may reveal this documentation and may have more relevance to how the ageing of SSCs can be modelled within the PSA.
Applicability to Beyond Design Life Expectations While the detail of this document does not provide meaningful information that could support the development of BDL expectations. It does, however, pose an interesting question around how ageing has been modelled within the PSA to determine if the ageing of specific SSCs has an adverse effect on the overall risk of the facility. This could be done on a component by component basis as part of a submission to extend the life of an SSC or for all changes across the whole facility.
Applicability to the ONR SAPs There are two SAPs relating to the PSA (FA.11 – Validity and FA.13 – Adequate representation) that could be linked to ensuring the effects of ageing are adequately reflected in the PSA. FA-11 states that the PSA should reflect the current design and operation of the facility or site, which would include the effects of ageing. The supporting notes that the PSA should be updated regularly, which for power reactors should mean adopting a 'living PSA'. In addition, FA-13 states that the PSA model should provide an adequate representation of the facility and/or site. The supporting notes indicate that facility-specific data should be used as far as possible for the calculation of the frequencies and probabilities used in PSA. Both of these items could/should be amended to explicitly identify that the PSA should reflect the effects ageing, noting that the changes made (and supporting information) should be clearly described and justified.
Future Considerations N/A

Reference: A-028 [EUR 22483 EN]
Additional Notes As noted above searches for further documentation associated with this project did not reveal obvious follow-on reports; however, another document was identified that covered how ageing effects may be incorporated into PSA applications. The report identified was: • Canadian Nuclear Safety Commission, R322.3 Incorporating Ageing Effects into PSA Applications, Final Report, ENCO FR-(14)-10, March 2014

Reference: A-029 [EUR 25142 EN]
Document Title/Version Number: Operation of Ageing Reactors: Approaches and Associated Research in the European Union
Date of Issue: 2011

Summary:

This report aims to provide overview of approaches proposed or followed in the USA and in EU countries when longer term operability (LTO) is considered as part of PLiM. A special attention is given to discussing existing regulatory framework available, as well as requirements set for ageing reactors in the corresponding IAEA safety reports and safety guides. A comparison of the US Licence Renewal Rule and Periodic Safety Review as a tool for assessment of Structure, Systems and Components (SSC) for PLiM and LTO is provided too.

This report was prepared before the Fukushima Daiichi event. Lessons need to be learned from the event that will have impact on the methodologies traditionally used in the safety evaluation of aged nuclear power plants, not captured.

The document presents a picture vary similar to the outcome of the Phase 1 BDL task; that is, the justification for extended operation (across the EU) follows two basic models, either Licence Renewal (as outlined by the US NRC) or is tied to the PSR. To support the licence renewal or PSR the use of AMPs to demonstrate appropriate management of ageing and degradation during the Long-Term Operation. The document notes that any plant programme, when credited for ageing management, should include the following 10 element criteria:

1. Scope of programme; it requires the programme scope to include the specific structures and components addressed.
2. Preventive actions; requires that service (i.e. environmental and operating) conditions and operating practices aim at slowing down potential SC.
3. Parameters monitored/inspected; it requires that parameters monitored and inspected should be linked to the degradation of the particular structure and component intended function(s) to detect the presence and the extent of effects of ageing.
4. Detection of ageing effects; it requires that effective technology (inspection, testing and monitoring methods) for detecting ageing effects allows time for corrective action before SC failure is established.
5. Monitoring and trending; it requires description of condition indicators and parameters monitored, data collection to facilitate assessment of SC ageing, assessment methods (incl. data analysis and trending), and that record keeping practices are followed.
6. Acceptance criteria; it requires listing the acceptance criteria against which the need for corrective action is evaluated.
7. Corrective actions; it requires listing any maintenance actions, repair, or replacement actions to correct detected degradation.
8. Confirmation process; it requires provisions to ensure that preventive actions are adequate and appropriate, and corrective actions have been completed and are effective.

Reference: A-029 [EUR 25142 EN]

9. Administrative controls; this criterion describes how formal review and approval process is performed.

10. Operating experience; this criterion describes how past corrective actions resulted in programme enhancements and provides evidence that the SC ageing effects will be adequately managed for LTO.

The report concludes that operation of nuclear power plants must identify and analyse associated ageing phenomena that needs to be timely and carefully considered, in particular by structural integrity assessment, accident analysis, nuclear power plant ageing assessment and mitigation, systems interactions and risk assessment and related human factor aspects.

In addition, the operation of ageing nuclear power plants requires a strong research support to address key issues relating to ageing and life prediction of SSC. The report notes that sometimes, the operating organization considers the ageing management programmes as something new, very special, that must be developed from "scratch", which is often not necessary. The international generic ageing lessons learned, when elaborated, could substantially contribute to improve understanding the ageing phenomena of SSC at different NPP design. Corresponding ageing management programmes can be harmonized throughout EU countries to effectively manage the ageing effects of different SC. A broad and effective dissemination of related scientific results is a further objective.

Key Themes

LTO Submissions

Across the EU, specific submissions are made for a facility as a whole to extend operation that are either undertaken as part of licence renewal or PSR processes. The submissions incorporate (or are supported by) reviews of AMPs, updates to TLAA and any national regulatory requirements.

Review of AMPs

The justification to extend the operating life of a facility includes a review of the AMPs; both in terms of individual AMP content and wider management of the AMP process. 10 key elements were identified, which are similar (if not identical in some cases) with the nine attributes of an effective ageing management programme.

Document Relationships & Referencing

Given the content of this document it is likely that any further research would reflect the content of IAEA SSG-25 and SSG-48.

Applicability to Beyond Design Life Expectations

Reflects output of Phase 1

Applicability to the ONR SAPs

Reflects output of Phase 1

Future Considerations

N/A

Additional Notes

N/A

Reference: A-031 [Hungarian Atomic Energy Authority - Guideline 1.28]
Document Title/Version Number: Regulatory procedures of operation beyond design lifetime
Date of Issue: April 2013
Summary: This Guideline describes the regulatory procedures related to operation beyond the design lifetime of a nuclear power plant unit and formulates recommendations on preparation of the programme and the license application required by Section 20 of Govt. Decree 118/2011 (VII.11.) Korm. The objectives of the Guideline are to make the regulatory expectations unambiguous by the recommendations included, and to facilitate the supervision of compliance with the nuclear safety criteria during legally required procedures. The guideline notes that the programme and license application of operation beyond design lifetime should be compiled in a way that provides appropriate proof to the authority on the following: 1. scope of SSCs constituting the subject of license application has been duly determined, 2. ageing processes required to be managed during the extended service life have been duly determined, 3. conditions of SSCs belonging to the scope of the license for operation of the unit beyond the design lifetime have been assessed, ageing management programmes implemented during the operation have been evaluated, the requirements for their modification and for launching of new programmes have been defined, 4. Time Limited Ageing Analyses (TLAAs) providing evidence for the compliance of SSCs in the scope of service life extension licensing have been re-evaluated in full scope, 5. required update of the Final Safety Analysis Report has been performed, 6. necessary modifications to the Operating Limits and Conditions (OLCs) of the nuclear power plant have been identified, 7. implementation of the improvement actions determined as results of the Periodic Safety Review is justified, 8. on the basis of the above listed activities it has been ensured, or it will be ensured until the expiry of the design lifetime, as latest, that – SSCs belonging to the scope of service life extension are able to fulfil their safety function during the extended service life, – safety analyses of the installation remain valid, – operating limits and conditions will meet the conditions of the license for the extended service life. As noted above, a review of ageing management should be carried out and the documentation should include: 1. description how the examined SSCs fulfil their intended safety functions, 2. identification of deterioration processes that need ageing management,

Reference: A-031 [Hungarian Atomic Energy Authority - Guideline 1.28]
3. description of those ageing management programmes that are applied by the operator in order to detect the identified ageing processes, to mitigate them or to manage their consequences, 4. demonstration that the above-mentioned programmes are suitable for maintaining the design safety function of the system component during the extended operating time of the installation. In addition, the guidelines note that in the license application the evaluation of ageing management programmes should address the following: 1. The programmes really cover all system components that need ageing management and belong to service life extension. 2. The preventing actions effectively avoid or mitigate the development of the deterioration processes caused by ageing, and the effectiveness is periodically checked. 3. There is a direct collection of information about the impact as well as parameters of ageing processes regarding the fulfilment of safety functions. This can be carried out by parameter monitoring, by in-service inspection or testing. 4. Effects of ageing are explored based on one or more approved programmes before they could lead to the loss of safety function of the system component. 5. Monitoring and trend analysis provide reliable forecast of adverse effects and ensure timely introduction of corrective or ageing impeding actions. 6. Ageing management programmes contain such acceptance criteria, based on which the necessary corrective actions can be determined in due time. 7. There are such tools available by which the efficiency of the performed corrective actions can be demonstrated. 8. Corrective actions are really executed in due time. (The corrective actions also include the root cause analysis and actions to prevent recurrence of events.) 9. Appropriate administrative control of ageing management programmes is provided. 10. Operating experience is taken into account and it is demonstrated that the ageing processes are managed in appropriate manner and will be managed during the extended service life. The guidelines also recognise that a review of TLAAs should be undertaken, it should be demonstrated that from the current licensing basis: 1. assumptions valid for limited period connected with ageing processes of the system components are identified; 2. importance of them during establishment of some safety related conclusion, and the role of them in justification of maintaining the functionality of a safety system component are determined; 3. TLAAs referred to in documents of current licensing basis (e.g. OLCs, FSAR, operating licenses) are determined. TLAAs specified by the steps above should be included in the application for license of service life extension. The document notes that not all TLAAs need to be reviewed and updated and in some cases the application will include justification of sustaining TLAA validity.

Reference: A-031 [Hungarian Atomic Energy Authority - Guideline 1.28]
The TLLA usually takes the design lifetime of the installation as basis. At the same time, it can be justified case by case that assumptions establishing the calculation will still be valid during the extended service life. Accordingly, it should be justified that the calculation and analysis results will be acceptable during the considered extended service life, i.e. the system component will be able to fulfil its designed safety function with the desired safety margin. However, if the validity of a TLAA cannot be extended until the end of the new design lifetime of the installation, but there is a possibility to decrease the conservatism applied in the calculation method or in the input data of the connected TLAA in a justified manner, then it should be described in the license application that the results of the analysis will still be valid without deterioration of the designed safety margins. Alternatively, the application may include the determination and introduction of ageing management actions instead of maintaining the validity of a TLAA. If the time of validity of a TLAA cannot be extended beyond the design lifetime of the installation then it should be demonstrated that the supposed impacts of non-compliance can be managed via ageing management actions during the extended service life; the necessary supplementary ageing management programmes should be described in the license application. The guidelines identify that following shall be presented in the license application: 1. general information related to the nuclear facility and the operator thereof, 2. definition of SSCs belonging to the scope of licensing the operation beyond the designed service life, 3. comprehensive review on ageing management of passive and long-lived components, 4. management of time limited ageing analyses, 5. required modifications of the Final Safety Analysis Report, 6. required modifications of the Operational Limits and Conditions document, 7. modifications of further documents upon which the operation license is based, 8. demonstration that the Service Life Extension Programme has been executed and based on those activities specified in it and throughout the service life – the nuclear power plant unit is in a safely operable condition, and that the technical and administrative conditions necessary for its long-term maintenance are provided for, and – the licensee possesses the resources necessary for the long-term maintenance of nuclear safety, furthermore 9. the planned duration of operation beyond the designed service life as substantiated by analyses.
Key Themes <u>General Note</u> The approach outlined above reflects a regulatory framework that requires a licensee to submit justification to extend the life of the facility as a whole, an LTO Submission. It recognises that not all SSCs require justification to extend the life as they will be subject to renewal or replacement as required. The documentation recognises the PSR and the input this may have in to the LTO Submission, but that it is prepared independent of the LTO Submission.

Reference: A-031 [Hungarian Atomic Energy Authority - Guideline 1.28]
Review of Ageing Management Programme As with most LTO submissions the guidelines highlight the need to review the Ageing Management Programmes in terms of coverage and content. The reviews should demonstrate that the right SSCs are reviewed, the degradation mechanisms for those SSCs are understood and that appropriate mitigating or monitoring strategies are in place. The AMPs should also include acceptance criteria and if/where appropriate corrective actions. The review should also consider the governance of the programmes and that OPEX is being used and managed appropriately. Review of TLAAs Similar to the review of AMPs noted above, the guidelines also highlight the need to review the TLAAs as part of the submission. The output from the reviews determines what action is necessary for individual TLAAs and recognises that, in addition to updating the TLAA to reflect the extended operation, some analysis may remain valid for the extended life. This may be due to conservatisms in the original analysis or changes to operation compared to initial assumptions. However, the guidelines also recognise that the validity of some TLAAs may not be extended beyond the original design life. In these cases, the guidelines note that the impact can be managed and supplementary AMPs may be developed to composite.
Document Relationships & Referencing The guidelines refer to various government documents and decrees where the applicable legislation is identified. These other documents may not add much to the summary of requirements presented in this document.
Applicability to Beyond Design Life Expectations The approach to present an LTO Submission for extended the operating life of a facility is consistent with the approach outlined in IAEA SSG-48. One item of note that perhaps differentiates this from other regulatory documentation is the recognition that for some TLAAs updating or renewing analysis may not always be possible. In these instances, the guidance identifies the use of additional AMP strategies to support the justification for continued operation. As part of a BDL submission it is not unreasonable to assume that some of the legs of the original safety case for an SSC may no longer be applicable. In these instances, other safety assessments/analysis or additional monitoring/inspections may be required to demonstrate continued operation is ALARP. However, the BDL submission should clearly identify any original assessments that may no longer be valid and present alternative strategies to support the justification for extended operation.
Applicability to the ONR SAPs The contents of this document identifies the Hungarian Regulatory expectations for operation beyond the design life a facility. The guidance provided focusses on the LTO submission and the assessment/analysis required to demonstrate safe operation over the extended period. The requirements would have applicability to a broad range of SAPs that should be demonstrated as part of 'normal operation', (including extended operational life), or would be required to be reviewed/updated to underpin extended life.
Future Considerations N/A
Additional Notes N/A

Reference: A-095 [NUREG-2214]
Document Title/Version Number: Managing Aging Processes in Storage (MAPS) Report – Draft Report for Comment
Date of Issue: October 2017

Summary:

This Managing Aging Processes in Storage (MAPS) Report provides guidance for the U.S. NRC technical reviewer. It establishes a technical basis for the safety review of renewal applications for specific licenses of independent spent fuel storage installations and Certificates of Compliance for dry storage systems, as codified in Title 10 of the Code of Federal Regulations Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste."

The MAPS Report evaluates known aging degradation mechanisms to determine if they could affect the ability of dry storage SSCs to fulfil their safety functions in the 20- to 60-year period of extended operation. The guidance also provides examples of aging management programs that are considered generically acceptable to address the credible aging mechanisms to ensure that the design bases of dry storage systems will be maintained. An applicant for a renewed license or Certificate of Compliance may reference the information in the MAPS Report to support its aging management review and proposed aging management programs.

The document identifies that the reviewer should ensure that the applicant addresses any design basis calculations that use materials properties that may be time dependent. For example, aluminium alloys used in some fuel baskets can lose strength over time at elevated temperatures, and this may affect the performance of the fuel basket in a cask tip-over analysis. If the original design basis calculations did not adequately account for such material property changes through the period of extended operation, the analyses should be updated.

The reviewer should ensure that the applicant has appropriately dispositioned an identified TLAA by using one of the following methods:

- Demonstrate that the existing analysis remains valid for the period of extended operation, has already considered the requested period of extended operation, and concludes that the SSC will continue to perform its intended function through to the end of the requested period of extended operation.
- Revise or update the existing analysis to demonstrate that it has been projected to the end of the requested period of extended operation and concludes that the SSC will continue to perform its intended function through the end of the requested period of extended operation.
- Manage the effects of aging on the SSC for the requested period of extended operation through an aging management program.

The document notes that (Section 6.2: Alternative approaches – to an AMP) an applicant may propose alternative approaches to manage the effects of aging. In its review of alternative AMPs, the staff should use the guidance in NUREG–1927, Revision 1, "Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel" (NRC, 2016). As described in greater detail in NUREG–1927, an AMP generally should contain the following 10 elements:

Reference: A-095 [NUREG-2214]
1. Scope of program: the specific SSCs and subcomponents covered by the AMP and the intended functions to be maintained, in addition to stating the specific materials, environments, and aging mechanisms and effects to be managed 2. Preventive actions: actions to prevent aging or mitigate the 1 rates of aging for SSCs 3. Parameters monitored or inspected: the specific parameters that will be monitored or inspected and a description of how those parameters will be capable of identifying degradation before a loss of intended function 4. Detection of aging effects: the inspection and monitoring details, including method or technique, frequency, sample size, data collection, and timing of inspections 5. Monitoring and trending: how data will be evaluated and trended to ensure timely corrective actions 6. Acceptance criteria: the criteria against which the need for corrective action will be evaluated 7. Corrective actions: The measures to be taken when the acceptance criteria are not met, including root cause determination and prevention of recurrence, as appropriate 8. Confirmation process: processes in place to verify that preventive actions are adequate and that appropriate corrective actions have been completed and are effective 9. Administrative controls: processes in place that provide a formal review and approval process for activities related to the AMP (e.g., inspector requirements, instrument calibration) 10. Operating experience: a review of operational experience that supports the determination that the AMP is capable of maintaining SSC functions in the period of extended operation The reviewer should examine the applicant's proposed 10 elements to verify that the program is capable of managing the specific aging mechanisms and effects identified by the aging management review (AMR). The reviewer should recognize that an applicant may develop AMPs following a different format or style. For such reviews, the NRC staff should ensure that sufficient detail (i.e., supporting technical bases) is provided in the alternative format in comparison with the 10 AMP elements of this guidance. An applicant may credit existing site maintenance and inspection activities to manage the effects of aging. In such cases, the reviewer should ensure that the design basis documentation describes those activities with sufficient detail ensure that the 10 AMP elements are fully addressed. The document also includes various tables that present examples of aging management programmes for a range of related SSCs that are in accordance with the 10 AMP elements identified above.
Key Themes <u>General Note</u> The approach outlined above reflects a regulatory framework that requires a licensee to submit justification to extend the life of the facility as a whole. The document demonstrates that the approach is technology neutral and can be applied to a range of nuclear facilities. What makes this document specific to storage is the inclusion typical AMPs for SSCs and materials generally associated with dry storage facilities. <u>Review of Ageing Management Programme</u> As with most LTO submissions the guidelines highlight the need to review the Ageing Management Programmes in terms of coverage and content. The reviews should demonstrate that for identified SSCs,

Reference: A-095 [NUREG-2214]
the degradation mechanisms for those SSCs are understood and that appropriate mitigating or monitoring strategies are in place. The AMPs should also include acceptance criteria and if/where appropriate corrective actions. The review should also consider the governance of the programmes and that OPEX is being used and managed appropriately. The information presented on the AMPs for specific SSCs associated with dry storage facilities may have limited value across UK Nuclear Facilities; however, there is the potential that some useful OPEX may be found in the document where similarities do exist.
Document Relationships & Referencing This document references NUREG–1927, Revision 1, "Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel" (NRC, 2016). It is noted that this document provides greater detail of the 10 elements an AMP should contain. There may be some value in looking at this document to determine if there is information that provides additional information that would add value to this task.
Applicability to Beyond Design Life Expectations The use of AMPs to support the justification of operation beyond the original design life has been highlighted repeatedly across a range of documents. In many cases a number of elements or attributes (normally 10) have been identified with the requirement for an AMP. The 10 elements (or attributes) all broadly include the same items and should form the basis or reviews of AMPs to determine if they are suitable and sufficient to support justification of extended life.
Applicability to the ONR SAPs The guidance provided focusses on the LTO submission and the assessment/analysis required to demonstrate safe operation over the extended period. The requirements would have applicability to a broad range of SAPs that should be demonstrated as part of 'normal operation', (including extended operational life), or would be required to be reviewed/updated to underpin extended life. Central among these is the use of AMPs and consideration for an additional principle, which would propose the use of them, has previously been recommended as part of task ONR376. Specific elements of the SAPs identified as being applicable include: • EAD.3: Material Properties – Any time dependent material properties used within design basis calculations should take into account anticipated relevant material property changes over the period of operations being justified. • EAD.4: Periodic Measurement – For the specific parameters that will be periodically monitored or inspected a description of how those parameters will be capable of identifying SSC degradation before a loss of intended function occurs should be defined. Periodic measurements should consider aspects such as measurement techniques, frequency of measurement, inspection requirements, instrument calibration, measurement consistency through-life, sample size, data collection and trending, acceptance criteria and the potential need for corrective actions.
Future Considerations N/A
Additional Notes N/A

Reference: A-096 [OECD NEA/CNRA/R(99)1]
Document Title/Version Number: Regulatory Aspects of Ageing Reactors - 1998 CNRA Special Issue Meeting
Date of Issue: March 1999

Summary:

Each year the CNRA selects a topic of special interest to members for discussion. The topic chosen for 1998 was Regulatory Aspects of Ageing Reactors.

This report integrates the work performed by the Organising Committee for the 1998 CNRA Special Issues meeting and the resulting discussions which took place during the meeting. It is important to note that the concept of ageing can be interpreted in various ways. This was clearly shown in the analysis of the responses to the questionnaire and during the Special Issues meeting. The report predominantly looks at answers provided by the Member countries and the analysis performed by a task group established by the Organising Committee group. Additionally, insights from the CNRA discussions are provided in appropriate sections.

Accordingly, ageing management was defined in the broader sense gradually gaining use, i.e. covering not merely ageing management of hardware, in the traditional sense, but in addition the management issues on keeping up in general with developments of the state-of-the-art in technology and management practices. The topic for discussion by the CNRA would thus be seen in the way the nuclear safety authorities and the nuclear utilities provide, in general, for capability of managing nuclear safety with regard to changing conditions, perspectives and prerequisites.

The report covers following specific issues of interest for the discussions on the topic:

- the relevant safety aspects (section 4)
- the related needs for research and development (section 5),
- actions actually taken in the different countries on related issues (section 6),
- what is thought to support necessary initiatives in the safety work (section 7),
- what strategies are used (section 8),
- the matter of communicating related information to the public (section 9), and
- certain specific questions are suggested for discussion (section 10).

Among conclusions reached, the following could be emphasised:

- The “broad concept” of ageing management has definite merits but remains to be generally accepted and understood in order to serve constructively in discussions about developments in regard of nuclear safety.
- The importance assigned to “traditional” ageing management, as seen from the national reports, and issues related to hardware degradation problems is clearly very high. The other aspects, like engineering developments, or other types of management developments, in regard of general progress of the state-of-the art are considered important as well but are less emphasised.

Reference: A-096 [OECD NEA/CNRA/R(99)1]
• Some countries see needs to develop the event reporting systems to reflect more accurately the ageing problems. • There is common interest in enhanced practices for in-service inspections and maintenance as well as “risk informed” approaches, also as applied to selection of research projects. • There may be reason, in regard of the need to establish safety requirements in terms of safety upgrading in ageing management, to consider developing the use of specific criteria for that purpose (safety goals). • There is some notable shift in focusing the regulatory efforts, in some countries, in the direction from verifying that systems and equipment meet the requirements to verifying that proper organisational arrangements are in place, that they are used in the utility processes, and that there is also development going on based on learning from experience. Some countries, however, continue to rely primarily on verifying the state of the plant. • Matters concerning communicating ageing related information to the public appear to be assigned special importance in most responses. Proper arrangements seem anyhow to be in place.
Key Themes <u>General Note</u> This document dates back to the early days of ageing management and LTO, in the years that have followed significant work has been undertaken in the development of ageing management and LTO processes. The collation of different experiences from across the industry to distil common approaches has contributed to the development of many documents including the current approaches outlined in SSG-48. This document represents the start of this journey and as such does not add any new or additional themes or considerations.
Document Relationships & Referencing N/A
Applicability to Beyond Design Life Expectations N/A
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-097 [NEA/CNRA/R(2001)1]

Document Title/Version Number: Regulatory aspects of life extension and upgrading of NPPs - CNRA Special Issue's Meeting 2000

Date of Issue: January 2001

Summary:

At its annual meeting in June 1999, the Committee on Nuclear Regulatory Activities (CNRA) agreed to hold a Special Issue Meeting in June 2000 on the topic of "Life Extension and Upgrading". The need for the meeting originated following the recommendations made in the report on Future Nuclear Regulatory Challenges. This document includes the synthesis of the responses received from Member countries and the results and conclusions of the CNRA discussions.

Many of the factors and issues discussed in the Future Nuclear Regulatory Challenges report draw attention to the need for regulators to address requests by licensees for plant life extension. As noted in the report it identified that for plant life extensions, analysis must show that the plant will continue to operate within its design basis. The consequential regulatory challenges include the need:

- to have an adequate knowledge of the current design basis of the plant;
- to have a correct picture of the actual state of the plant; and
- to define the analysis needed to support life extensions and demonstrate that the plant will still operate within its design basis.

In discussing the special issues topic, Life Extension and Upgrading, the Committee reflected on the meaning of the terms "life extension" and "upgrading". Differences in the terminology used, both nationally and internationally, make any definitions difficult but the Committee reached a general consensus on using the following terms to identify the issues:

- Life Extension: Where applicable, continuous operation maintaining an acceptable level of safety of a facility beyond an established licensed term or period established by a safety evaluation.
- Upgrading: Applying measures to enhance the safety level of the plant.

The Report then focuses on four main topics:

- Legislative and regulatory aspects
- Key technical issues
- Key management issues
- The use of deterministic and probabilistic methods in safety evaluation

In the sections of the Report devoted to these topics, the experiences of respondents are summarised, similarities and differences noted, and any general conclusions stated.

The document notes that PSRs give important insights into the key technical issues associated with upgrading and long-term operation that may be grouped conveniently under the following headings:

1. Correcting deficiencies in the original design

Reference: A-097 [NEA/CNRA/R(2001)1]

2. Correcting deficiencies in the original construction
3. Dealing with ageing of materials and components
4. Dealing with obsolescent components and procedures
5. Applying modern requirements (as far as reasonably practicable)
6. Other technical issues related to public perception

The detailed technical issues identified in the responses to the Questionnaire clearly depend on the design of the nuclear power plants concerned but the Working Group noted a growing awareness in most countries of the importance of accurate predictions of life-limiting ageing effects in safety-related structures and components

Some of the key management issues that relate specifically to older NPPs include:

1. The role that the regulator should play in helping to ensure there is a continuing supply of competent personnel to operate and maintain older plants where the design details, technical limits etc. may be less well documented than for modern ones.
2. The steps the regulator needs to take to ensure that economic pressures are not allowed to compromise the long-term maintenance of materials, components, infrastructures or processes on ageing NPPs.
3. The steps the regulator needs to take to ensure that the facilities make proper plans to anticipate the possible replacement of major components subject to ageing degradation.
4. Taking appropriate regulatory action, as required by national laws and policies, to ensure that the licensees make adequate financial provisions for decommissioning, dismantling and disposing of the waste from ageing NPPs.

The main issues that respondents identified as likely to be important in the future for upgrading and long-term operation fall into three general categories:

- Organisation and management issues, especially in the increasingly difficult environment for nuclear power.
- Technical issues, particularly those associated with ageing and the incorporation of new technologies.
- The role of PSA in risk-informed regulation and the strategies needed to ensure that it is properly integrated with the traditional deterministic approach.

Key Themes

General Note

This document dates back to the early days of ageing management and LTO, in the years that have followed significant work has been undertaken in the development of ageing management and LTO processes. The collation of different experiences from across the industry to distil common approaches has contributed to the development of many documents including the current approaches outlined in SSG-48. This document represents the start of this journey and as such does not add any new or additional themes or considerations.

Reference: A-097 [NEA/CNRA/R(2001)1]
Document Relationships & Referencing N/A
Applicability to Beyond Design Life Expectations N/A
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-098 [NEA/CSNI/R(2002)26]	
Document Title/Version Number: Technical Aspects of Ageing for Long-Term Operation	
Date of Issue: January 2003	

Summary:

Besides national activities there are a number of international activities in particular under the umbrella of the IAEA, the OECD and the EU. For example, ageing research plays an important role in the 4th and 5th Framework Programme of the European Commission. A bibliography on major ageing related EU research activities under the 4th and 5th Framework Programme is given. International working groups and networks dealing with ageing related issues are summarised. Relevant guidance documents on plant ageing management, which could be used for orientation, are listed. This document restricts itself to the technical aspects of the basis for long-term operation. Its objective is the characterisation of technical key items. Regulatory aspects are being discussed within CNRA.

The report notes that to provide a technical basis for long-term operation of nuclear power plants it is necessary to:

- Invest in research methods and strategies related to plant life management
- Promote computer-aided modelling to predict degradation at a quantitative level
- Update the individual plant documentation to avoid gaps in knowledge caused by the reorientation of industry and by the retirement of experienced people
- Initiate, develop and promote clubs of users of similar technology internationally
- Establish a system of information retrieval to bridge gaps between today's and previous design and manufacturing standards
- Increase the flexibility of the quality assurance system to qualify products manufactured to other standards for plant specific use.

At the time the report was produced it noted that due to the drastic changes in industry, influenced by the declining demand for new nuclear power plants, it was expected that in most countries the industrial infrastructure will be reduced to match the requested level of service. The report also noted that in many technical areas continuous development will take place driven by other industrial developments than nuclear. This is certainly to be expected for instrumentation and control but also in the areas of civil engineering, material production and welding technology along with surveillance, testing and inspection technologies. However, the report also recognised that, there has been a tradition for the nuclear industry to be the driving force for engineering development and it is not certain that non-nuclear industries will fully replace this driving force. For non-nuclear industry the level of in-depth analyses and safety demonstration is less demanding up to now.

Key Themes

<u>General Note</u>

This document dates back to the early days of ageing management and LTO, in the years that have followed significant work has been undertaken in the development of the understanding of ageing, degradation and obsolescence. The collation of different experiences from across the industry to distil common approaches has contributed to the development and evolution of many documents, including the current approaches

Reference: A-098 [NEA/CSNI/R(2002)26]
outlined in SSG-48. In addition, there has been wide-spread sharing of information across the industry, to share good practice and learn from experience, this includes tools like the IGALL database. This document represents the start of this journey and as such does not add any new or additional themes or considerations. However, the key activities that the document promotes to provide a technical basis for long-term operation of nuclear power plants (and listed above) are areas that could or should be demonstrated when extending the life of an SSC beyond the original design life. For less safety significant SSCs it may be appropriate for only a number of these activities to be demonstrated, but for the most safety significant SSCs life extension would require more of these activities to be demonstrated as part of a 'multi-layered' justification. The number of activities undertaken and the level of detail within the outputs to support the BDL substantiation should use activities that are considered appropriate and proportionate to the SSC and the associated nuclear safety significance. This is not dissimilar to the requirements outlined in SAP ECE.2, (for civil structures), which states that "for structures requiring the highest levels of reliability, multiple independent and diverse arguments should be provided in the safety case". In addition, it notes that the "multiple, independent and diverse arguments should provide a robust, multi-layered justification in which weaknesses in individual layers of the argument are offset by strengths in others".
Document Relationships & Referencing The document refers to many other documents or projects (including R&D) that deal with ageing and degradation, specifically for LWRs. However, these all date back to the late 90's or early 2000's and most of this information has been superseded over the last 20 years and overtaken by more recent experiences (e.g. Fukushima).
Applicability to Beyond Design Life Expectations N/A
Applicability to the ONR SAPs Similarities to ECE.2 as the documents identifies various activities that could support multi-layered arguments to extend the life of an SSC. The activities include: • Invest in research methods and strategies related to plant life management; • Greater use of computer-aided modelling to predict degradation at a quantitative level; • The update the individual plant documentation to avoid gaps in knowledge caused by the reorientation of industry and by the retirement of experienced people; • To initiate, develop and promote clubs of users of similar technology internationally; • To establish a system of information retrieval to bridge gaps between today's and previous design and manufacturing standards; • To increase the flexibility of the quality assurance system to qualify products manufactured to other standards for plant specific use.
Future Considerations N/A

Reference: A-098 [NEA/CSNI/R(2002)26]
Additional Notes The document contains some OPEX around degradation mechanisms and monitoring methods. The information is all focussed on LWRs and reflects understanding over 15 years ago; as such, it may have limited use in the UK.

Reference: A-102 [NEA/CNRA/R(2012)5]

Document Title/Version Number: Challenges in Long-Term Operation of Nuclear Power Plants - Implications for Regulatory Bodies

Date of Issue: 2012

Summary:

Following discussions at the CNRA meeting held on 7-8 June 2010, the Senior Task Group on Long-Term Operation (LTO) was established to prepare a document on regulatory challenges for LTO of nuclear power plants. The group was to review the principles and criteria that should be considered in making a regulatory decision to approve an operator's application for operation of a nuclear power plant beyond the operation period considered in the plant's design. During the preparation of this document, the 2011 Fukushima Daiichi nuclear power plant accident occurred. As a consequence, the CNRA requested that aspects of the event related to LTO should also be addressed in the review. This report was prepared by the Senior Task Group on LTO, in collaboration with the International Atomic Energy Agency (IAEA), on the basis of discussions and input by members of the group and consideration of information from a wide array of documents produced by the NEA, its member countries and other international organisations.

This document presents the basic premise for consideration of LTO called the fundamental principle. This principle should be the underpinning of any programme on extended operation. Beyond that, this section provides three high-level key principles that are intended to define and shape the development of an LTO programme.

- **Fundamental Principle -** The safe operation of the nuclear power plant needs to be ensured during the period considered for long-term operation.

  To achieve this, the regulatory body has the responsibility to evaluate, monitor and regulate the operator's activities to ensure that the requirement of safe operation is met. This includes a requirement for assurance of the fitness of the plant and the operator for safe and reliable operation over the projected period of continued operation. It is noted that the approaches applied by regulatory bodies may differ but each regulatory body needs to ensure that the safety objectives are achieved within the regulatory framework and monitor the operator's performance against these objectives.

Beyond the fundamental principle, three key principles should be considered. The consideration of these key principles is contingent upon the regulatory approach for LTO, whether licence renewal or periodic safety reviews is the regulatory framework for extended operation. The following key principles should be taken into account to support the above-mentioned overriding fundamental principle for LTO.

- **Key Principle 1 -** the regulatory body must be organised to regulate long-term operation

  As a starting point, the regulatory body needs to understand that different and additional considerations apply to LTO. Once this is understood, the regulatory body (regulator) needs to be prepared to ensure that a regulatory framework exists that will respond effectively to LTO. Such a framework is needed to define safety requirements and regulations, as well as a system of licensing, assessment and inspection for LTO.

- **Key Principle 2 -** the goals and safety level required for long-term operation need to be clearly defined

  The regulator, within its regulatory framework, needs to define what operators have to achieve (goals) through the process of endorsing LTO and thus what the required safety level should be during LTO. Clearly defining these goals is the essential starting point for articulating the regulatory requirements.

Reference: A-102 [NEA/CNRA/R(2012)5]

Important considerations for defining the acceptable level of safety during LTO include the following:

- The time period of LTO;
- The operational history and experience at the plant;
- The physical condition of the plant;
- The ageing of safety-related systems, structures and components; and
- The degree of certainty about the long-term performance of safety components.

- **Key Principle 3 -** the operator's proposed programme for LTO needs to be evaluated

  Irrespective of the option chosen by the regulator, the operator's proposal to extend the life of its plant needs to be evaluated by the regulator. This evaluation will be consistent with the defined goals and safety objectives to be achieved.

  The document also notes under this principle that in cases where regulators adopt a periodic safety review approach, the evaluation should confirm compliance of the plant with the established licensing basis and should assess the effects of ageing, modifications of the plant, changes in operating procedures and anticipated ageing on the safety of the plant. In addition, the review should include the assessment of potential improvements in plant safety level taking into consideration requirements in modern safety standards and internationally recognised good safety practices. The regulator's assessment should include the expected safety benefits of the improvements as well as the adequacy of the assessment method utilised.

The report includes information on identified regulatory challenges and considerations. The discussion is structured around four functions of the regulator. These functions, each of which is tied to a key principle, are:

1. Developing a regulatory framework that is compatible with LTO;
2. Defining the scope of the regulatory assessment for LTO;
3. Assessing the safety basis of LTO; and
4. Ensuring oversight of the plant in LTO.

Against Item 1 above (**Developing a Regulatory Framework**) the document notes that the regulator should determine:

- The applicability of the existing regulatory framework during LTO; and
- The need for new regulatory requirements for LTO.

Regulatory Framework – Assurance of safety during LTO will require a comprehensive safety review by the regulator, and enhanced consideration of the impact and management of materials ageing on the safety functionality of critical systems, structures and components. The regulatory framework should also include inspections and audits, as needed, to verify and validate the sufficiency of actions proposed by the operator to support LTO. The regulator should also determine whether new requirements are needed to supplement the framework for LTO. An assessment of the adequacy of the existing framework for LTO requires a thoughtful review, considering the fundamental and key principles presented previously in this document.

Reference: A-102 [NEA/CNRA/R(2012)5]
Openness and Transparency – Public interest may encompass a number of areas, for example, issues related to the safety impact arising from ageing or differences in safety and security levels between existing reactors and new reactors. In many cases, demonstrating the acceptability of aged and potentially-degraded plants requires detailed technical consideration and state-of-the-art knowledge. Associated with Item 2 above (**Defining the Scope of the Regulatory Assessment**) the document identifies that the LTO safety assessment can include the following topics, depending on the country's regulatory framework: • Ageing management for LTO; • Environmental assessments; • Operating experience; • Safety improvements; • Security improvements; and • Emerging issues. **Ageing Management for LTO –** Ageing management helps to ensure that systems, structures and components that are important to safety are capable of performing their required safety functions. This is a broad activity that involves maintenance, surveillance, equipment qualification, in-service inspection, water chemistry control, and other plant programmes. It provides a methodical process to detect, assess and correct, as necessary, the effects of ageing. Thus, an effective ageing management programme is a key element of safe and reliable operation of nuclear power plants during the originally planned operation time frames, as well as for periods of LTO. A systematic process should be in place to determine which systems, structures and components should be subject to ageing management programmes. Time-limited Ageing Analysis may be required for major structural and safety components to assess the effects of ageing, fatigue and relaxation (creep), as well as degradation due to environmental conditions. Safety analyses which use time-limited assumptions must be updated to include additional time periods for LTO and to determine whether any additional ageing management is required. A comprehensive ageing management programme includes co-ordinating, integrating and modifying existing programmes and activities that relate to managing the ageing of systems, structures and components and developing new programmes that may be needed for LTO. It is also of importance to utilise operating experience feedback to support the conclusions that the effects of ageing will be managed adequately so that the intended functions of a system, structure or component will be maintained throughout the planned LTO period. It is essential that the operator obtain a comprehensive understanding of the plant's ageing behaviour which is the foundation for a well-functioning ageing management programme. This foundation consists of systematic data on numerous issues such as material and fabrication data, operational conditions and stressors, possible ageing mechanisms, as well as the location and consequences of ageing and failures. The regulator should ensure that the operator reviews data and information collected from ageing management programmes to confirm that safety analysis assumptions, credited parameters and predictions remain valid, and that limiting criteria and required design margins continue to be met as the plant ages. The operator should consider not only the physical ageing of systems, structures and

Reference: A-102 [NEA/CNRA/R(2012)5]

components but also technological ageing (obsolescence) that may arise in plant systems, structures and components.

Environmental Assessment – The document also notes that in addition to consideration of plant safety for LTO, the environmental impacts of LTO may also need to be considered and assessed.

Operating Experience – Both the regulator and the operator should consider operating experience from a variety of sources, both domestic and international, on a continuous basis. These sources include:

- Plant-specific experience;
- Experience from similar plant designs (i.e. The same class of plants);
- Experience from similar materials, operating conditions, and systems, structures and components; and
- Relevant experience, regardless of plant type, that contributes to the judgements on acceptability for LTO (e.g. The accident at Fukushima Daiichi).

Regulatory review of adverse operating experience from all sources is critical in providing robust regulatory oversight, assuring that appropriate short-term operator actions are taken and long-term ageing management adjustments are planned for implementation.

Safety Improvements – When the objective is to assess the safety level against modern standards, the regulator may include, in the regulatory assessment, safety improvements or broader modifications to the safety approach. Improvements that may be needed can be identified based on an assessment of:

- Evolution of regulations, safety objectives and practices (nationally and internationally); and
- Lessons learnt from other plants or equipment involving risk.

There is a general recognition that newer safety requirements should be accommodated to the extent that is reasonably practicable, taking account of the potential safety gains and costs involved. On the basis of the identified improvements, an implementation plan should be agreed between the regulator and operator to be monitored as part of the ongoing oversight process.

Security Improvements – Older nuclear power plants may not have been designed and constructed to the same physical security standards that apply at new plants. The LTO review should examine the extent to which provisions for physical security can be augmented if such a requirement is part of the country's regulatory framework.

Emerging Issues – The start of the period of LTO could occur a number of years after the submission of the operator's application for authorisation of LTO. Consequently, the regulator should ensure that the operator has established a process for responding to any issues that might emerge during this intervening period. This process will identify:

- The approach for consideration of new operating experience and research results or revisions of codes, standards and practices; and
- A methodology for assessing the safety significance of differences with revised codes, standards and practices.

The safety of LTO should be kept under review by both the regulator and the operator throughout this period and modifications to planned ageing management activities should implemented as necessary to ensure safe operation during the period of LTO

Reference: A-102 [NEA/CNRA/R(2012)5]
Against Item 3 above (**Assessing the Safety Basis of LTO**) the document notes that the regulator should determine whether the operator's safety basis is acceptable. In general, the design of a nuclear power plant includes consideration of the degradation that could be caused by ageing mechanisms that were known at the time of design. Consequently, the designs incorporated suitable margins to account for degradation over the projected lifetime, based on the technical knowledge available. Over an extended period of service, there will likely be degradation beyond the provisions allowed in the design of the plant. In some situations, it will be feasible to address ageing issues through refurbishment or replacement of degraded systems, structures or components. However, it must be recognised that such remediation work may not be feasible in some systems or areas of the plant. When assessing the safety basis some items to consider include: • Period to be Considered for LTO; • Assessment Approach; • Research and Development; and • End of Operation **Assessment Approach –** The approach to address any improvement in plant condition must be demonstrated and the remaining risk demonstrated to be as low as reasonably practicable. In making these judgements, a reasonably reliable projection of planned operating life is required to enable appropriate judgements to be made, i.e. for a modification which may not be justified on the basis of "as low as reasonably practicable" for five years of planned operation may well be justified for a proposed operating life of ten years or longer. The regulator should therefore clarify its view on the plant operation time that should be considered to assess the LTO safety basis. **Research and Development –** In support of this LTO assessment, the regulator may need to undertake technical studies and research and development work to confirm the adequacy of the operator's technical basis for LTO. The scope of these confirmatory programmes should be compatible with the scope of the regulatory assessment for LTO. Associated with Item 4 above (**Ensuring Oversight of the Plant in LTO**) the document identifies that once LTO has been authorised, the regulator should ensure adequate implementation of LTO programmes through inspections or audits. This oversight should, in particular, evaluate the effectiveness of the implementation of ageing management programmes and of safety improvements when such improvements are required to support LTO. **Ensuring Human Capability –** The regulator should require confirmation that the operator has qualified and experienced personnel available to operate and maintain the plant in the period of LTO, if such a requirement is a part of the country's regulatory framework.
Key Themes <u>General Note</u> The document focusses on two regulatory approaches to LTO, licence renewal and PSR, neither of which directly apply to the UK. However, recognising the role PSR does play in supporting extended operation useful information relating to PSR has been summarised above.

Reference: A-102 [NEA/CNRA/R(2012)5]

Regulatory Approach/Framework for LTO

The document identifies the need to review the applicability of the existing regulatory framework for LTO and to determine if there is a need for new regulatory requirements. To some extent Phase 1 of this task reflects this first part of the review and this Phase relates to determining the need for new requirements. In addition, the document identifies that there is openness and transparency in the approach to address and potential concerns from the public. However, there is perhaps a need to ensure there is clarity within the ONR's approach to LTO and where the interfaces are with an operator, in terms of assessing justification for extended operation and where the oversight is provided. This approach should be mapped out for internal and external use.

Scope of Regulatory Assessment

The approach to regulator assessment within the UK is more aligned to the PSR approach, although it is recognised that the PSR is not the regulatory instrument for approval to extend the life of a facility. The scope of regulatory assessment outlined in this document (and in many others) is largely within the scope of the PSR either directly (as part of TAG-50) or indirectly (TAG-50 points to SSG-25 as a guide to the PSR scope).

However, the individual analysis/assessment for specific SSCs to extend the life beyond the original design life will generally be tackled as part of the modification process (LC22) as and when it is required. Internationally, these would more closely aligned with updated analysis being reported in the PSR and outstanding analysis being part of the forward plan. These assessments, along with a review of the AMP (programmatically and at component level) would form the basis of the LTO justification and the key elements of the regulatory assessment.

While it is not appropriate to recommend changes to the regulatory approach for LTO, it is perhaps worthwhile looking to strengthen the links between the PSR, the development of an AMP and LC22 to recognise the combination these have in the justification for BDL.

Use of Operating Experience and R&D

The document recognises the value of OPEX and R&D can have in supporting and LTO Submission or PSR to extend the life of a facility. However, the document highlights the need for both the operator and regulator to consider operating experience from a variety of sources, both domestic and international, on a continuous basis. It notes that regulatory review of adverse operating experience from all sources is critical in providing robust regulatory oversight, assuring that appropriate short-term operator actions are taken and long-term ageing management adjustments are planned for implementation.

Safety & Security Improvements

The report highlights the need for safety improvements to made on a facility in order to support LTO and that PSR is a method for the identification of potential gaps. While this reflects other documents on the subject there are two aspects that differentiate this document from others. The first is that the document recognises that not all improvements are applicable or appropriate, but all 'reasonably practicable' improvements should be made. The use of the term 'reasonably practicable' is generally understood in the UK; however, it is rare for the term to appear in international documentation. The other difference is that the potential need for safety improvements is extended to consider security improvements also. This perhaps crosses over to the SyAPs and any PSR type reviews undertaken for security.

Reference: A-102 [NEA/CNRA/R(2012)5]
Emergent Issues Where LTO is linked to licence renewal emerging issues may arise as the facility move into extended operation; or if linked to PSR issues may arise between PSR reviews. The document highlights the need to ensure that a process is established to categorise the significance and consider the appropriate response for the facility. As SSCs age and degrade an emerging issue may have a more significant effect as the plant becomes less tolerant to issues. The PSR would examine such processes as part of the existing PSR scope; however, there is perhaps a need to reflect that changes in significance can occur with time as a facility becomes less resilient. In addition, there is perhaps a need to reflect that some emerging issues may lead to the extended operation ending earlier than anticipated, especially if it deemed not technically feasible or financially viable to address the issue. Ensuring Capabilities & Resources The document notes that the regulator should require confirmation that the operator has qualified and experienced personnel available to operate and maintain the plant in the period of extended operation. However, there is also a need for the regulator to ensure it has the capability & resources to support extended operation also. This may result in additional demands on the regulator to undertake more frequent inspections and audits or the review of more complex and novel solutions to technical issues posed by extended operations.
Document Relationships & Referencing The document references a number of IAEA reports, including the predecessors to SSG-48 and SSG-25.
Applicability to Beyond Design Life Expectations The document highlights a number of key themes for consideration; however, they do not explicitly lead to any additional expectations for BDL substantiation. The key themes do reinforce the links between the PSR and BDL, in terms of the impact changes have had (or will have) on the facility as a whole. In addition, this document outlines the need for a regulator to internally challenge if it is set up for LTO, both in terms regulatory requirements and capabilities & resources.
Applicability to the ONR SAPs The document does not identify anything that is related to a specific SAP or TAG, but instead challenges regulators to ensure their requirements are suitable for extended operation. This research task, to a certain extent, is that check and is actively looking at BDL or LTO RGP to determine if the ONR Guidance (through the SAPs & TAGs) support LTO and developing the expectations for BDL substantiation, mapping these to the SAPS & TAGs.
Future Considerations N/A
Additional Notes **Security Improvements –** Is life extension and security improvements (resulting from the review of 'modern' codes & standards) captured in the SyAPs or associated guidance?

Reference: A-113 [NuPEER 2005 Symposium]
Document Title/Version Number: NuPEER 2005 Symposium (Dijon) – Ageing issues in nuclear power plants
Date of Issue: 2005

Summary:
 	
The French Nuclear Safety Authority (ASN) organised an international symposium on regulatory aspects of ageing issues for nuclear pressure equipment. The ageing of nuclear pressure equipment is an issue of growing importance for nuclear regulators and material experts worldwide as age-related degradation of major pressure-retaining components challenges the remaining operating life of nuclear power plants. This symposium aimed at providing a forum for technical exchange among the staffs responsible for nuclear pressure equipment within the safety authorities and the associated expertise organisations.
 	
The document includes the papers presented over the course of the symposium and incorporates the proceedings from the event also. The papers that were presented were from across the international community including the US (from the NRC), various European countries and the IAEA. The papers summarise various approaches to Ageing Management (AM) and justification for Long-Term Operation (LTO) from across the world and provide some OPEX on the implementation of the processes in country. The approaches outlined reflect the evolution of processes at the time of the symposium and the different elements of good practice that would go on to form the current approaches in SSG-48 are in evidence.
 	
In addition to the process aspects of AM and LTO, the symposium also captured information on degradation mechanisms, monitoring methods and analysis techniques for significant 'pressure-retaining' SSCs. The experiences shared are all focused on LWR SSCs but recognise different classes of SSC based on the consequences of failure and the safety significance of the plant item. The information presented reflects understanding nearly 15 years ago and understanding of these issues will have moved on since then, as such the OPEX may have limited use in the UK.
 	
One of the papers presented at the symposium highlights the importance of SSC data to support extended operation. The presentation identified as an IAEA Guidelines Presentation was delivered by someone from EDF France. It notes that data availability is a key aspect in life management and the quality and availability of relevant information is directly related to the quality of the decisions on service life and the reliability of nuclear power plants. While most utilities keep data on key components, the data requirements have not necessarily been specified with regard to plant life evaluation. The data needs for this purpose needs to be established at an early stage. In addition, there will be the requirement to include data on component repair and replacement, associated hardware etc. The aim of the work should be to enable lifetime of components to be evaluated and should encompass the following groups of data to allow the identification of the ageing component and ageing behaviour:
 	
• Component specification data (baseline)
  – Materials
  – Initial properties
  – Design loading
  – Anticipated ageing data (ageing sensitivity)
• Ageing or failure tracking data

Reference: A-113 [NuPEER 2005 Symposium]

- Operational history
- In-service inspection
- In-service monitoring

- Stress or and root cause data
- Failure or degradation mechanism data
- Test and maintenance data
- Measures to improve design and operations
- Relevant generic or other plant/R&D information

Data sets required for plant life management can therefore be categorised as follows:

- A baseline (including design and basic design from construction),
- Operating history;
- Current plant state (including ISI);
- Maintenance;
- Technology developments;
- Material properties (including results from surveillance testing);
- Relevant generic data.

The paper also notes that reviews have shown that existing records of baseline, operation and maintenance of reactor components are not sufficiently comprehensive or readily retrievable to allow for trend analysis and prediction of component performance, identification and evaluation of the extent of ageing.

One paper from Germany (presented by someone from EON) discusses the ageing management approach in the country and typical activities based on the safety significance of the plant. In the summary it notes that the current activities of the German utilities focus on the optimization of the description of the measures in a so-called plant specific base report on ageing management. This base report covers the technical as well as the non-technical aspects of ageing management. In addition, periodic status reports are being prepared showing if new ageing effects have been occurred and what remedial actions have been taken to demonstrate adequate lifetime and ageing management in a more systematic way.

There are two aspects of interest from this paper; the first is the optimisation of description of measures for SSCs, and the second is the inclusion of non-technical aspects in the plant specific base reports. With respect to the first point, the paper highlights an approach to ageing management based on safety significance and type of SSC (i.e. Mechanical, EC&I or Civil). While many other processes have screening criteria to determine those items to be included or excluded from the AMP, there are not too many that use a graded approach to systematically determine the measures being utilised.

The other point of interest is the recognition that non-technical issues will also have a role in the management of ageing. When justifying extended operation for an SSC, ensuring Knowledge Management or analysis tools (e.g. SSC specific computer models or codes) are maintained for the extended period is an important aspect that may not always be apparent. For some SSCs demonstrating knowledge management

Reference: A-113 [NuPEER 2005 Symposium]
over the period of extended life could be a key part of the arguments presented in the BDL submission and the absence of them may need to be challenged. Another paper of interest presented the approaches to ageing management and LTO in Spain. The Spanish system is centred on performing of a PSR to be granted 10-year term permits. However, the paper notes that besides the traditional PSR requirements, specific requirements regarding LTO include: 1. An Aging Management and Evaluation Program that identifies SSC degradation effects/mechanisms and mitigating programs. Identification and evaluation of Time Limited Aging Analysis (TLAA) should be also performed. 2. An updated Radiological Impact Study that considers site changes and new trends in radiological protection, as well as any accumulative effects or issues that might contribute to an increased impact. 3. A Radioactive Waste Management Plan The paper identifies that when the PSR covers a period beyond the original design life (i.e. moving into LTO) then the main objective of the PSR will be to determine whether ageing of certain SSCs is being effectively managed so that required safety functions and design bases are maintained, and whether an effective ageing management programme is in place for long term operation. Additionally, TLAAs must be identified and evaluated in order to demonstrate that SSCs will remain valid for the new period of operation. Demonstration that the effects of ageing are being adequately managed is achieved by undertaking the following steps: 1. Identification of the SSCs and its intended functions within the scope (Scoping) 2. Identification of the structures, components, and commodities subject to ageing management review (Screening) 3. Demonstrating that the effects of aging will be managed (Ageing Management Review) 4. Identification and evaluation of time-limited ageing analyses (TLAA) 5. Preparing the Safety Analysis Report Supplement, identifying changes to Technical Specification and describing the format and contents of the LTO application. The scoping & screening approaches presented in the paper are consistent those adopted and presented in various documents. The paper identifies that the goal of the Ageing Management Review step is, for each SSC identified in the screening step, to demonstrate that the effects of ageing will be adequately managed so that the intended functions will be maintained consistent with the current licensing bases for the period of extended operation. Plant programs and activities that apply to the SSCs should be reviewed to determine if they include actions to detect and mitigate the effects of ageing. Ageing management programs are generally of four types: prevention, mitigation, condition monitoring and performance monitoring. A description of the four was expanded in the paper, it identified that: • **Prevention** programs preclude the ageing effect from occurring, for example coating programs to prevent external corrosion of a tank. • **Mitigation** programs attempt to slow the effects of ageing, for example, chemistry programs to mitigate internal corrosion of piping.

Reference: A-113 [NuPEER 2005 Symposium]

- **Condition Monitoring** programs inspect and examine for the presence of and extent of ageing effects, for example, visual inspection of concrete structures for cracking and ultrasonic measurement of pipe wall for erosion-corrosion induced wall thinning.
- **Performance Monitoring** tests the ability of the structure or component to perform its intended function, for example, heat balances on heat exchangers for the heat transfer intended function of the tubes.

Once a specific programme or combination of programmes have been selected for an SSC a review is undertaken using a checklist of the following attributes:

- The scope of the program/activity should include the specific structures and components subject to an ageing management review for long term operation.
- Preventive actions are in effect that mitigate or prevent the onset of degradation or ageing effects, and their effectiveness is periodically verified.
- Parameters are monitored, inspected and/or tested, that provide direct information about the relevant ageing effects, and their impact on intended functions.
- The ageing effects are detected by one or more of the credited programs before there is a loss of the structure's or component's intended function,
- Monitoring and trending provides an adequate predictability and timely corrective or mitigating actions.
- The programs contain acceptance criteria against which the need for corrective action will be evaluated and ensures that timely corrective action will be taken when these acceptance criteria are not met.
- There is a confirmation process that ensures that the corrective actions were taken and was effective.
- Corrective actions are taken (this includes root cause determinations and prevention of recurrence where appropriate) in a timely manner or an alternative action is identified,
- The program is subject to administrative controls.
- Operating experience of the program/activity, including past corrective actions resulting in program enhancements, should be considered. It provides objective evidence that the effects of ageing have and will continue to be adequately managed.

The paper goes onto identify that TLAA are those license calculations and analyses that:

1. Involve systems, structures and components within the scope
2. Consider the effects of ageing
3. Involve time-limited assumptions defined by the original design plant life, i.e. 40 years;
4. Were determined to be relevant by the licensee in making a safety determination;
5. Involve conclusions or provide the basis for conclusions related to the capability of the system, structure and component to perform its intended function (as defined in the scoping process)
6. Are contained or incorporated by reference in the current licensing bases.

Reference: A-113 [NuPEER 2005 Symposium]
A list of TLAAs should be provided as part of the submission, in order to demonstrate that: • The analyse remain valid for the period of extended operation; • The analyses have been projected to the end of the period of extended operation; or • The effects of ageing on the intended function will be adequately managed for the period of extended operation. To support the process for the first NPP to progress through to LTO an initial piece of work was undertaken, which was described as 'very important'. This document was the basis for the identification of the aging mechanisms that can potentially affect the SSCs, which contained the following content: • The constitutive materials of the SCC's were identified and described. • The internal and external environments where the SCCs are located were identified and described. • AMR groups were defined as the possible material/environment combinations. • The applicable and not applicable aging mechanisms and their effects were identified. Not applicability of aging mechanisms is properly justified. In addition, the paper identifies that as part of the Ageing Management Review (AMR) documents the components, the aging mechanisms, their effects and the aging management programs (AMP) have been compared to those included in the GALL report. Due to the generic nature of the GALL information this exercise appears to be undertaken as part of a benchmarking/verification process to demonstrate no significant gaps have been missed. The AMR for SSCs are presented in tables which include the following information: • Component type • Intended function • Material • Environment: internal and external • Aging effect that requires management • Applicable AMP • GALL report volume 2 item number • GALL TABLE item number • Additional Notes The paper also notes that in addition to reviews of the documentation prepared (PSR and LTO Documents) the regulatory policy on ageing management, as well as on LTO, require a comprehensive regulatory plan of inspections and assessments on the programmes conducted by the licensees.

Reference: A-113 [NuPEER 2005 Symposium]

Key Themes

General Note

The approaches outlined across the different papers reflects the ageing management and LTO process at the time of the symposium, in the years that have followed these have evolved taking on board OPEX shared at events like this. The collation of different experiences from across the industry to distil common approaches has contributed to the development of many documents including the current approaches outlined in SSG-48. These papers represent a point in time on this journey and as such does not add any new or additional themes or considerations associated with the key BDL processes. However, it does highlight areas not necessarily picked up elsewhere and these are included below.

The symposium also captured information on degradation mechanisms, monitoring methods and analysis techniques for significant 'pressure-retaining' SSCs. The experiences shared are all focused on LWR SSCs but recognise different classes of SSC based on the consequences of failure and the safety significance of the plant item. The information presented reflects understanding nearly 15 years ago and understanding of these issues will have moved on since then, as such the OPEX may have limited use in the UK.

Data Recording & Availability

The presentation notes that while most utilities keep data on key components, the data requirements have not necessarily been specified with regard to plant life evaluation. The data needs for this purpose should ideally be established at an early stage. However, in developing AMPs consideration around the degradation mechanisms, the monitoring or measuring methods should also consider the data required to evidence change. There will also be the requirement to include data on component repair and replacement, associated hardware, etc. The aim should be to enable lifetime of components to be evaluated and encompass a range of groups of data to allow the identification of the ageing component and ageing behaviour.

The paper also notes that reviews have shown that existing records of baseline, operation and maintenance of reactor components were not sufficiently comprehensive or readily retrievable to allow for trend analysis and prediction of component performance, identification and evaluation of the extent of ageing. This is likely to be similar in the UK, across a range of facilities. As a result, potentially part of the BDL submission is focussed on how this gap can be addressed to better determine the 'actual condition' of the plant.

Indirect Aspects of AM & LTO

One presentation included the recognition that non-technical issues will also have a role in the management of ageing. When justifying extended operation for an SSC, ensuring Knowledge Management or analysis tools (e.g. SSC specific computer models or codes) are maintained for the extended period is an important aspect that may not always be apparent. For some SSCs demonstrating knowledge management over the period of extended life could be a key part of the arguments presented in the BDL submission and the absence of them may need to be challenged.

Checklist Review of Programmes

Within the Spanish presentation largely aligns with the approach detailed in IAEA SSG-48, with some specifics around the approach adopted in the country at the time of the symposium. However, it highlights a checklist around the programmes put in place for SSCs, the list contains valid challenges to a BDL submission that should be presented in the individual submission or evidenced in a PSR. The challenges include:

Reference: A-113 [NuPEER 2005 Symposium]

- The scope of the program/activity should include the specific structures and components subject to an ageing management review for long term operation.
- Preventive actions are in effect that mitigate or prevent the onset of degradation or ageing effects, and their effectiveness is periodically verified.
- Parameters are monitored, inspected and/or tested, that provide direct information about the relevant ageing effects, and their impact on intended functions.
- The ageing effects are detected by one or more of the credited programs before there is a loss of the structure's or component's intended function,
- Monitoring and trending provides an adequate predictability and timely corrective or mitigating actions.
- The programs contain acceptance criteria against which the need for corrective action will be evaluated and ensures that timely corrective action will be taken when these acceptance criteria are not met.
- There is a confirmation process that ensures that the corrective actions were taken and was effective.
- Corrective actions are taken (this includes root cause determinations and prevention of recurrence where appropriate) in a timely manner or an alternative action is identified,
- The program is subject to administrative controls.
- Operating experience of the program/activity, including past corrective actions resulting in program enhancements, should be considered. It provides objective evidence that the effects of ageing have and will continue to be adequately managed.

In addition, the paper goes onto identify that a list of TLAAs should be provided as part of the submission, in order to demonstrate that:

- The analyse remain valid for the period of extended operation;
- The analyses have been projected to the end of the period of extended operation; or
- The effects of ageing on the intended function will be adequately managed for the period of extended operation.

Again, these challenges for TLAAs presented within a BDL Submission and a clear list be presented as part of the PSR process.

Document Relationships & Referencing

The document contains a broad range of linked documents; such as a number of IAEA reports, including the predecessors to SSG-48 and SSG-25.

Applicability to Beyond Design Life Expectations

As noted previously, the presentations are broadly consistent the information presented in SSG-48 and SSG-25; however, it does identify a few things that not readily highlighted in the other nuclear related RGP reviews. This includes:

Reference: A-113 [NuPEER 2005 Symposium]
<u>Data Recording & Availability</u> Data availability is a key aspect in life management and the quality and availability of relevant information is directly related to the quality of the decisions on service life and the reliability of nuclear power plants. <u>Indirect Aspects of AM & LTO</u> As part of the BDL submission for certain SSCs, demonstrating knowledge management (including SSC specific computer models or codes) over the period of extended life could be a key part of the arguments presented and the absence of them may need to be challenged. <u>Checklist Review of Programmes</u> Here, as in other RGP reviews, are a list of questions/challenges around extended operation that relate to understanding the degradation mechanisms, the preventative or monitoring programmes in place, the corrective measures identified and the governance in place. These appear in a number of places and the main Phase 2 Technical Report should consolidate the various questions into a single list.
Applicability to the ONR SAPs The information presented focusses on the LTO submission or PSR for LTO and the assessments/analysis required to demonstrate safe operation over the extended period. The requirements would have applicability to a broad range of SAPs that should be demonstrated as part of 'normal operation', (including extended operational life), or would be required to be reviewed/updated to underpin extended life. Specific elements of the SAPs identified as being applicable include: • A number of aspects associated with EAD.1 to EAD.5 and the evidence these provide to substantiate extended operation. • The SAPs associated with the assurance of validity of data and models, which contains principles governing the methods and data used in safety case analyses would be equally applicable to extended operation and the supporting submissions. Including the assessment of transient, radiological and other analyses forming part of fault analysis and also in other areas of the safety case underpinned by analysis and/or data, e.g. engineering substantiation. These SAPs do not explicitly identify BDL considerations, but perhaps there is a case for amending this part of the SAPs reflect the requirements for TLAAs and data to support the justification of operation beyond the original design life of an SSC.
Future Considerations Collation of questions, checklists and challenges associated with LTO to consolidate for further consideration in either an Ageing Management or BDL related TAG.
Additional Notes The various papers collected from the conference contain some OPEX around degradation mechanisms and monitoring methods. The information is all focussed on LWRs and reflects understanding nearly 15 years ago; as such, it may have limited use in the UK.

Reference: A-114 [ISBN 978-1-84569-511-8]	
Document Title/Version Number: Understanding and Mitigating Ageing in Nuclear Power Plants - Materials and Operational Aspects of Plant Life Management (PLiM)	
Date of Issue: 2010	

Summary:

This book reviews the ageing-degradation mechanisms of materials used in nuclear power plant structures, systems and components, their relevant analysis and mitigation paths, and reactor-type specific plant life management (PLiM) practices. Obsolescence and other less obvious ageing-related aspects in nuclear power plant operation are also examined in depth.

The necessity for always keeping SSCs 'fit-for-service' is a vital safety related aspect, but it is also an important commercial requirement as well, since NPPs may thereby retain the technological basis, and thus the regulatory possibility (in satisfying licence requirements), to continue safe and reliable operation, even in excess of their original design life. The chance that this 'long-term operation' (LTO) can be realized is significantly enhanced when NPP plant life management (PLiM), ageing management (AM), ageing surveillance programmes (ASPs) and standard operational practices (OPs) are optimized, and when plant-specific and worldwide lessons learned are continually and robustly integrated into the operational management of NPPs. The effectiveness of PLiM, AM, ASPs and OPs is also shown to depend significantly on the level of safety culture prevailing in the NPP's workforce, as well as on efficient plant knowledge management (KM) and associated job succession and training strategies for personnel. These essential themes are discussed throughout the book.

Part One introduces the role of nuclear power in the global energy mix, and the importance and relevance of PLiM for the safety regulation and economics of nuclear power plants. Key ageing degradation mechanisms and their effects in nuclear power plant systems, structures and components are reviewed in Part Two, along with routes taken to analyse the ageing of materials and to mitigate or eliminate ageing degradation effects. Part Three reviews analysis, monitoring and modelling techniques applicable to the study of nuclear power plant materials. Part Four reviews the particular ageing degradation issues, plant designs, and application of PLiM practices in a range of commercial nuclear reactor types.

It should be noted that many of the SSCs and degradation mechanisms discussed in this book, predominantly in Parts II to IV, relate to Light Water Reactors (LWRs) with some information included on CANDUs and AGRs. Given much of the technical information is focussed on LWRs and reflects understanding from 10 years ago, it may have limited use in the UK. However, it does provide a different source of OPEX that may be of some value. The aspects of this book of interest are presented in Part I, which includes:

- Chapter 2 – Key elements and principles of nuclear power plant life management (PLiM) for current and long-term operation
- Chapter 3 – Safety regulations for nuclear power plant life management and licence renewal
- Chapter 4 – Probabilistic and deterministic safety assessment methods for nuclear power plant life management

Chapter 2 presents key elements and principles of NPP life management for current and extended operation (LTO). Concepts and methodologies of NPP ageing surveillance programmes (ASPs), ageing management (AM) and plant life management (PLiM) are discussed. Ageing degradation (AD) terminology concerning NPP SSCs is included in this chapter. In addition, it highlights the importance of safety classification of SSCs

Reference: A-114 [ISBN 978-1-84569-511-8]
in supporting scoping and applying optimum operational practices, ASPs, AM and PLiM programmes. The chapter also considers design requirements, knowledge management, human factors, safety culture, radiological protection, SSC AD mechanisms and AD mitigation, obsolescence in equipment, regulatory aspects, radioactive waste disposal and radiological protection. Concepts for future NPP designs and PLiM are introduced. The chapter also highlights that by implementing the state-of-the-art, science and technology into the existing standard plant operational practices, which include ASPs, and AM & PLiM programmes, SSC ADs can be managed to keep the option open for NPPs to reach, and then exceed, their original design lives in a safe way. Many of the elements presented in this chapter are not uncommon in the various approaches to extending the life of a facility. However, one of the elements that stands out as being different, is the human element; the recognition around Safety Culture, Knowledge Management and human factors is not routinely covered in LTO discussions. Chapter 3 presents the regulations at the time the book was produced to ensure safety and reliability of ageing nuclear power plants. The regulations discussed include the NRC approach, the LTO Submission approach and the approach that uses the PSR to extend operation. Management of ageing in SSCs requires an understanding of ageing mechanisms and how to detect and control them through surveillance, feedback of operating experience and maintenance programmes. Nuclear power plants' longer-term operation needs to be addressed by designers, plant operators and regulators within the umbrella of international organizations to implement, complete and augment research and enact new regulation. The chapter notes that **the interest of the regulator is based in the applicant knowing, managing and maintaining ageing within the plant safety envelope**. Chapter 4 addresses safety assessment methods in relation to ageing effects and develops an integrated safety and economic plant life management system able to effectively manage ageing effects at nuclear power plants. After a short summary with definitions and framework, a reference Plant Life Management (PLiM) model is discussed, as background for a detailed analysis of the main issues related to component and system degradation. A Probabilistic Safety Assessment (PSA) approach where time-dependent ageing effects are considered is also discussed, with emphasis on the evaluation of time-dependent component reliabilities. Some case studies on component reliability calculations are described, where ageing considerations have a strong impact, providing suggestions on how reliability and data analysis for active components can be carried out in an effective way and incorporation of age-dependent reliability and data into PSA models can be implemented.
Key Themes <u>General Note</u> The information presented in this book, outlined across the different parts and chapters reflects an aggregated overview of ageing management and LTO process at the time the book was written. It is difficult to see the target audience for this book, given that organisations like the IAEA or NRC have been primary sources for much of this type of work. The OPEX presented is also reflective of the time the book was produced and by its nature (i.e. mainly LWR focussed) may have limited applicability within the UK. This book represents a point in time and as such does not add any new or additional themes or considerations associated with the key BDL processes. However, it does highlight a few areas not necessarily picked up elsewhere and these are included below. <u>Safety Classification of SSCs</u> A fundamental step in the LTO process is the SSC scoping & selection criteria; however, this book uses 'safety classification' to support optimisation of the applicable programmes. The level of substantiation to justify operation beyond the original design life should be linked to the safety classification of SSCs but this

Reference: A-114 [ISBN 978-1-84569-511-8]
label is not always used. The depth and breadth of analysis undertaken or the number of different legs to a (multi-legged) argument should reflect the safety classification; however, the book does not offer the reader any guidance on what this might look like as is will depend on a number of factors, not least the regulatory framework in place. <u>Indirect Aspects of AM & LTO</u> One of the elements that stands out in this book as being different, is the human element. The recognition around Safety Culture, Knowledge Management and human factors is not routinely covered in LTO discussions, as the focus tends to more SSC or technology related. These elements would be covered by the PSR and in other countries an LTO Submission, but not necessarily as part of an individual SSC BDL Submission. While there are aspects around the human element that are generic and better suited to the PSR, specific elements (for instance around knowledge management) may form a part of the argument to extend the operation of an SSC. These aspects should not be forgotten and perhaps some guidance can be provided on what may be captured in a PSR and what could/should be included in a BDL Submission.
Document Relationships & Referencing The book, which includes contributions from a number of different authors, contains a broad range of linked documents; such as a number of IAEA reports, including the predecessors to SSG-48 and SSG-25.
Applicability to Beyond Design Life Expectations As noted previously, the book is broadly consistent with the information presented in SSG-48 and SSG-25; however, it does identify a few things that not readily highlighted in the other nuclear related RGP reviews. This includes: <u>Importance of SSC Safety Classification</u> The importance of the safety classification in determining breadth and extent of justification proportionate with the significance of the SSCs, is an integral part of any LTO or BDL process(es). It is worth highlighting this as part of any future guidance. However, an appropriate challenge to any BDL submission is whether the safety classification changes with time compared to the original design intent. In addition, this challenge should not only be limited to the SSC being considered, but also if extended operation places further demands on supporting systems. While this specific aspect is not identified in this reference, it seems a logical challenge to make when considering the safety categorisation during extended operation. <u>Indirect Aspects of AM & LTO</u> As part of the BDL submission for certain SSCs, demonstrating how human aspects will be managed (including knowledge management or human factors) over the period of extended life could be a key part of the arguments presented and the absence of them may need to be challenged.
Applicability to the ONR SAPs The information presented focusses on the LTO submission or PSR for LTO and the assessments/analysis required to demonstrate safe operation over the extended period. The requirements would have applicability to a broad range of SAPs that should be demonstrated as part of 'normal operation', (including extended operational life), or would be required to be reviewed/updated to underpin extended life. Specific elements of the SAPs identified as being applicable include:

Reference: A-114 [ISBN 978-1-84569-511-8]
• A number of aspects associated with EAD.1 to EAD.5 and the evidence these provide to substantiate extended operation. • The SAP associated with safety classification of SSCs, ECS.2, should be considered not only in terms of the SSCs at the heart of the BDL submission, but also if extended operation places additional demands on supporting systems. • Aspects around knowledge management (MS.2), around being a 'capable organisation', and those relating to Human Factors (EHF.1 to EHF.12) may also need to consider how these aspects are demonstrated beyond the original design life of an SSC.
Future Considerations N/A
Additional Notes N/A

Appendix D. Output of Other High-Hazard Industries RGP

Reference: A-032 [HSE-2001/088]
Document Title/Version Number: Beyond lifetime criteria for offshore cranes
Date of Issue: 2002
Summary: This report presents a review of current regulatory requirements and best practice to enable checklists to be produced to assist HSE (OSD) inspectors when reviewing/auditing a duty holder's safety case justifying the continued operation of a pedestal crane once it has gone beyond its design life. The approach considered the contents of the duty holder's crane safety case submission, and how they would be affected by beyond design life issues. The report included the appraisal of the ongoing cross industry Step Change Initiatives to improve safety management performance on platforms that are below the industry average. This guide is divided into two main parts; 1. the front sections of the document that discuss, in general terms, the various issues affecting operation beyond the design life of cranes, and 2. the checklists contained in the Appendices that could be used as part of an audit specific to beyond design life issues. There are 10 sections and 4 appendices within this report. Sections: 1. Introduction 2. Offshore safety case 3. Oil and gas regimes 4. Design, manufacture and testing standards 5. Testing and inspection 6. Ageing and degradation 7. Controls and procedures 8. Review of step change initiatives 9. Human factors 10. References Appendices: 1. Appendix A, Pedestal Crane Essential Features

Reference: A-032 [HSE-2001/088]
2. Appendix B, Principal Recommended Safety Systems 3. Appendix C, HSE Inspectors Checklists 4. Appendix D, Generic Safety Case Elements
Key Themes <u>Safety Cases and Reviews.</u> 2.2 considers the justification for the extended life of cranes, which should follow an assessment of the installation and maintenance records, here the report lists some of the documentation required: 1. Original design specifications 2. Operating history 3. Incident records 4. History of modification 5. Inspection and maintenance records 6. Fault analysis 2.2 states, *"Using the above information to determine the current condition of the crane, all the relevant life limiting mechanisms must be assessed such that a greater operating life may be justified"*. 2.3 looks at the reviews of the operations and categorisation of cranes, splitting the safety significance of each into 3 categories as follows: 1. Major safety significance 2. Minor safety significance 3. No safety significance 2.3.1 states, *"A review of the routine lifting operations of each crane should be presented which establishes the safety significance of each crane and its suitability for routine use for the duration of the proposed life extension validity period"*. 2.4 considers the duty holders responsibilities regarding the reviews. It lists the lifting operation review requirements and what should be covered: 1. Review the structural and mechanical integrity of the crane against current British Standards and other applicable regulations. 2. Assess the control, maintenance procedures and inspection associated with lifting operations. 3. Review the crane operating history to establish the effects of ageing and degradation. 4. Assess the protection provided against dropped loads, uncontrolled load lowering and related hazards such as collision, swinging loads and structural collapse that could occur as a consequence of lifting faults and operating errors.

Reference: A-032 [HSE-2001/088]
2.4.2 states, *"The safety case should give an overview of the operating history of Category 1 and 2 cranes and include a description of incidents which could have a significant influence on the integrity of the crane. Modifications which have been introduced to overcome operational faults or significant defects identified as a consequence of undertaking the tasks included in the Maintenance, Inspection and Test Schedule should also be described"*. Also listed here are different types of records to be reviewed. 2.4.4 states, *"The structural assessment to demonstrate adequacy of the crane integrity must include assumptions for the duty conditions during the proposed extended operating period, e.g. that the duty conditions will remain within the original design envelope.* Here it also considers the possible requirement of operation beyond the platform's operational life, during the decommissioning period. 2.5.1 states, *"Structures are generally designed to end of life criteria as a minimum. However, changes to the crane's load spectrum schedule and the maximum estimated dynamic loading resulting from faults must be assessed against the original design parameters. Where these parameters are shown to be exceeded, then an engineered change should be introduced by the Duty Holder, or a fitness of purpose case, supported by identified residual life monitoring techniques"*. 2.5.5 describes the QRA (Quantitative Risk Assessment) and the life stages at which this should be updated. It states here that *"the QRA should be an ongoing process throughout the life of an installation, as an integral part of its risk management"*. The life stages listed are as follows: 1. Feasibility studies and concept design 2. Detailed design 3. Operation 4. De-manning 2.6.1 states, *"Other than the supporting structure and the power supplies, the crane is considered to interface directly only with the load being lifted. The crane interfaces indirectly with safety critical plant/systems when lifting loads above, or in the vicinity of, such items with hydrocarbon inventories or plant safety protection. The potential hazards to safety critical plant/systems should have been identified in the safety case"*. 2.6.2 states, *"The Duty Holder's review of the crane design, manufacture, maintenance and operation should show how it compares to modern standards. If the crane does not meet modern standards then its acceptability for continued operation should be justified, possibly by a programme of improvements and/or demonstration of a "Fitness for Purpose" case should be submitted by the Duty Holder"*. 4.1 states, *"As part of the assessment for considering using a crane beyond its design life, the original codes, testing standards, etc., specified at the time of crane manufacture require to be reviewed to ascertain there were no shortcomings during the original supply of the crane"*. It continues by stating that *"This information should be supported with drawings, diagrams and schematics. The level of detail, the quality of drawings, etc, should be sufficient to support and facilitate understanding of the case demonstrating safety of load handling and the constraints in relation to the crane's intended use"*. Section 4 continues with a list of Duty holder responsibilities to the offshore regulations and contains 4.3 and 4.4 which list the relevant design codes and legislation. 6.2 states, *"By comparing the findings of periodic QRA and SMS reviews with the original design basis, the crane usage of design life can be determined. Where uncertainties exist concerning degradation or life*

Reference: A-032 [HSE-2001/088]

limiting factors, assessment of crane SLI lifting history recording facility and other condition monitoring records should have been undertaken by the Duty Holder.

Ageing and Degradation.

2.5.2 states, *"Physical ageing leads to a reduction in the safety margins of the crane and should be counteracted by a regime of detection, monitoring and mitigation to ensure that safety margins are not eroded to the extent that there is an increased risk to health and safety. Each mechanism as relevant to the safety critical areas of the crane, including the monitoring, inspection and maintenance systems in place to guard against future problems, should have been addressed in the Duty Holder's safety case to the appropriate detail".*

6.1 describes the bathtub curve and its stages, and states that *"the ageing and degradation mechanisms experienced by cranes vary in degree due to environment, usage, maintenance, etc".*

6.2 states, *"The maintenance and operating history of the crane must be presented and be examined in order to identify potential ageing and degradation mechanisms. The main physical mechanisms of ageing include fatigue, wear and corrosion, and for some materials embrittlement. Physical ageing leads to a reduction in the safety margins of the crane and should be counteracted by a regime of detection, monitoring and mitigation to ensure that safety margins are not eroded to the extent that there is an increased risk to Health and Safety".* The report also considers the faults which have not yet occurred towards the end of the equipment's life, it states, *"Inherent unrevealed faults should also be addressed in the crane safety case, and during the wear out phase of its life cycle, there is a greater propensity for unrevealed faults, particularly for second line of crane protection".*

6.4 considers the applicable aspects of ageing on cranes.

"The following aspects of the crane ageing and degradation specifically apply when using cranes beyond their design life:

1. Maintenance and operating history.
2. Physical ageing mechanisms; fatigue, creep, corrosion, erosion, brinelling, wear and failure due to vibration and seal leakage.
3. Detection and monitoring to ensure that safety margins are not eroded beyond agreed limits.
4. Integrity inspections in accordance with HSE Report OSD INS JM/010A, Crane Inspection Sheets.
5. Time elapsed between inspections based on perception of risk derived from the QRA and agreed by a competent person.
6. Crane usage of design life.
7. Evidence of wear in gearbox and bearings from debris and metal particles in oil and grease samples.
8. Fault condition dynamic loading.
9. Electrical insulation testing/earth leakage monitoring.
10. Drift in control and instrumentation calibration.

7.2 follows the theme from 6.4 regarding the applicable aspects of BDL on crane operation, here the report refers to the management controls.

Reference: A-032 [HSE-2001/088]

"The following aspects of management controls specifically apply when using cranes beyond their design life:

1. Procedures addressing how the operating and maintenance risks, identified by a QRA assessment, will be eliminated or adequately controlled
2. Offshore crane operator and banksman/slinger integrated safety operating procedures should be followed, an example of this type of procedure is that produced by Sparrow Offshore.
3. Pedestal crane essential features and guidance on lifting and crane operating procedures contained in HSE OSD Document OTO 096 041 'Technical Guidance - fixed cranes and lifting equipment'.

<u>OPEX.</u>

Section 8, Step Change Initiatives. This initiative was designed to improve safety by working to find best practice amongst the industry. The initiative included various working groups which are described in more detail in this section.

<u>EIMT.</u>

Section 5; *"This section discusses the beyond design life parameters that effect testing and inspection, and the issues that may lead to changes in the testing and inspection regimes currently in use. The testing and inspection regime to conform the current condition of the crane should have been described by the Duty Holder along with the effects of all identifiable ageing and degradation processes over the projected life extension period".*

"Projected changes in material properties and component wear–out processes over the projected life extension period should also have been considered by the Duty Holder".

5.2 considers the testing and inspection procedures, here the report lists what should have been considered when making changes to these:

1. The operating history should have been reviewed, particularly from the point of view of changes in the past (i.e. de-manning regime) and proposed changes in the future.
2. The maintenance, test and inspection history should also be reviewed, along with any proposed changes in the future. Availability of spares for ageing components should have been considered.
3. Non-standard operational events should have been reviewed (i.e. workovers etc), particularly with respect to trends.
4. Changes in design standards since construction should have been addressed, and an assessment should have been made of the consequences of any such changes.
5. Any potential for loss of integrity (i.e. safety critical component wear-out and/or fatigue limits) should have been identified and a demonstration provided that they are not being approached during the proposed extended life of the crane.
6. The original design calculations for the crane and other items in its load path should have identified the various component allowable life limiting stress and fatigue limits required by applied code. The actual life limiting parameters may, however, be determined by the worst postulated dynamic scenarios under the fault conditions identified by the hazard assessment which are not covered by code. Additionally, these dynamic conditions may also vary during the life of the crane due to changes introduced to the load spectrum schedule in regard to weight, size and frequency. These dynamic scenarios could take the

Reference: A-032 [HSE-2001/088]

crane beyond its design basis and require engineered protection or make downrating necessary before continued operation would be acceptable.

A reference to Appendix C is included, the appendix gives a checklist of the issues listed and includes areas which should have been covered by the duty holder.

6.2 states, *"The Duty Holder would be expected to provide a much increased level of surveillance towards the crane's 'wear out phase' at the approach of the end of the crane's design life".*

6.3 considers Condition Monitoring (CM) of the equipment and lists some of the failure mechanisms which can be found using a variety of CM techniques, also listed. It states here that *"The application of the above condition monitoring techniques has grown in importance over recent years to become central to the maintenance management function and the detection of the onset of component wear out beyond its safe limit. This provides, if adopted by the Duty Holder, an invaluable tool to loss prevention and monitoring of safety critical parameters in support of their crane life extension safety case".*

<u>Human Factors.</u>

Section 9 considers the human factor criteria for operating beyond the cranes design life. It states here that there are 3 significant areas which may arise from the beyond design life phase.

Area 1.

"The first of these areas is where, as part of the justification for beyond lifetime extension, the operating limits (envelope) for the crane have been changed from those in operation prior to the lifetime extension. This would give rise to a number of concerns:

1. *There must be clear communication/warnings/detailing of the changed operating limits for the crane, particularly for operators who have used the particular crane before and may have expectations based on the previous operating limits;*
2. *Where a particular crane will be used as part of a not normally manned installation, the risk of an operator attempting to operate the crane outside of its new operating limits is likely to be increased due to lack of familiarity and infrequency of use.*

Area 2.

"The second area where care needs to be taken is where a modification is made to the crane to allow continued operation beyond lifetime:

- *Communication of the modification status needs to be carefully managed to ensure that all maintainers and operators are aware of the modification and that all documentation is in place offshore to support changed maintenance or operating procedures.*

Area 3.

"Finally, there is the consideration of the effects of increased frequency of revealed and unrevealed faults which will be associated with the crane operation in the wear out phase. As the frequency of faults associated with the crane increases (even though they may not be critical), this may have an effect on the operator perception of a 'tolerable' level of background faults. Against this increased background 'noise' of faults, occasional critical faults may be missed. Similarly, there may be faults occurring that would not normally be seen by the maintainers and operators, and which they do not have the requisite experience to recognise or deal with".

Reference: A-032 [HSE-2001/088]
Section 9 suggests that as a way of countering the effects of the above issues there should be a programme of training in place for operators and maintainers. Also added here is the need for the correct level of expertise and detailed maintenance procedures.
Document Relationships & Referencing N/A
Applicability to Beyond Design Life Expectations Although specific to offshore platforms and cranes, this report shows the levels at which HSE inspectors operated in the early 2000's. The appendices included give a good indication to the types of questions asked of the duty holders regarding the operational and safety implications of BDL and the justifications required.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes Appendix C, HSE Inspectors Checklist, contains the following topics addressed by the checklist: 1. Policy/Objectives 2. Design, Manufacture and Testing 3. Management Procedures and Controls 4. Operating and Maintenance History 5. Structural and Mechanical Integrity 6. Protection Against Dropped Loads

Reference: A-033 [HSE-EEMUA-Pub231]
Document Title/Version Number: EEMUA Publication 231 - Ed 1 - The mechanical integrity of plant containing hazardous substances: A guide to periodic examination and testing.
Date of Issue: 2012
Summary: This document has been developed and written by the Safety Assessment Federation (SAFed) and the Engineering Equipment & Materials Users' Association (EEMUA) in consultation with the Health and Safety Executive’s (HSE) Hazardous Installations Directorate, together with other interested stakeholders who use such plant, including operators, inspection bodies (including ‘competent persons’) and providers of specialist services to the process. Regarding hazardous substances within pipework and vessels this document aims to provide guidance on managing the mechanical integrity of such equipment. This is a matter for the whole lifecycle, from original specification and design, through its operation to decommissioning. However, this guidance focuses on the issue of ensuring integrity through periodic examination and testing. This document contains 12 sections, they are: 1. Introduction 2. Overview of integrity management throughout the plant lifecycle 3. Legislative consideration 4. Examination policy 5. Organisational arrangements for integrity management 6. Written scheme of examination 7. Delivery of periodic examinations 8. Reporting of examinations 9. Post examination integrity assessment 10. Postponement of examination 11. Record keeping 12. Change, review and audit. This document has been reviewed as part of the Ageing and Degradation task (ONR376).
Key Themes <u>2; Overview of Integrity Management Throughout the Plant Lifecycle.</u> This section considers the original specifications, ensuring that these are correct and therefore suitable for the intended use, the design considerations and the operating lifecycle and history of the plant. Some lists

Reference: A-033 [HSE-EEMUA-Pub231]
of considerations for the early stages of the plant are included along with a diagram showing integrity throughout the plant lifecycle. <u>4; Examination Policy.</u> This section includes the objectives, types, strategies and techniques of examination. Parts of this referring to the degradation, have been included in the ONR376 task (Ageing and Degradation) specifically 4.3 and 4.4. This section refers to Section 6 of this document (Written Scheme of Examination) and also out to HSE RR509 (Plant ageing - management of equipment containing hazardous fluids or pressure). 4.1 states, "*It may be expected to monitor damage from known degradation mechanisms or it may be required to guard against or identify an unexpected degradation mechanism. A combination of both may be the aim. Alternatively, a one off examination may be required to provide information for a fitness for service assessment or to allow specification of a repair".* 4.4 refers to equipment age and states *"As the equipment gains service history, experience of degradation will increase. If degradation assumptions can be verified, including predictability of rates, and service conditions remain within limits, it may be justifiable to extend service periods. With further age, damage may begin to accumulate. Safety margins, such as corrosion allowance or remaining fatigue life, may reduce significantly".* <u>5; Organisational Arrangements for Integrity Management.</u> Section 5 considers the competence and conformity of the management and staff carrying out the inspection and testing of plant items. Here it refers to the British Standards for conformity assessments (BS EN ISO/IEC 17020). It also refers to an example of personnel required to carry out Non-destructive testing referring to their competencies being confirmed with a PCN certification and includes a reference to the relevant ISO standard (BS EN ISO 9712). Further quotes are included in the Ageing and Degradation review. Section 6 contains information on the Written Scheme of Examination (WSE), some of which has been referred to in ONR376. 6.2.6 states, *"it is essential to consider the modes of deterioration and this will help to clarify what damage might be present and, therefore, how to detect it. Additionally, it is necessary to consider the consequence of failure of an item, for example, how its failure might affect other plant in the area and this will clarify the significance of each type of deterioration".* <u>9; Post Examination Integrity Assessment.</u> 9.1; *"As part of the assessment, any deterioration identified during the examinations and tests should be considered. This may be within previously defined limits (e.g. corrosion allowance), and it would be considered acceptable to allow continued use. In other cases, further work is required. This process is often referred to as a Fitness for Service assessment or Engineering Criticality assessment and is a re-evaluation of the structural integrity of an item of equipment for further service. As a minimum for assessment of deterioration, rates of deterioration should be determined to substantiate that the equipment will remain safe to operate until the next inspection. Trending of deterioration following several inspections should be carried out e.g. corrosion rates, crack growth rates as this data can then be utilised to assist in the prediction of end of life when repairs/replacement of equipment will be necessary".* Reference is made to the HSE Plant Ageing (RR509). Referring back to section 6, 9.2 suggests that the post examination findings should be fed back into the WSE to aid with future examinations and direct efforts in the correct areas.

Reference: A-033 [HSE-EEMUA-Pub231]
9.3; looks at the assessment record and what should be included: 1. A clear and unambiguous statement as to the equipment's ongoing fitness for service 2. All deterioration is recorded 3. Prediction that current deterioration will remain within acceptable limits by the next inspection 4. When future examinations should be carried out. This will normally be a calendar date but may also include additional parameters such as running hours, operational cycles, changes in process etc 5. Any limitations to the equipment's use 6. A statement that the WSE continues to remain suitable or give details of any necessary changes required to the scheme 7. When the equipment is not considered suitable for further service then details of required repairs should be included. <u>Section 11, Record keeping.</u> *"As part of an integrity management system it is necessary for the operator to keep accurate, timely records, this ensures that decisions about the specific integrity of an individual piece of equipment can be easily traced and justified".* These records would be expected to contain the following: 1. Documentation confirming the safe operating limit of the equipment, i.e. original declaration of conformity or certification 2. Manufacturing information such as Databook including material information, welding information, testing information etc 3. Details of the normal maintenance routine including reports of such 4. Any reports of inspection/examination testing 5. Information pertaining to any repairs/modifications that have been carried out. (see point b) above) 6. The WSE, including records of amendments 7. Any information pertaining to any postponements etc 8. Details of the operating conditions and the operating history of the item, i.e. how long has it been on certain duty, what duty was it on previously etc 9. Any associated risk assessments, periodic reviews, ageing plant reviews etc 10. Any other reports which contain information relevant to the assessment of safety. <u>Section 12, Change, review and audit.</u> During the life of a plant it will see many changes, some of which will affect the integrity management strategy for that individual item, a list of some possible changes is noted below:

Reference: A-033 [HSE-EEMUA-Pub231]
1. A serious process or operational upset 2. Failure of an item of equipment 3. Operational regime 4. Internal or external operating environment 5. Where time dependant operating conditions exist such as fatigue or creep 6. Industry practice 7. Plant management or ownership 8. Level of operator training and knowledge 9. Technology. 12.3; suggests that a high level review of integrity management should be conducted to ensure that the information used as a basis for decisions is still valid. A formal record of this review should be kept. 12.4; considers an independent audit of the integrity management and suggests that this should establish the following: 1. The process exists 2. The process is properly designed 3. The process meets its objectives The audit reports should be formally recorded and acted upon should any non-conformance be identified.
Document Relationships & Referencing This document contains several references to HSE RR509 (Plant ageing - Management of equipment containing hazardous fluids or pressure), which has been reviewed as part of this phase of the project.
Applicability to Beyond Design Life Expectations This publication considers the types of internal assessments and audits required to substantiate a beyond design life claim. The examples within this publication direct the organisation through the WSE requirements via the integrity assessment and provides a good list of what should be included in an assessment.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes Lifecycle integrity management overview diagram (p10).

Reference: A-034 [HSE-073]
Document Title/Version Number: Guidance on the Management of Ageing and Life Extension for UKCS Oil and Gas Installations
Date of Issue: April 2012
Summary: This guidance is applicable to the management of aging and life extension in relation to all structures, topside plant and equipment associated with offshore production installations. Many of the principles set out in this guidance are likely to be transferable to on shore major hazard sites. This guidance is designed to inform duty holders, involved in the management of asset life cycles, about management systems in respects to asset ageing and life extension factors. This document is split into the following sections: 1. Introduction. 2. Systematic approach to effective management of ageing and life extension. 3. Organisational factors. 4. Planning and implementation. 5. Monitoring, audit and review.
Key Themes <ins>*Organisational Factors.*</ins> <ins>Training and Competence (p.9)</ins> The guide considers the competency and responsibilities of the personnel in respect to demonstratable knowledge of ageing mechanisms. The guidance here states, *"Basic professional and technical competence should be supplemented where necessary with training in the management of ageing"*. Updates to standards, knowledge and technology must be taken into account when reviewing competency levels, the organisation should ensure that these levels are current. <ins>Staff turnover, succession planning and corporate knowledge retention (p.10)</ins>. This part of the guide suggests that planning for the transfer or turnover of staff should be in place to ensure that the skills and knowledge are not lost. Regarding key roles within the organisation the guide states, *"the duty holder should identify all ALE sensitive positions and develop candidate selection criteria for the key integrity assurance positions with effective handover process".* <ins>*Planning and Implementation.*</ins> <ins>Management Systems (p.11).</ins> Existing systems and processes should be reviewed, and the duty holder should address any shortfalls in the systems and ensure that any ALE factors are included where necessary.

Reference: A-034 [HSE-073]
<u>Design and procurement (p.11).</u> This section lists the ALE considerations in relation to management and EIMT. Design; *"in relation to the management of ageing and life extension, the following aspect require attention":* 1. The original design should be aligned with the anticipated service life 2. The design documentation will show the engineers the key requirements and design assumptions 3. The design documentation must be controlled to ensure it is the latest version 4. The design documentation should be reviewed and endorsed by the relevant technical authorities 5. The design documentation should be readily accessible 6. The design documentation should be subject to audit and review Procurement; This should be *"aligned with the anticipated service life of asset and associated EIM&T to ensure that ALE considerations address the following":* 1. Ensuring, as far as possible, that the items have a service life and support commitment 2. Identify and respond appropriately to potential obsolescence issues 3. Support effective ongoing EIMT including repair or replacement 4. Spares management 5. Vendor sharing of lessons learned and upgrade proposals <u>Management of Change (p.12).</u> This section looks at the effective management of ALE and the effects of changes to ALE plans. A list of 'prompts' are provided for duty holders to aid the identification of ALE related changes, some examples of these are: 1. Recognising ageing and obsolescence as a trigger for change at any stage of life 2. Changing the Cessation of Production (CoP) date or extending life 3. Modifications 4. Operating standards/procedures 5. Spares management 6. Succession planning 7. Competency/training requirements 8. Safety case reviews A list of guidance for the planning of ALE is provided: 1. Long term planning

Reference: A-034 [HSE-073]

2. Identification of ALE issues by assessing performance history and reviewing asset documentation
3. Use Gap analysis to identify ALE issues
4. Develop the ALE scope
5. Assess the ALE costs and asset economics
6. Review options
7. Implement ALE plan

Inspection, test and maintenance regimes (p.15).

The guide states, *"the management of inspection, testing and maintenance has to be a continual learning process that targets the degradation mechanisms that will affect plant and equipment and an assets Safety Critical Elements (SCEs) and their sub-systems and components. The process should anticipate, assess and respond to degradation risks…to an asset so that deterioration is detected and addressed before failure can occur"*. The guide suggests an EIMT process that would support this, this process must have:

1. An asset register
2. An assessment of the asset register (integrity risk assessment)
3. An EIMT programme
4. Planning and Scheduling
5. Task implementation based on work plans and instructions
6. Reporting process for results and defects
7. Corrective maintenance and defect assessments
8. An EIMT review
9. Asset improvement based on the EIMT review

Information management (p.19).

The guide considers the availability, quality, accuracy and complete records of asset history throughout the lifecycle to be *"a key component of effective integrity management"*.

Acquisition and divestment (p.20)

The acquisition/divestment process of offshore assets helps to realise the need for asset life cycle management within the selling business. The requirement of due diligence from the buyer promotes the need for evidence of the asset's integrity. Some examples of these requirements by the purchasing organisation are listed in this section.

Safety Case and Thorough review (p.20).

This section refers to the Offshore Safety Case Regulations 2005 and an HSE Information Sheet (no.4/2009). Here the guide states that the safety case review is a key process in evaluating the safe operation of the installation and this safety case should demonstrate that it will continue to operate safely until the projected end of life. *"This should involve the consideration of changes which may have occurred*

Reference: A-034 [HSE-073]

as a result of the ageing of the installation, and how these are related to the effective control of hazards, concerning fire and explosion, structural integrity, organisational and other ageing issues".

The thorough review should include details of the following:

1. The considered ageing issues
2. The impact of ageing issues on the risk analysis
3. Any extended life assessment or revision to the fire and explosion risk assessment
4. Changes to the management assessments accounting for ageing
5. Conclusions of the impact on the case for safety

<u>Anticipated service life (p.21)</u>.

The guide suggests that there are two ageing impacts on components which are:

1. Changing conditions
2. Operation beyond life

The two ageing considerations regarding a change to conditions are:

1. Environmental
2. Operational

"Component integrity should be re-evaluated against the new conditions to establish that it still meets currently acceptable standards in line with MOC" (Management Of Change).

It also states here that there are three options to consider for the management of ageing components, these are:

1. Replace the component at or before it reaches its design life
2. Repair or upgrade the component
3. Justify an extended service life using condition assessments and EIMT

<u>Obsolescence.</u>

"Obsolescence can be defined as structure, systems or components passing out of usefulness as a result of changes in knowledge, standards, technology or needs".

Obsolescence can result from any of the following:

1. Vendors will no longer support equipment
2. Vendors are out of business
3. Spare parts are no longer available
4. Upgrades made to software systems

Reference: A-034 [HSE-073]

5. Equipment functionality no longer meet industry requirements or standards

"Note that obsolescence should not necessarily be synonymous with age…where obsolescence issues are noted but no action is taken, it is important that the reason is documented and properly risk assessed".

Examples of acceptable actions are:

1. Replacement with suitable alternatives
2. Replace with a new component
3. Identify an alternative solution
4. Identify an operating mode which allows equipment to be used

Monitoring, Audit and Review.

Monitoring (p.23).

The guide gives some examples which *"will provide reasonable assurance that there is compliance with ALE management arrangements".*

1. Active line monitoring by site based supervisors/managers. Processes should be in place to encourage active monitoring and enable reporting.
2. Active monitoring from shore based positions such as technical authorities.
3. Monitoring by shore based management. Management should be conversant with ALE issues and be able to ask the right questions.
4. Regular monitoring of performance against key performance indicators.
5. Reactive monitoring in the form of investigation of incidents. Investigations should identify ALE related root causes so that effective longer improvement actions are identified.

Audit (p.24).

Audits should be implemented as part of an internal assurance process. Such audits could be used to; assess compliance with ALE management processes, assess third parties who could influence ALE (suppliers etc.), and assess internal management processes by an external party.

Review (p.24).

The review should provide an overview of ALE management processes and identify areas of improvement and raise senior management's awareness of ALE issues and challenges.

Action management systems (p.24).

These systems should be used to track any actions arising from the monitoring, audits and reviews and ensure that the activities *"are recorded, documented and tracked to closure"*.

Lessons learned (p.24).

Reference: A-034 [HSE-073]
A final brief statement within this guide states, *"ALE related lessons learned from assurance activities or from incidents should be captured and communicated within the duty holder organisation and across the wider industry as necessary"*.
Document Relationships & Referencing This guidance refers to the Offshore Safety Case Regulations, specifically Section 13 (thorough review of the safety case). Also noted is the HSE offshore information sheet No. 4/2009.
Applicability to Beyond Design Life Expectations This document is aimed at offshore installations; however, could be used to help guide onshore facilities plan and review the effectiveness of their ageing management programmes. This does not add any new themes or considerations beyond that of the other HSE Report series documents.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes HSE offshore information sheet No. 4/2009 could be worth review as part of this project.

Reference: A-035 [HSE-KP4]
Document Title/Version Number: Ageing and life Extension Programme – Key Programme 4.
Date of Issue: 2013

Summary:

This is a report of the inspection findings of the Health and Safety Executive's (HSE's) Energy Division's (ED's) Key Programme 4 (KP4) covering the ageing and life extension (ALE) challenges facing hydrocarbon exploration and production installations on the UK's Continental Shelf (UKCS). The programme investigated the impact of ALE on the risk of major accidents involving the death or serious personal injury to people on an offshore installation.

HSE's KP4 ALE programme was initiated in 2010 and followed the KP3 Asset Integrity Management (AIM) programme which reported in 2007 (www.hse.gov.uk/offshore/kp3.pdf).

KP4 findings.

"The KP4 programme found a range of areas where ALE management was developing well, and areas where extra focus is required. From the programme, a number of illustrative case studies were developed by duty holders to elaborate good practices, which can be found in the Appendix".

Examples of KP4 findings:

1. Some Safety Critical Elements (SCE)/Safety Related Equipment (SRE) lists and engineering drawings needed updating
2. More focus is required on forecasting potential failure mechanisms
3. Not enough ALE consideration at the component level
4. Evidence of missing data and insufficient data trending
5. Audits were generally to follow previous rather than addressing future needs
6. Insufficient use of data for forecasting equipment failure

Within the executive summary, this report recognises that the *"management of ageing requires a good understanding of the condition of safety critical elements (SCEs), how that condition is changing over time, and carrying out maintenance in a timely manner to minimise risk of major accidents. There is evidence that installation age is not necessarily a reliable indicator of condition or likelihood of hydrocarbon leak frequency. Management of life extension requires the advanced, and continuing, assessment of SCEs to ensure they are fit for purpose, and safe to use when required to operate longer than their anticipated service, with particular consideration for primary structures".*

The inspections for KP4 were broken down into 10 topics:

1. Safety management systems
2. Structural integrity
3. Process integrity

Reference: A-035 [HSE-KP4]
4. Fire and explosion 5. Mechanical integrity 6. Electrical, control and instrumentation 7. Marine integrity 8. Pipelines 9. Corrosion 10. Human factors Each of the above topics included an introduction, current strengths and areas for additional focus. The report structure is as follows: 1. Introduction 2. Topic findings 3. Discussion 4. Recommendations 5. Appendix (Case studies)
Key Themes Section 2, Topic findings. Safety Management Systems (SMS). Areas for additional focus: 1. Safety Critical Elements (SCE) performance data should be trended to forecast when they are likely to reach their criteria of non-conformance, so that mitigating programmes are put into place in a timely manner. 2. more needs to be done to ensure there is adequate succession planning to capture knowledge from the experienced specialist workforce, to ensure awareness of legacy issues, and pass on knowledge to new entrants. Structural Integrity. *"Structural analyses for life extension should commence sufficiently early to allow for the size and complexity of the primary structure".* Areas for additional focus: 1. The assessment, inspection and maintenance regimes should reflect operational experience, with the potential for data trending and extrapolation to forecast when the future criteria of non-conformance will be met. To assist this process there should be a reassessment of the current and potential future

Reference: A-035 [HSE-KP4]

failure and deterioration mechanisms, and a reassessment of the barriers to failure to ensure they are suitable for ageing structures, and the anticipated remaining life of the installation.

2. Structural integrity management ALE policies could be developed further to include the identification of potential failure and deterioration mechanisms, and the identification and reassessment of barriers to failure to ensure they are suitable for ageing structures and the anticipated remaining life of the installation.

Process Integrity.

"Process integrity management involves preventing the uncontrolled loss of containment of hydrocarbons, which may result in a fire and/or explosion. For ALE, the process integrity system should anticipate future risks, and consequences of the loss of containment, and put plans into place at an early stage to ensure risks are ALARP".

References are made to two case studies in the appendix, case studies 2 and 4 for ALE management examples.

Areas for additional focus:

1. The offshore industry uses operational risk assessments (ORAs) to assess and manage the risks associated with degraded SCEs/barriers, until they can be repaired. Duty holders should minimise the number of ORAs by putting into place long-term repair and maintenance strategies, and where an SCE has more than one ORA, the consequences should be considered in combination to ensure they do not unduly increase the risks to the installation.

2. ORAs in place for extended periods should be regularly reviewed to ensure they remain fit for purpose, do not cause creeping changes ('normalisation of deviance'), and do not adversely affect the long term integrity of the asset.

3. Staff performing ORAs should be suitably trained to ensure they are competent.

Fire and explosion.

Regarding an effective fire management system this reports states, *"The system should anticipate the degradation and obsolescence issues of monitoring and shut down equipment, and trend degradation data with a view to forecasting when they will reach their criteria of non-conformance, and put early measures into place to manage risks to ALARP".*

Areas for additional focus:

1. To guarantee availability of firewater at times of need, there must be reduced reliance on defined life repairs. To overcome compromised integrity there should be greater forward planning to ensure pipework is managed to minimise corrosion, perhaps by chemical treatments.

2. Performance data should be trended to avoid 'fix on fault' maintenance of gas detection and emergency shutdown equipment, to ensure long-term risks are predicted and proactively managed.

Mechanical Integrity.

"Effective ALE management of mechanical equipment requires a comprehensive equipment list with PMRs (Planned Maintenance Routines) *in place, which consider long-term degradation risks and obsolescence".*

Pipelines.

Reference: A-035 [HSE-KP4]

"A suitable pipelines ALE management system would include long-term prediction of likely degradation mechanisms and their rates. The inspection programmes, including in-line intelligent inspection pigging, should be designed to reflect the predicted analysis combined with historical data".

Areas for additional focus:

1. Duty holders should formally reassess the basis for continued safe operation before a pipeline reaches its planned service life, and for those lines already beyond this point, reassessment is recommended.
2. While it is recognised the offshore hydrocarbon industry has developed sophisticated corrosion modelling programmes to forecast degradation rates, they should be validated at suitable intervals with non-destructive testing data and in-line inspections tools. This will enable more accurate estimates of when pipelines are likely to meet their criteria of non-conformance, and so enable timely proactive maintenance.

<u>Corrosion.</u>

"A good corrosion ALE management programme considers future reservoir profiles and the effects the changing fluid properties will have on topsides corrosivity".

Areas for additional focus:

1. To fully assess the corrosion risks there should be complete lists of equipment and lines, with up-to-date engineering drawings and isometrics.
2. To monitor degradation and prevent future failures there needs to be further development of non-destructive testing equipment to improve accuracy in specific areas such as corrosion under pipe supports, under insulation, and of nuts and bolts.

<u>Human factors.</u>

"To manage health and safety effectively it is important to consider how the work environment influences human behaviour. For ALE, this means a need to better understand how current organisations could affect future health and safety management, and in particular, the indicators of what may potentially be a major accident, so they are addressed in a timely manner and have effective responses to prevent escalation".

Areas for additional focus:

1. KP4 found that while there is consideration of how the 'system' can harm the person, there is a need to consider in more detail how the person can harm the system.
2. Offshore staffing levels should be commensurate with the current high workloads, with some additional flexibility for peak periods.

<u>Section 3, Discussion.</u>

In this section the discussion is broken down into various identified issues, each of these were given recommendations for long term safety management.

<u>Asset integrity management.</u>

For long-term safety management, industry should:

1. maintain SCEs to cessation of production, with primary structures fit for purpose to the time of removal;

Reference: A-035 [HSE-KP4]
2. ensure SCE information is complete; 3. consider risk-based assessment of rotating machinery; 4. trend data to forecast long-term asset integrity management; 5. continue to develop non-destructive testing accuracy. <u>Obsolescence management.</u> *“Managing obsolescence effectively ensures greater reliability and availability of SCEs”.* *“Industry ALE guidance is needed to help decision making for when to repair, replace, or purchase extra spares in anticipation of when vendors will cease support. There should also be improved interaction between suppliers and end users to anticipate obsolescence and generate solutions in a timely manner”.* *“To develop obsolescence management, duty holders should improve data trend analysis of equipment performance so that future repair and replacement requirements can be identified and resolved early”.* For long-term safety management industry should: 1. identify and manage obsolescence in a timely manner; 2. work together to improve prediction and develop solutions; 3. use data trending to improve equipment performance prediction. <u>Data management and trending.</u> This section was reviewed as part of ONR task 376 (Ageing and Degradation). <u>Skills, training and competence.</u> *“Competent onshore and offshore staff are essential for a safe offshore industry, and duty holders spend considerable sums on training. However, the current and future skills shortages need to be resolved to overcome some of the current and future upgrade projects if ALE is to be managed successfully to cessation of production of UKCS installations”.* <u>Workforce involvement.</u> For long-term safety management, industry should continue to use the skills of the offshore workers to gather information, feedback improvements, contribute to guidance, and to promote the importance of ALE. <u>Decommissioning.</u> *“Duty holders should link ALE management with decommissioning. Ageing equipment can become redundant or obsolete as processing requirements change, and of course, fabric maintenance is an ongoing requirement. Early, targeted, expenditure to achieve long-term benefits while revenues are relatively healthy will reap safety and business rewards when fields become marginal towards the end of field life”.* For long-term safety management industry should encourage ALE teams to interact more closely with decommissioning teams to get the best benefit for offshore safety through cessation of production to removal of the asset from the sea.

Reference: A-035 [HSE-KP4]
Section 4, Recommendations. Individual theme recommendations from this section have been reviewed as part of ONR task 376 (Ageing and Degradation). Industry recommendations from this report are: 1. Continue promoting industry-leading ALE management practices. 2. Develop and encourage a corporate culture which embeds an ALE philosophy into AIM for the long-term future. 3. Improve focus on obsolescence management. 4. Early preparation for life extension will enable the identification of key issues to be managed to assure continued safe operation. 5. Incorporate decommissioning into ALE management. 6. Develop leading ALE KPIs to help prevent future loss of integrity. 7. Undertake periodic ALE management audits. 8. Improve data management, e.g. maintaining complete SCE and SRE lists, and contemporaneous engineering drawings. 9. Improve data trend analysis. 10. Further promote workforce involvement through Step Change in Safety. 11. Further develop approaches to encourage and train people with the required skills to join, and remain in, the oil and gas industry.
Document Relationships & Referencing This report was also reviewed as part of the ONR376 task on Ageing and Degradation. Reference is given to the HSE document RR509, reviewed as part of this phase of the project (Ref: A-038).
Applicability to Beyond Design Life Expectations N/A
Applicability to the ONR SAPs Other than those discussed in ONR376, no other considerations within this document add anything new to the SAPs.
Future Considerations N/A
Additional Notes N/A

Reference: A-038 [HSE-RR509]
Document Title/Version Number: Plant Ageing: Management of Equipment Containing Hazardous Fluids or Pressure.
Date of Issue: 2006

Summary:

The purpose of this report is to increase awareness of the factors to consider when managing equipment containing hazardous fluids or pressure, and to help those responsible for equipment to understand and assess the risks of accumulated damage and deterioration. The information is at a general rather than an equipment-specific level and can be applied to a wide range of static equipment and associated machinery.

The management of equipment begins with an awareness that ageing is not about how old the equipment is, but is about what is known about its condition, and the factors that influence the onset, evolution and mitigation of its degradation. Once the symptoms of ageing are understood, and detected from inspection, a decision can be made how to proceed. The options can include putting together a case to justify continued service, re-rating, repair, or scrapping the equipment.

This document contains the following 4 sections:

1. Awareness of Ageing
2. Getting Organised for Managing Ageing
3. Identification of Ageing
4. Addressing Ageing

Also included in this document are 4 appendices:

1. Process Map and Audit Tool
2. Case Studies
3. General Approach to Inspection and a Process Map
4. Capabilities and Limitations of Various NDT Methods

The aims of this report are to:

1. Improve the management of your organisation and people for ageing equipment.
2. Highlight indicators and risk factors to enable you to identify the risk of ageing.
3. Help you plan maintenance and inspection of your equipment with the appropriate techniques, procedures and periodicity and to record what has been done.
4. Explain non-destructive testing techniques that can enable you to measure and assess the effects and rate of ageing, and hence determine safe operating limits, and appropriate monitoring measures.
5. Assist you in assessing the remaining safe life of equipment, for example, in cyclic service, in corrosive environments, or if ageing damage is found.
6. Provide information and practical examples through case studies on the organisation, management and human factors involved in ensuring safety of ageing equipment.

Reference: A-038 [HSE-RR509]
7. Provide an audit tool for you to determine whether the standards of managing ageing equipment are adequate.

Key Themes

Responsibilities.

2.1.2; Operators, Maintainers and Supervisors.

Depending on the nature of the equipment and the hazards of the products being contained, the role of operators, maintainers and supervisors in respect of the management of ageing includes some or all of the following:

1. Communicating within the management hierarchy (both up and down)
2. Control of equipment
    d. Keeping an asset register
    e. Backing up of data
    f. Auditing of equipment data
3. Production of equipment condition indicators
    a. Collating operational data
    b. Reporting failures including Root Causes
    c. Reviewing current inspection techniques
4. Reviewing comparative equipment performance
    a. Comparing items
    b. Trending data
    c. Analysis of changes
5. Setting of requirements for inspection and maintenance
    a. Agreeing qualifications and experience required for tasks
6. Verification of inspection and maintenance
    a. Assessing and ensuring competency and training
    b. Periodic review of maintenance records

Strategy.

2.3.2; Structural Integrity Management Plan (SIM).

Elements to be considered for a SIM:

1. The original design assessment and design life.

Reference: A-038 [HSE-RR509]
2. Operating limits and instructions. 3. Maintenance policy document and equipment schedules. 4. Inspection policy and schemes of examination. 5. Fitness-for-service assessment and revalidation. 6. Repairs, modifications and replacements procedures. 7. On-line and periodic condition monitoring. 8. Equipment retirement policy. 2.3.4; Examination, Inspection and NDT Policy. *"Unnecessary inspection can be detrimental if it involves opening or disturbing equipment or allowing in corrosive media. It can increase the risk of future failures (e.g. by damaging lagging, protective coatings and flanged joints). Incorrect application of NDT or inappropriate selection of inspection areas can produce a false sense of security by reporting no damage in the areas inspected, whereas damage may have occurred, or damage elsewhere may be missed. Inspection affects production and is usually labour-intensive and can therefore be a significant cost".* 2.3.6; Strategies for Machinery. Two types of strategy are listed: 1. Time-based 2. Condition based *"It states here that the control of the adverse effects of ageing of mechanisms is an important element in integrity management".* 2.3.7 states, *"Degradation of equipment is usually strongly linked to the process operating conditions in terms of the environment, loads and duty. Process control is therefore an important part of the equipment management strategy. Its aims are to ensure that equipment operates within its safe operating limits, while optimizing performance and minimising degradation, and it is a key instrument to prolonging equipment life… In many cases during fitness-for-service assessment where damage has been detected, it has become clear that changes in operation increased degradation rates or introduced mechanisms that were not considered at design. Small changes that may not have been significant, as individual steps (e.g. small temperature changes, modified flush systems) became important over extended operation".* <u>Record Keeping.</u> 2.4; Systems for knowledge management and retention. This part considers the importance of an asset register, an equipment record and maintenance log and suggestions for dealing with backlogs and postponements. 2.4.2 states, *"The record system should contain full details about the equipment. Design and manufacturing information should include design drawings, material mill and test certificates, welding and NDT specifications and reports, installation and commissioning tests, and quality assurance documents.*

Reference: A-038 [HSE-RR509]
Regarding the maintenance log the report suggests that records of repairs and modifications recorded in date order need to be accessible and difficult to erase. It goes on to say that *“There is a need to have an understanding of the frequency and effect of past maintenance and repairs to help set priorities. This will allow a focus on the actions that most contribute to sustaining equipment integrity”.* 2.4.5 looks at the management of changes in duty and modifications. Here it states, *“As each piece of equipment is utilised, it is useful to record regularly on the maintenance log the duty and time of service, and when equipment is removed from service for maintenance and examination…This information will be useful in determining potential deterioration mechanisms…”* Regarding the modifications it states, *“There is a need for proper specifications of repairs and a record of changes in the equipment as a result of the repairs”.* <u>Obsolescence.</u> 2.4.9 states, *“Contingency planning can save time when obsolete equipment needs to be repaired or replaced. Some manufacturing processes are simply not used any more, and there are frequently great difficulties with defining how to repair such an item. There may be no relevant modern design code, although the original code of construction may provide some guidance”.* <u>Ageing and Degradation.</u> 3.1.1; The manner of operation, maintenance, inspection and repairs can strongly influence the rate of degradation. Invasive work can introduce contaminants into the system, and increase the rate of degradation, both temporarily and in the longer term. Appropriate inspection, maintenance and repairs of damaged areas can reduce both the amount and rate of damage, while unnecessary work has little gain. 3.1.3; describes the 4 stages of equipment life as: 1. Post Commissioning *“Typical faults include incorrect dimensions, faulty material, welding procedures and fabrication defects that have not been identified from manufacturing NDT, or the effect of loads and environments that were not foreseen. Under these circumstances, rapid degradation of the equipment early in life is possible and it can progress quickly through the different Stages”.* 2. Risk Based *“Examination and inspection, maintenance and NDT are generally to confirm the basis for these assumptions, and their scope and periodicity can be risk-based”.* 3. Deterministic *“A more proactive approach to equipment management, inspection and NDT is required. Design margins may be eroded and the emphasis shifts towards fitness-for-service and remnant life assessment of specific damaged areas”.* 4. Monitored *“by Stage 4 no guarantees can be made about future service life beyond the next examination”.* 3.2.2; different types of ageing mechanisms are described here, including a note directing the reader to the types of NDT which are located in table 5 and appendix 4 of this document.

Reference: A-038 [HSE-RR509]
Section 3, Indicators of Ageing. 3.3.1; Two tables are shown here: Table 2a; Indicators or symptoms of ageing Table 2b; Risk factors for ageing 3.3.2; considers the inputs into the indicators and risk factors, here the report suggests areas where key data should be gathered: 1. Manufacturing data 2. Service data 3. Competence and management data 4. Absence of information Table 4 shows the factors which promote premature/accelerated ageing. 3.4; considers the NDT inspection approaches and refers back to the stages listed above (3.1.3). Table 6 shows the NDT methods and inspection techniques used for the degradation mechanisms. 4.2; this part looks at the fitness for service (FFS) and remnant life and states, *“When damage is detected in service, the actual scale of the damage as measured from NDT can be used. The rate of damage accumulation may be estimated from measurements repeated over a period of time but be aware that historic trends are not always a good indication of future behaviour. At all stages, the objectives of carrying out an FFS assessment are to determine whether the equipment is safe in its current condition, and if so, what is its predicted lifetime given that further damage may occur, and to install a suitable inspection and monitoring programme”.* *“If an FFS assessment has been carried out in the past, it is important to consider whether the results are still valid. It may be that the assessment procedure used previously has been revised or superseded, so that the same assessment carried out to current standards might give different results” … “although the recommendations of the original assessment would have been valid at the time, they may no longer be justifiable, even if none of the operating conditions have changed”.* 4.2.2 lists some of the key factors for assessing the remnant life, these have been listed in the previous review (ONR376, Ageing and Degradation). There is also a figure shown with the types of data required for FFS assessments (Fig. 7). This part concludes with more detail on the assessment of specific faults and tables listing the techniques for obtaining FFS data, Semi-destructive tests of material and testing methods for FFS data. 4.3: describes the repair and modification of equipment during service and the consideration of revalidation of that equipment once the changes have been made. (Revalidation – 4.4). The report also considers the alternative option to repair, De-rating, and recommends that the organisation take account of the following: 1. The original design specification 2. The system duty after the repair 3. The effects the repair will have on the integrity of the system

Reference: A-038 [HSE-RR509]

4. The protective devices remain adequate
5. The written scheme examination remains suitable
6. If welding is required, would this create a hazard to live plant

Revalidation.

4.4; this part of section 4 discusses the considerations and requirements for revalidation of equipment post modifications or changes in operational conditions etc. Figure 8 shows some of the key considerations for revalidation.

4.4.2 states, *"Even though the modification/repair may comply with the design codes, consideration is needed of the effect of the change on structural integrity, and on flow and temperature distributions"*.

Following and modifications or repairs the maintenance logs/records should be amended, a list of recommended record contents is shown:

1. A reference number and drawing of the completed modification/repair.
2. The design code and construction category used.
3. Design loads (including local, cyclic, dead and imposed, dynamic and wind loading).
4. The calculated design stress, minimum thickness, corrosion allowance.
5. Pressure-temperature combinations for which the modification/repair is suitable.
6. Materials of construction including supports, attachments and gaskets.
7. Heat treatment charts.
8. NDT reports.
9. Quality assurance documents (e.g. welder approvals, weld procedures etc.).

This report continues with the theme of revalidation and considers the effects of change in operating conditions regarding temperature, pressure and load.

OPEX.

4.4.11; this part of section 4 considers the industry experience which is gained over time and the ways in which this information is disseminated. It states, *"Organisations are encouraged to keep up to date with current practises and codes, and to participate in research, development and information sharing via organisations such as:*

1. Institution of Mechanical Engineers (Pressure Systems Group and Process Industries Division)
2. Institution of Chemical Engineers.
3. Institution of Plant Engineers.
4. British Institute for NDT.
5. The Welding Institute.

Reference: A-038 [HSE-RR509]

6. Institute of Materials, Minerals and Mining.
7. The Energy Institute.
8. Engineering Equipment and Materials Users' Association.
9. Safety Assessment Federation.
10. Health and Safety Executive.
11. UK Offshore Operators Association etc".

<u>Operational Programmes.</u>

4.5, Review of Schemes and Condition Monitoring.

4.5.1; scheme review states, *"The Duty Holder for the equipment should therefore ensure that the scheme is reviewed by a competent person on a regular basis throughout the lifetime of the plant".*

Regarding the responsibilities of the competent person, the report suggests that in addition to carrying out any examinations, they should recommend and implement adjustments to the existing scheme and use a risk-based approach taking into account indicators of deterioration. It also states, *"The Competent Person will take account of factors that could lead to a modification to the nature, extent or frequency of examination, such as recognition of a previously unsuspected potential mechanism, or a change in the operating conditions or contents of the system".*

4.5.3 and 4.5.4 consider the nature and frequency of examinations. They state here that *"The use of diverse techniques and repeat inspection using multiple NDT operators are considerations if higher inspection reliability is required"* and *"As the ageing process progresses and accelerates, it would be expected that the periodicity between examinations would decrease to reflect the increase and uncertainty in the damage rate".*

4.5.5; Condition Monitoring, here the report considers the types of condition monitoring and splits it into two groups, Periodic/Sampling and Continuous. It states, *"If the rate of ageing is to be determined accurately from condition monitoring, it is essential that the same set-up parameters are used from examination-to-examination".*

<u>Economic Optimisation.</u>

4.6.1 states, *"Unplanned or forced shutdowns have financial consequences in terms of lost production, while explosions, fires and releases can cause major plant damage, casualties and off-site consequences that can significantly damage a company's liability, reputation and sales".*

Regarding the cost to risk optimisation it states, *"Excluding initial purchase and direct operating costs, the main costs that have to be considered are:*

1. The costs of inspection, maintenance and repairs.
2. The expected value of the cost consequences of failure.
3. The cost of replacement".

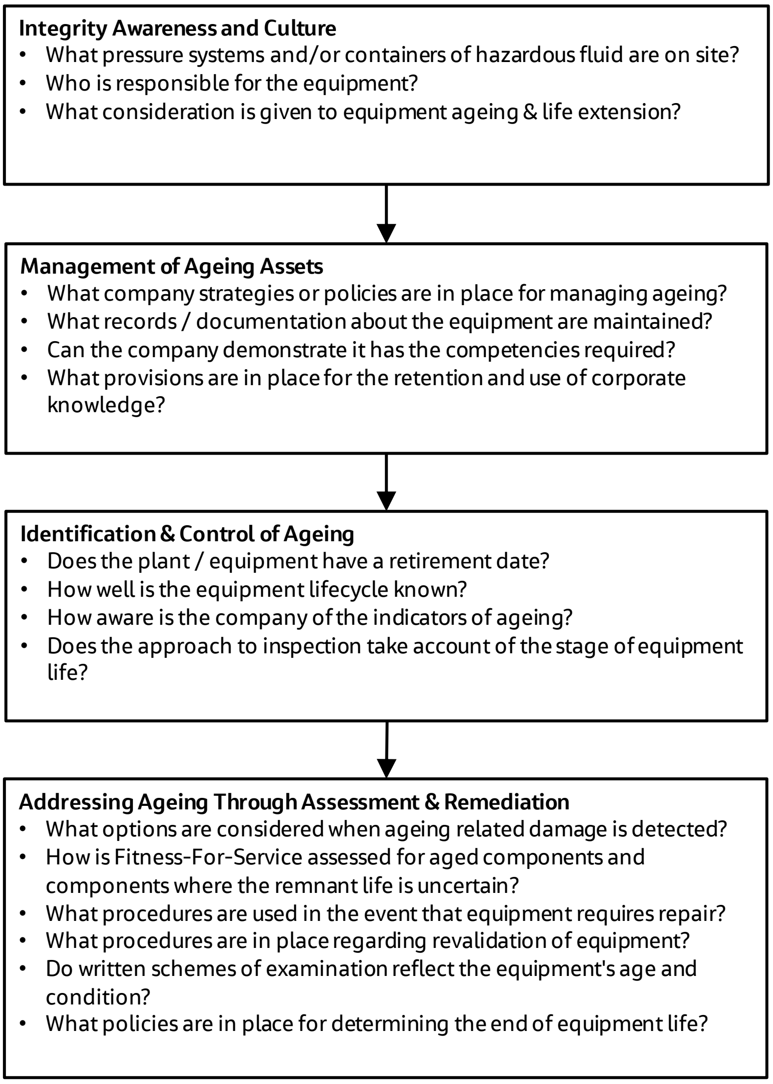
When considering the optimisation of inspection, maintenance and repairs it states, *"Without adequate IMR, the failure probability will undoubtedly increase as ageing and wear-out take place. Good practice is to invest*

Reference: A-038 [HSE-RR509]

sufficiently in IMR so as to keep this probability under control. The costs of running equipment therefore usually rise at an increasing rate".

<u>Audit Tool</u>

The Process Map & Audit Tool presented in Appendix 1 provides a simple approach to some key aspects of ageing management, which are covered in the text above. This figure is presented below.



While this figure may not be directly applicable to civil nuclear plants, there is merit in considering something like this for other nuclear facilities where the consequences of equipment failure of hazardous fluids or pressure are as significant (if not more so) as a failure nuclear related equipment.

Document Relationships & Referencing

There are direct links between this report and RR912 (Management of Ageing), where it is stated that these two documents should be cross-referenced.

Reference: A-038 [HSE-RR509]
Applicability to Beyond Design Life Expectations This document dates back to the mid 2000's and although there are some details within this document that are relevant to an organisation considering long term operation, many other bodies such as the IAEA have since completed SALTO reviews and programmes to build on these ideas and the understanding of ageing and degradation.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes The Audit Tool found in Appendix 1 may be of interest as this lists the type of questions which should be asked of an organisation regarding their ageing programme and practices.

Reference: A-039 [HSE-RR823-Phase1]
Document Title/Version Number: Plant Ageing Study - Phase 1 Report
Date of Issue: 2010

Summary:

Onshore chemical plant in the UK is ageing. Health and Safety Executive (HSE) field inspectors often have to consider the Operators' safety justification for continued use of ageing plant taking account of a variety of issues such as usage, design life, known research, known operational and failure history, maintenance and inspection history, etc. The issues also need to be considered against a background of increasing competition from overseas, and the pressure on resources and investment which this has had over recent years, with reductions in manning levels, early retirement of experienced staff, and pressure on operating budgets.

The HSE have commissioned this study with the objectives to:

1. Identify whether or not ageing is an issue contributing to plant HSE performance.
2. Determine which types of assets are affected and in what way.
3. Define “ageing” in general terms and, if appropriate, for specific asset types.
4. Establish ways in which HSE inspectors can identify ageing issues on sites.
5. Identify risks associated with plant ageing.
6. Identify best practices in management of ageing issues.
7. Understand any differences in plant ageing that may exist in different locations throughout the UK.
8. Develop a Delivery Guide on Plant Ageing for use by HSE Inspectors.

This report summarises the findings of Phase 1, which had the objectives of:

1. Estimating the extent to which ageing is an issue contributing to plant HSE performance, and whether this is significant in risk terms.
2. Evaluating if there are any regional trends or variations within the UK that could be used to prioritise ageing issues

The overall aim of Phase 1 was to establish if ageing was a significant concern, and to identify any particular failure mechanisms or ageing anecdotes by analysing the available incident data to guide Phase 2 with its focus on the technical issues and a delivery guide for inspectors.

The report refers to HSE RR509 (reviewed as part of this phase of the project, Ref: A-038) when defining ageing, quoting the following:

“Ageing is not about how old your equipment is; it is about its condition, and how that is changing over time. Ageing is the effect whereby a component suffers some form of material deterioration and damage (usually, but not necessarily, associated with time in service) with an increasing likelihood of failure over the lifetime. Ageing equipment is equipment for which there is evidence or likelihood of significant deterioration and damage taking place since new, or for which there is insufficient information and knowledge available to know the extent to which this possibility exists. The significance of deterioration and damage relates to the potential effect on the equipment’s functionality, availability, reliability and safety. Just because an item of

Reference: A-039 [HSE-RR823-Phase1]
equipment is old does not necessarily mean that it is significantly deteriorating and damaged. All types of equipment can be susceptible to ageing mechanisms." This report continues this by stating, *"Overall, ageing plant is plant which is, or may be, no longer considered fully fit for purpose due to age related deterioration in its integrity or functional performance".* The Summary Guide attached to this report adds to this statement: *"Overall, ageing plant is plant which is, or may be, no longer considered fully fit for purpose due to deterioration or obsolescence in its integrity or functional performance. 'Ageing' is not directly related to chronological age".* Appendix 1: Ageing plant topics EC&I including mechanical Appendix 2: Non-metallic failure mechanisms Appendix 3: EC&I Appendix 4: EC&I Appendix 5: Databases and analysis The databases interrogated for this task were the EU Major Accident Reporting System (MARS), Reporting of Injuries Diseases and Dangerous Occurrences Regulations (RIDDOR) and the Major Hazard Incident Data Service (MHIDAS). This report raises the question of 'Is plant ageing really a problem?' Sections 1 to 3 are an introduction to the objectives and structure of the report. Section 4 concentrates on the review of the databases, this also includes a review of previous HSE incident data and compares this with the ageing findings. Section 5 gives the definition of ageing, here the report looks back at the results of the report and considers the highlighted issues. Section 6 reviews the location of UK plant and whether the geographic location increases the likelihood of events. Section 7 summarises the relevant plant ageing questions. Section 8 summarises the project objectives and lists conclusions drawn from the report.
Key Themes <u>Definition of Ageing.</u> Section 5 describes ageing and refers to RR509 (reviewed as part of this phase of the project, Ref: A-038) for several quotes. *"As highlighted above, there is a need to distinguish between plant that has been in place for many years, and that which is 'wearing out' such that it may exhibit a higher risk of failures or leaks. The former can be considered old or aged plant. Aged plant may be fully fit for purpose and could be in a good condition as per its original design intent. However, aged plant may be susceptible to fatigue cycles or corrosion beyond its*

Reference: A-039 [HSE-RR823-Phase1]

design basis, even if it has been well maintained. Plant life extension justifications are one way to ensure these issues are recognised and addressed".

Also included in this short section is the need to review the plant against the current standards/codes which may be different from those with which it was designed.

Databases.

Section 4 reviews the databases and considers the data found during the review.

They state here that, *"In terms of uncertainty in the data analysis, it is concluded that the limited descriptive data provided in the RIDDOR and MHIDAS databases means that a considerable degree of judgement had to be used to assess if a given event was in any way ageing related"*, and, *"The MARS database provides significantly better information, though by no means fully comprehensive. This has allowed specific causes such as corrosion, fatigue, vibration and erosion to be identified. These mechanisms for containment or structural failure can be classified as ageing related with a high degree of confidence".*

From the data analysed the report concludes that *"This analysis indicates that approximately 50% of Technical Integrity and EC&I related incidents are age related. Given the uncertainties in the analysis a broad assessment of the size of the ageing problem may be made by the statement:*

"60% of 'potential major accident' incidents are Technical Integrity or Control and Instrumentation related issues and 50% of those are associated with ageing of one type or another".

From the data several observations were made, some of these are:

1. The absolute number of incidents that can be directly attributable to plant ageing for primary containment systems is not insignificant. This is further focused by the observation from the MARS data that ageing issues appear to play a proportionately more significant role in major accidents when the reporting formats allow more positive identification.
2. Corrosion remains a significant issue.
3. Failure mechanisms that can lead to rapid failure but are still significantly influenced by age, e.g. fatigue, stress corrosion cracking, CUI etc, are a significant issue.
4. Planning of inspection and maintenance activities significantly influences the results, i.e. failure to plan for ageing issues is apparent in the databases.

Non-metallic materials. **(ENC.2)**

4.4.2.1 considers the Non-metallic materials used and the degradation of these types of materials. The report states that, *"there is a perception within industry that such materials are not susceptible to age related degradations".*

"Composites do not corrode per se but can be subject to a number of degradation mechanisms in-service including physical ageing, mechanical ageing and chemical ageing. The consequence of these can be a reduction of 20 - 40% or greater in the strength characteristics of the polymer during the lifetime of the component and introduction of damage including matrix cracking and delamination".

Regarding the design stage tests for the pressures over the design life of the component the report raises the concern that these methods are insufficient *"given the increasing diversity of applications in which composites are applied. In contrast to steel vessels or pipework where non-destructive methods such as ultrasonics, electromagnetics and radiography are widely applied, very little inspection other than visual*

Reference: A-039 [HSE-RR823-Phase1]

inspection or pressure testing is currently undertaken on composite components in the chemical, process and petrochemical industries".

When considering the ageing studies of non-metallics, the report suggests that the accelerated ageing tests can offer a good indication of the component's behaviour over a longer period. *"However, if the mechanisms encountered over the longer term differ to those in the accelerated tests, the degradation curves and predictions of remnant life obtained may be unrepresentative".*

"Areas of bend, variations in thickness, support or change in geometry are particularly susceptible to damage or degradation in composite systems. These may encounter local stress concentrations and care is needed in design to ensure these can adequately support the operating pressures of the piping or vessel and that the allowance made in regression curves for ageing is sufficient".

Ageing Management.

4.4.4 considers the key elements of a management system for plant ageing, here it provides an illustration of a management system capable of managing plant ageing. The report states, *"The development and maintenance of a well-defined Safety Management System is the key to ensuring that plant and equipment is purchased, constructed, maintained and reviewed in a structured way. This will reduce the potential for conditions to develop which could give rise to major incidents. Such a system will also ensure the effects of change, and the life cycle of the operation is monitored, reducing the development and effects of ageing and the potential for an incident to be realised due to aged or ageing conditions".*

Within this part of section 4 a further list of elements, which require the most focus, are provided along with a number of reasons why these systems can fail.

4.4.4.2 states, *"As plant ages either through its normal operational life cycle expectancy or increased exposure to external conditions and/or changes in operational conditions effecting its performance, management systems need to be updated and reviewed to ensure all the potential failings are identified and controlled".*

The following areas are considered key to controlling the ageing plant and equipment:

1. Management of Change process across all areas including procedures, equipment and staff, including contractors.
2. Competence development and training programmes
3. Review of updated standards against existing plant and equipment operation.
4. Maintenance of a structured Risk Assessment process.
5. Regular procedural reviews and updates by competent staff, against operational changes.

Section 4 continues with some examples of UK based incidents which relate to the above key areas.

Structures.

"The data review has highlighted a small number of incidents related to the ageing of structures. These are not statistically significant but, as for management systems, it is considered that the nature of the databases does not lend itself directly to reporting of such incidents, i.e. most are concerned with loss of primary containment and do not focus on the types of asset represented by this category".

Reference: A-039 [HSE-RR823-Phase1]
4.4.5 continues with some incidents relating to the failure of structures and links this to the review of management systems. *"The key question for structures appears to be that from the review of Management Systems, i.e. whether or not inspections extend to civil and structural features of the plant and safeguards e.g. flood control embankment, ground subsidence, integrity of paved areas, drainage systems and bunds, buildings, walls, plant supports, pipe-bridges, pits and culverts, tall structures, etc. If so, how are the data handled and are these assets part of the integrity management system for the plant in terms of periodic review".* <u>Safeguards.</u> 4.4.6 has the results, some examples from each of the databases and examples of lessons learned, the introduction states, *"An analysis of incident and dangerous occurrence data has been undertaken to identify those events where the reliability or effectiveness of safeguard systems could have been compromised by ageing factors. Safeguards have been taken as any technical (hardware) control or mitigation equipment or systems relevant to the incident EC&I equipment has been excluded, as these are considered separately".* The conclusions from this search show that there is a lack of detail on the safeguards present, if they failed and if so, why they did. The report does however state, *"the data does provide a number of examples highlighted in the results above that suggest specific safeguard failings that may be age related. It is not clear how many of these are entirely age related, but they do indicate a lack of appropriate testing, inspection or maintenance, or violations of safety arrangements over long periods of time".* This section continues by looking at the offshore hydrocarbon leak database and gives examples and findings of this review, the report states, *"The review appears to confirm that similar ageing issues are faced offshore and onshore for management of primary containment systems. The evidence suggests that although emphasis has been placed on more active management of ageing degradation, loss of containment incidents due to ageing still occur and may be increasing. It is perhaps reasonable to postulate that the rate of increase would be more significant if such focus had not been applied".* <u>Plant Ageing Questions.</u> Section 7 contains various questions raised in each of the previous sections within this report. Primary Containment Systems questions: 1. Are age-related damage mechanisms identified and assessed in the plant inspection and maintenance plans? 2. Are appropriate inspection and maintenance techniques applied that are effective in management of age-related degradation? 3. Is corrosion, both internal and external, monitored and trended? How are the results of the monitoring used to influence future integrity management actions? 4. Is the potential for cracking understood? Do justifications exist for planned actions, or lack thereof, to manage cracking? 5. Are changes to the process assessed in respect of impact on plant integrity over short, medium and long terms? 6. Does the installed equipment meet the requirements of modern design standards? If not, are the key differences between the original standard and its modern equivalent understood and the potential impact for plant integrity assessed?

Reference: A-039 [HSE-RR823-Phase1]

Management System questions:

1. Do management systems recognise the existence of aged plant and ensuring suitable attention is paid to this (identification and awareness of the issue) ?
2. Are mechanisms in place to identify new codes, standards, lessons learnt, or good practice and to review these to check the implications for existing plant?
3. Do Management of Change arrangements exist to identify and assess changes to plant, structures, processes or operating/maintenance regimes which could invalidate the original design or lead to accelerated ageing?
4. Are there systems to gather information from inspections, surveys, audits, maintenance systems, incidents reports, etc and analyse these to help identify any trends or issues AND feedback mechanisms to update these arrangements (e.g. change inspection frequency) if an issue is identified or suspected ?
5. Do these inspections etc extend to civil and structural features of the plant and safeguards e.g. flood control embankment, ground subsidence, integrity of paved areas, drainage systems and bunds, buildings, walls, plant supports, pipe-bridges, pits and culverts, tall structures, etc?
6. Are there Management of Change/Competency Assurance arrangements to ensure key skills, knowledge and experience with aged plant is retained, especially as older personnel retire or move on or when reducing manning levels or when outsourcing maintenance work for example. Are there suitable qualified resources available to identify and address ageing issues, i.e. competent corrosions engineers, structural/ mechanical engineers, EC&I specialists, etc ?

Structure questions:

1. Do inspections and maintenance procedures extend to civil and structural features of the plant and safeguards, for example
   - *flood control embankment*
   - *ground subsidence*
   - *integrity of paved areas*
   - *drainage systems and bunds*
   - *buildings*
   - *walls*
   - *plant supports*
   - *pipe-bridges*
   - *pits and culverts*
   - *tall structures*

Safeguard questions:

1. Are there hazard or risk assessments in place and do these identify all the safeguards required?

Reference: A-039 [HSE-RR823-Phase1]
2. Are safeguards provided to meet these requirements? 3. Are the safeguards adequate in terms of their capacity, speed of response, coverage etc to achieve the required functionality? 4. Are the safeguards adequate in terms of their availability, reliability, survivability and endurance to provide a high probability of working when required? 5. Are the safeguards recognised as HSE critical systems and included in the maintenance, testing and inspection arrangements? <u>Conclusions.</u> Section 8 contains the conclusions for this report breaking those down into general conclusions and also a brief statement from each of the sections. This report considers some of the ageing related questions and answers it's earlier question of, 'Is plant ageing really a problem?', with *"Overall it can be concluded that plant ageing does constitute a threat to health and safety performance of hazardous installations onshore in the UK. Within the uncertainties of the review conducted a reasonable statement to describe the size of the issue is "60% of incidents are Technical Integrity issues and 50% of those are associated with ageing of one type or another".*
Document Relationships & Referencing A document is referred to in section 4 regarding Non-metallics, 'Ageing of Composites' which looks at the non-destructive evaluation of actual damage of in-service components. Several references to RR509 (reviewed as part of this phase of the project, Ref: A-038) are given within this document, mainly focusing on the definition of ageing.
Applicability to Beyond Design Life Expectations This document contains a list of plant ageing questions which could be used by installations considering LTO. These questions coupled with the type of database review shown here could aid an organisation in substantiating a beyond design life case. This has been the only document seen so far which has analysed data collected from incidents. Several ageing and degradation studies and programmes of learning have been completed since this report was published and many of the themes here have been developed further.
Applicability to the ONR SAPs The inclusion of non-metallic components and their consideration for further testing or changes to the current design stage tests may be of interest as part of ENC.2.
Future Considerations N/A
Additional Notes Across the documents reviewed so far as part of the HSE and IAEA phase of reviews, this has been the only document to consider non-metallic components, the Ageing of Composites referenced could have some useful notes for ENC.2.

Reference: A-040 [HSE-RR912]
Document Title/Version Number: Management of ageing - A framework for nuclear chemical facilities.
Date of Issue: 2012
Summary: The report focuses on the competencies and processes required to proactively manage ageing in nuclear chemical facilities. Rather than being a prescriptive set of rules, this report is intended as a hands-on resource, describing what is required to effectively manage ageing within the wider context of asset management. The ONR commissioned this report to examine the procedures and practices necessary to identify and assess ageing within the overarching asset management processes of the British Standard Publicly Available Specification for Asset Management (PAS 55), this has since been withdrawn (2015) and replaced with an ISO 55000 family of documents. This report would collate information on good practices for the management of ageing that Site Licence Companies (SLCs) across the nuclear industry could use to achieve their strategic objectives. ONR site inspectors would also find it helpful when making statutory inspections. The main body of the report covers a number of topics in detail: 1. Relation to asset management; 2. Processes; 3. Organisation, roles and competencies for ageing management; 4. Knowledge management and hierarchical databases; 5. Risk based categorising of asset condition; 6. Condition assessment and scoring; 7. Role of inspection and NDT techniques; 8. Methods for prioritising defects and remedial work based on risk profiles; 9. Managing ageing for non-operating plant. Sections: 1. Introduction 2. Management of Ageing 3. Understanding and Identifying Ageing 4. Addressing Ageing 5. Good Practices – A summary of 16 points enabling facilities to implement effective AMPs. Appendices: A. Appendix A is an audit tool which aims to help asset managers (and senior managers and inspectors) assess the effectiveness of their current ageing management programme.

Reference: A-040 [HSE-RR912]
B. Appendix B summarises the concept and theory of ageing and ageing management. C. Appendix C provides flow charts detailing each step of the ageing management process (from screening assets to condition assessments, the ageing model, the asset management plan and use of the data collected). D. Appendix D is a collection of degradation mechanisms relevant to ageing nuclear plant, grouped by facility. It describes each degradation mechanism, the potential consequences and how best to detect the degradation. E. Appendix E provides information about non-destructive testing techniques relevant to ageing assets.
Key Themes <u>Ageing Management.</u> 1.3 states, *"Maintaining continuity in management and corporate knowledge must be matched with the development of new methods and techniques for monitoring and managing ageing. The generation of new knowledge from research into long term ageing processes and surveillance of materials is a key aspect".* 1.4, considers the control of hazards at a nuclear site. Here the report summarises the Fours C's (Containment, Cooling, Criticality prevention and Control) for nuclear safety and lists further hazards in addition to radiation. This section finishes by stating, *"Control of each of these hazards depends on the physical integrity of the fabric of the relevant facilities and the knowledge and human resources available to manage that integrity. Ageing can undermine any of these if not properly managed. Thus, there is a direct link between ageing and the control of nuclear hazards to maintain safety and production".* Regarding Licence Condition 28 the report states, *"This condition is operative throughout life, but clearly more work may be required to fulfil it as a plant ages or is in a degraded non-operating state waiting final decommissioning".* 1.8 state, Best Available Techniques *"(BAT) is defined to include the way in which an installation is designed, built, maintained, operated and dismantled. The expectation is that the techniques used are, and are maintained at, "the latest stage of development" or "state of the art". With older designed equipment there is the expectation that ageing and obsolescence will be managed according to BAT in order to minimise permitted disposals and discharges".* Regarding asset integrity management (2.1.2) the report states, *"Asset integrity management covers many of the activities of ageing management, such as degradation risk analysis, inspection and condition assessment, maintenance and remediation, and major repairs and replacement. There also needs to be an analysis of whether this investment is efficient and cost effective"* and *"Life extension of plant and facilities beyond original design life is a process of asset integrity management relevant to many long established nuclear sites. While ageing is a key part of this process there is an interaction of asset integrity with the lifetime plan to consider".* 2.1.3 looks at the Lifetime Plans which are used to convert the *"strategic objectives for the assets into plans of actions for delivery that incorporate the Ageing Management Programme as part of the approach to risk management".* This section also states, *"The rate at which assets are deteriorating may force decisions about early decommissioning or interventions".* 2.2.1 states, *"Controls to prevent or mitigate ageing comprise a mixture of activities including optimised operation, maintenance and asset care. The management of ageing is also concerned with research into failure rates and characteristics". This section also* considers the link between the ageing management

Reference: A-040 [HSE-RR912]
programme (AMP) and asset management. *"All the activities required to manage ageing need to be co-ordinated through an Ageing Management Programme within a total asset management plan".* 2.2.2 considers the stages of ageing, this section also includes a figure containing a bathtub curve. Regarding the bath-tub curve the report states, *"The shape of the curve reflects the rate of degradation and the effect of accumulated damage on operating margins: it is a symptom of typically poor asset management without ageing management interventions".* This section lists the stages of ageing as: 1. Post commissioning - Initial 2. Risk based - Maturing 3. Deterministic - Ageing 4. Monitored - Terminal *"Stage 3 is where proactive ageing management intervention can be of most benefit…At this stage it becomes more important to have greater confidence and control in the condition through a more quantitative and frequent inspection and NDT".* 2.2.4 lists the nine attributes of an ageing management programme, these are the same nine found in many of the documents reviewed as part of this stage of the project. The list and further AMP information can be found in the IAEA SSG-48 review. 3.4.1 considers the control of the inspection process with regards to the quality assurance arrangements (LC17). The report states here that *"when buying in products or services, ISO 9000 requires that the organisation shall ensure 'that purchased products meet specified purchase requirements. When applying this to inspection or NDT, it is important to specify the requirements of the inspection at the start:* 1. What defects do the inspection/ NDT need to detect? 2. Where are the defects likely to be? 3. What size of defect must be detected? 4. What level of confidence is required that a defect has been detected? 5. Is sizing of defects required? 6. If so what precision is necessary? 3.4.2 refers to an Inspection Authority within the site business to oversee the quality, competency and efficiency of inspections. The report states here that this role is important for ensuring that all inspections meet the required standard and that this role remains independent of operational pressures and reports directly to the licensee management. Section 4, Addressing Ageing, shows examples of a scoring system for the actual condition of assets, a figure which shows typical changes through life of the asset and some tables showing the safety risk profile criteria for degraded facilities. Further information in this section gives an overview of defect categorisation, fitness for service assessments, remediation and trending of data. 4.2 refers to an aging model. These types of tools can be used to predict the future condition of the asset by using current understanding of the asset's failure mechanisms and operational/OEM data. Here the report

Reference: A-040 [HSE-RR912]
considers the uncertainties *"Where there are uncertainties, particularly over long timescale or new mechanisms or environments, adequately funded research and development programmes may be necessary to improve confidence in the models".* 4.2.2 looks at the development and implementation of an AMP, this contains information similar in nature to that of NS-G-2.12 (superseded by SSG-48). This paragraph does consider the need for regular review of the AMP to account for new knowledge and experience and states that *"consideration should be given to arranging independent peer review of AMPs in order establish whether the AMP is consistent with generally accepted industry practices and knowledge".* <u>Knowledge Management.</u> 2.2.1 states, *"In addition to the physical ageing of assets, lack of knowledge or history due to retirement of key personnel or loss of corporate memory or records can be just as much of a problem".* 2.5.1 considers the skills and knowledge base required for ageing management, here the report touches on the link between an AMP and asset management again. *"Ageing management is a key part of the larger umbrella discipline of asset management. PAS 55 supports the need for competence of all staff involved with these processes. The skills and competence-base for ageing management are similar to those required for developing and implementing asset management plans, with the additional requirement for specific competences in ageing mechanisms and management for the particular system".* 2.5.2 looks at the SQEP and training requirements for ageing plant, the expectations of the duty holder and the requirements for NDT. *"The Duty Holding organisation is expected to determine the necessary competence for each role and provide appropriate training or take other actions to achieve that competence. It will normally maintain appropriate records of education, training, skills and experience…the qualification of personnel is most established in the field of inspection and NDT. Personal certification for NDT (PCN) and inspection personnel exist at different levels and there are recommendations for the types of work each level can do".* Section 2.5 continues with a table of competencies for certain roles and describes the nuclear professionalism culture for staff. 2.6.8 states, *"Ageing management spans the life of plant which in some industry sectors can extend to over one hundred years. In this time, key staff will retire so procedures must be in place to elicit and retain the experience which the individual has gained during their employment on the plant…one valuable tool is to ensure that Learning-From-Experience (LFE) exercises are conducted following any ageing management related project or incident. These exercises should be conducted in an open manner with contributions from all levels of staff involved".* 4.4.6 considers the effect of the decommissioning phase on the personnel, the retention of knowledge and the need for decommissioning training. *"Asset management on decommissioning sites may be made more difficult if many of the staff who worked on the plant during operation (and who may have been experts in a particular area of plant) have left, taking with them knowledge about the behaviour, design and quirks of the plant. The converse problem is that staff who remain, and who were familiar with the site during operation, may be unaware of the new hazards and modes of degradation that affect the non-operational plant.* <u>Obsolescence.</u> 2.2.1 also states, *"Obsolescence and a lack of spare parts or the disappearance of the original equipment manufacturer or non-conformance with current safety requirements, codes and standards and procedures*

Reference: A-040 [HSE-RR912]
may also be indications of an ageing asset. It no longer becomes possible to predict future performance from design and past service". 3.1.2 looks at the changes to design codes over the lifetime of the plant and links these changes in standards to obsolescence, where the changes may lead to materials used becoming obsolete. 3.1.3 builds on the statement above (2.2.1) by stating that *"If the manufacturer no longer exists, then obtaining spare or replacement parts which are compatible with the existing asset can be difficult".* This section continues by considering the need for asset managers to *"identify components that are or may become obsolete and make allowance or contingency within asset management plans".* <u>EIMT.</u> 2.1.4 considers the monitoring and performance indicators as set out in PAS 55. The report lists some of these processes and procedures that should be considered: 1. Reactive monitoring – identifies non-conformity in the asset management system after deterioration, failures or incidents have taken place 2. Proactive monitoring – provides assurance that asset management systems are operating as intended 3. Leading performance indicators – provide forewarning of non-compliance with performance standards 4. Lagging performance indicators – enable detection of failures of the asset management system from incidents and/or deficient performance of assets 5. Qualitative and quantitative measures – judgment and numerical metrics may be used 6. Monitoring the effectiveness and efficiency of the asset management system (e.g. in terms of cost and resource) 7. Recording of monitoring and measurement data to facilitate analysis of problems for continual improvement. 2.2.5 states, *"The complex issues surrounding inspection, such as lack of access and the radioactive environment, may require novel inspection techniques to be developed. If a defect is detected, appropriate and validated assessment methods must be used to ascertain the component's fitness for service, depending on the particular combination of materials, flaws and loading conditions".* Section 3.2 considers the condition assessments to gain an understanding of the asset/s *"physical and functional condition".* This section introduces the concept of these assessments, the requirements, methods and also how these fit alongside the legislation for nuclear licenced sites (LC28). More information on LC28 is listed in section 3.3. 3.4.4 looks at the challenges present within a nuclear facility with regards to the inspections. Access issues in this environment can range from poor installation (not considering the maintenance requirement during install) to the dose limits in certain areas which may limit worker and equipment exposure time. Suggested here are the remote inspection options and the need for further research into these. 3.4.4 concludes with *"Plant which on its own may not be classed as a high risk, may impact on more critical plant if it does fail, introducing a layer of complexity into the inspection planning. Decommissioned plant adds to this complexity, with different damage and failure mechanisms having to be considered compared to when the plant is operating".*

Reference: A-040 [HSE-RR912]
3.5 refers to full plant walk-downs (full system review – a review of all relevant information) as the best practice. Further information on walk-downs, NDT pitfalls and developments are also considered. 3.6 continues the theme from 3.5 regarding inspections and focuses on the use of the results and the understanding of the results provided. 3.6.3 adds to the 3.4.4 discussion of access challenges and refers to the 'un-inspectable areas. Here the report states, *"It is not acceptable to simply label an asset as un-inspectable and take no further action. In the first instance, a risk assessment must be carried out to evaluate the risk associated with failure of the un-inspectable item…If it is not possible to inspect the item but possible to mitigate the risk sufficiently by some other means, then not inspecting the item may be justified. Methods of mitigating the risk include, for example, the use of leak detection systems. The mitigation chosen must be sufficient to reduce the risk such that the consequences of failure are acceptable".* This paragraph also suggests that where items may be 'un-inspectable' a site may be able to demonstrate the tolerance to defects and show that these would occur with a very low probability, any fit for service analysis should show that these defects are within the safety case, therefore any lack of in-service inspection data "*may be tolerable*". 3.6.4 states, *"It is important that inspection reports are reviewed and information fed back into the ageing management process; not just stored away. Inspection records should be kept for the life of the component and include the procedures, statements of capability and the inspection reports".* <u>Scoping and Screening.</u> 2.7, risk assessments and screening, considers the approach to the screening process and the link with risk based assessments. 2.7.3 states, *"A systematic approach should be applied to screen for those systems, structures and components where ageing degradation or failure would have a direct negative impact on the health and safety of workers or the public and the safe operation of the site, and that are susceptible to ageing degradation…the screening should include SSCs that do not have direct safety functions but whose failure or unavailability could prevent other SSCs from performing their intended safety role".* 2.7.4 states, *"The screening process should be periodically reviewed as system configuration and radioactive inventory may change over time. The risk should influence the approach to condition assessments and the priority given to remediation actions when ageing is found".* 2.7.5 states, *"As well as its use for screening for ageing management, risk can be used as a basis to determine inspection and maintenance priorities where sufficient data and expertise exists. Risk based inspection (RBI) and maintenance (RBM) are well established in the high-hazard industries where there are user inspectorates and industry standards".* <u>Decommissioning</u>. 4.4.1 suggests that once operation ceases assets become liabilities as the site is decommissioned. *"In principle there should be no difference in approach between asset management of operating and non-operating facilities. The things that differ are the mechanisms that come to age the assets and the nature of the resulting hazards. Whereas the objective of the operating phase to sustain the facility for production and to prolong its life, during decommissioning the ultimate objective is removal. The aim is to act as 'caretaker' of liabilities until they can be removed: this can affect the view on maintenance and repair".*

Reference: A-040 [HSE-RR912]
4.4.2 states, *"Once sites enter the decommissioning phase and later become fuel-free and partly decontaminated, the level of nuclear hazard is reduced but not eliminated. However, deterioration of civil and other structures and plant may create more 'conventional' hazards, such as the risk of fire, structural collapse, loose objects, and electrical faults… Some hazards may never have been present before and so may be more difficult to recognise in the decommissioning phase"*. This paragraph also considers the emergency equipment that will need to be kept in good working order such as fire detection systems and diesel generators, the report suggests that these can be easily neglected during this phase of plant life. Also considered here are the normal ageing processes that affect ancillary items which may not have regular maintenance or inspection regimes. 4.4.3 states, *"Sites in the process of decommissioning are in a constant state of change as liabilities are removed or demolished. To manage risks effectively, tight controls are needed and the asset register must be kept up to date with the changing configuration… As liabilities are removed, ageing problems may 'cascade' due to the complexity and interaction between systems"*. 4.4.4 looks at the role of the AMP in decommissioning, some facilities may be required as part of the decommissioning process. The AMP must consider the effects of the degradation mechanisms that may have not been present before. Additional plant walk-downs will be required, included in these should be items that may not have been considered during operation and items with no previous monitoring in place. 4.4.5 lists three options for facilities at the decommissioning stage: 1. Preserved in good order 2. Abandoned 3. Abandoned in a known state to be recommissioned at a later date They consider the recommissioning of a crane as an example and state, *"The process of re-commissioning such a crane after being in a dormant state for many years is currently not well understood and may carry significant risks and unforeseen costs"*.
Document Relationships & Referencing This document has been reviewed as part of the Ageing and Degradation task (ONR376). Links to the HSE RR509 report are found throughout the document, with the report stating that users of this report (RR912) can cross reference information between the two documents. Section 1.9 refers to international guidance, in particular IAEA documents such as NS-G-2.12 (This has been superseded by SSG-48 which has been reviewed as part of this phase of the project). This section also refers to the EPRI database, The US Nuclear Energy Institute and the Institute for Nuclear Power Operations. Figures and tables are taken from the IAEA NS-G-2.12 document, examples of this can be found in 2.2.3/4, shown here are the concept of ageing management programmes (Plan-Do-Check-Act) and the nine attributes of an AMP. These are both listed along with further information on AMPs in the IAEA SSG-48 review.

Reference: A-040 [HSE-RR912]
Applicability to Beyond Design Life Expectations This document gives a broad overview of ageing management containing information taken from SSG-48's predecessor (NS-G-2.12). Many of the approaches within this document have been developed further and included in more recent documents which have been reviewed as part of this project.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes This document contains some useful appendices which could aid the formation of BDL questions for the review/audit by inspectors.

Reference: A-042 [HSE-RR823-Phase2]
Document Title/Version Number: Managing Ageing Plant – A Summary Guide
Date of Issue: Unknown date, post 2010 (RR823-Phase1)
Summary: The purpose of this guide is to provide targeted information to help HSE inspectors better understand the issues of ageing plant and to promote good practice for managing ageing assets. It is hoped that the guide will also provide a useful resource for industry, both in terms of understanding HSE's approach, understanding of the issues and expectations on industry for managing ageing assets, and in raising awareness throughout industry of the effects of ageing plant and how this can be managed effectively. This document is the guide developed as part of the RR823 Plant Ageing Study (Phase 1 Report). Further details of the analysis can be found in the Phase 1 Report. This guide gives a detailed description of ageing mechanisms, such as corrosion and erosion and the signs and symptoms and management options for these. The guide includes a table in the introduction which contains some examples of physical assets which could be relevant to ageing (*Table 1, p.2*).
Key Themes <u>Ageing Mechanisms.</u> Section 2 considers the ageing mechanisms and what they can affect. A table (*Table 2, p.6*) is provided showing some ageing mechanisms and their effect on the types of physical assets listed in Table 1 (*Introduction, p.1*). Another table (*Table 3, p.7*) provides an indicative guide to plant degradation based on process and material type. Section 2.2 explores the physical degradation due to corrosion. This section is broken down further into mechanisms, signs and symptoms, susceptibility and management options. The guide states that corrosion can be prevented or monitored and controlled. Monitoring and controlling of corrosion can be achieved through the following: 1. Identification, usually a risk assessment 2. Detection, application of a suitable inspection technique 3. Quantification, achieved by measuring remaining thicknesses 4. Assessment, when detected this assessment should consider the implications for the integrity of the equipment Sections 2.3, 2.4 and 2.5 look in more detail at Stress Corrosion Cracking and Erosion. 2.6 lists some specific key issues, under this heading the guide has several descriptions and inspection techniques for the following: 1. Insulated equipment 2. Machines and rotating equipment

Reference: A-042 [HSE-RR823-Phase2]

3. Fired heating equipment
4. Non-metallic materials
5. Concrete support structures
6. Glass reinforced plastic
7. Buried pipes

2.6.2, Machines and Rotating Equipment, the guide states, *"the dynamic nature of machines can exacerbate the rate of deterioration in some instances".* This paragraph refers to RR509 and RR076 Inspection Guide notes for examples.

2.6.3, Fired Heating Equipment. In addition to the normal ageing processes, high temperature oxidisation and creep the guide states, *"significant thermal cycling can give rise to fatigue over a period of time and metallurgical changes can occur because of prolonged service at high temperatures".* For further details the guide recommends the API Recommended Practice 573 on Inspection of Fired Boilers and Heaters.

2.6.6, Glass Reinforced Plastic and Epoxy Tanks states (GRP/E), *"Typical damage mechanisms for composite materials can include wall thinning due to exposure to chemicals which are incompatible with the resin used in manufacture…Erosion and cavitation are two other internal wall thinning mechanisms which can also damage these materials internally. Delamination of the composite layers can occur due to thermal or chemical ageing of the resin layers or because the glass fibres have not been sufficiently wetted by the resin during manufacture".* ISO 14692, Part 4 is considered a useful source of further information and the issues listed are equally applicable to other GRP components.

Ageing Management.

Section 3 contains some short statements on the Health, Safety and Environment Management System (HSEMS) that this guide states should be well structured and include plant ageing. This section has a table (*Table 5, p.27*) which contains some risk control systems and the considerations in relation to ageing plant.

"The identification and management of ageing plant issues in relation to process safety is recognised in a number of key risk control systems which must be identified and documented in order that they are regularly reviewed and updated".

Elements include:

1. Maintenance Management Systems
2. Asset Management and Integrity Systems
3. Audit and Inspection regimes
4. Risk Assessment Management processes
5. Management of Change procedures
6. Permit to Work
7. Responsibilities and Communications
8. Training and Competence development

Reference: A-042 [HSE-RR823-Phase2]
"In recognising ageing mechanisms, businesses can identify key performance indicators (KPIs) which can be monitored to identify how effectively the risks are being controlled". *"Recognising the ageing mechanisms that affect the process and then introducing and maintaining a structured management system approach to mitigate the potential for failure will significantly reduce the incidents of major accidents in the industry".* This guide focuses on the ageing mechanisms and provides several tables to aid understanding of the problems ageing plant can cause and the ways in which these can be prevented, monitored and controlled.
Document Relationships & Referencing This document is the guide developed as part of the RR823 Plant Ageing Study (Phase 1 Report). Further details of the analysis can be found in the Phase 1 Report. The Phase 1 Report has been reviewed as part of this phase of the project and in ONR376 Ageing and Degradation. As with RR823 this document repeats the ageing definition and refers to other information from RR509 (Plant Ageing, 2006). Further recommended documents are: • ISO 14692, Part 4, this document gives requirements and recommendations for the fabrication, installation, inspection and maintenance of GRP. • API Recommended Practice 573 on Inspection of Fired Boilers and Heaters. • RR076 Inspection Guide notes, Machine and rotating equipment integrity inspections.
Applicability to Beyond Design Life Expectations N/A
Applicability to the ONR SAPs Following on from RR823 Phase 1, this report adds another consideration for ENC.2. GRP/E used in tanks and pipework; additional in-service testing programmes may be required to understand the degradation of this type of material.
Future Considerations N/A
Additional Notes N/A

Reference: A-134 [AAPWG-010]
Document Title/Version Number: A Framework for Ageing Aircraft Audits
Date of Issue: June 2014
Summary: The UK MOD has now been undertaking Ageing Aircraft Structural Audits (AASA) for over 15 years. These were initiated following the well-known Aloha Flight 243, Boeing 737 pressure cabin failure in 1988. Initially research and regulations concentrated on measures to identify and mitigate ageing in aircraft structures. However, following several civil accidents in the mid-1990s, the aviation community became aware of the need to consider ageing effects of electrical, mechanical and propulsion systems alongside structural implications. AAAs were extended to encompass systems and propulsion. This paper expands on the content in RA 5723 (Reference A-144) which has been reviewed as part of this project. Ageing Definition. Throughout this Paper the term ageing refers to the following threats to integrity: 1. Overload 2. Fatigue 3. Accidental and Environmental Damage 4. Compromised Configuration Control 5. Maintenance/Supply Errors 6. Calendar Based Environmental Ageing or Degradation. This paper contains nine sections: 1. Introduction 2. Ageing aircraft regulation and policy 3. Preparation for an AAA 4. Common audit areas 5. Structures 6. Systems 7. Propulsion 8. Condition survey 9. Materials

Reference: A-134 [AAPWG-010]

Key Themes

Plan.

Para 3.1 states, *"Early in the planning phase the PT SME should consider the cost/benefit/risks of the extent of the audit process. Significant issues which have occurred before include the level of finance available for the Audit, the commercial access to the OEMs/DOs and commercial issues such as Non-Disclosure Agreements and the slowing effects of ITAR compliance on the Audit process".*

Regarding the pre audit planning phase para 3.2 states, *"An essential part of any AAA is careful planning by personnel with the correct level of experience and skills".* The paper also states here the importance of including all stakeholders and team members in the scoping of the audit.

Para 3.3 refers to the management plan for the audit, this aligns with RA 5723s recommendation of appointing an AAA coordinator and a specialist for each of the audit areas. The management of the audit should include a start-up meeting with all stakeholders and working groups managed by the AAA coordinator.

Organisations which should be involved:

1. The Design Organisations (DOs) Airframe and Engine
2. The Continuing Airworthiness Management Organisation (CAMO)
3. Independent Specialist Airworthiness Advisors (ISAwAs)
4. The Release To Service Authority (RTSA)
5. Front Line Command (FLC) Operators
6. The Contracted Maintenance Organisations

Section 3.5 considers the importance of previous audits and programmes, the paper states here that these programmes *"will inform the audit planning phase and provide guidance on where to focus the Audit effort".*

The following are examples of the type of programmes:

1. Previous AAAs or similar programmes
2. Zonal Hazard Analysis
3. Life Extension and Out of Service Date Extension programmes
4. Fatigue tests and modification programmes
5. Engine upgrade programmes
6. Forensic sampling
7. Ageing programmes by other nations

Section 3.6 investigates the issues surrounding documentation and data management. Para 3.6.1 states, *"The experience gained from previous audits has shown that many organisations have difficulty retrieving*

Reference: A-134 [AAPWG-010]
archived information, not least because frequent reorganisations have resulted in file identification numbers and file references changing". Access will be required to both electronic and hard copy records, some design organisations require a non-disclosure agreement to be in place which can slow the process down. Considerations for delays in this process should be accounted for during the audit planning phase. Para 3.6.2 states, *"A robust, auditable mechanism for tracking issues, references and decisions should be in place at the outset of the audit".* Section 4.2, general considerations for design reviews, refers to the baseline condition of the aircraft, what it was designed to do and what standard it was at when accepted into service. *"Familiarity with the top level `Baseline' condition should enable the Auditor to establish whether the original qualified life and the planned OSD/OSDEP* (Out of Service Date/Out of Service Date Extension Programme) *are compatible and if not whether an LEP/OSDEP* (Life Extension Programme) *has been carried out".* Section 4.3 states, *"The Audit should review, as far as possible, the system for recording concessions granted during production though in practice these are often difficult to verify and records may not be accessible especially on older aircraft. The review should verify that where concessions affected the life of a component or invoked a maintenance regime appropriate measures are still in place or that subsequent actions have cancelled the concession".* <u>Do.</u> Section 3.7 considers the sample size of the audit, stating that it is not always practical to carryout whole fleet audits. Sampling from groups that lead in usage, hours and fatigue index and also the youngest and oldest in terms of calendar life should be considered. *"As the audit progresses it may be necessary to add to the samples, for instance, should evidence emerge suggesting there may be ageing associated with the undercarriage then the fleet leader in landings might be added".* Sections 4.4, 4.5 and 4.7 consider the importance of reviewing the maintenance policy, records, schedule and data. Section 4.4 states, *"A review of the Maintenance Policy is an essential element of any ageing programme as it is the primary tool to identify and mitigate ageing. The aim of the Audit should be to determine whether the Maintenance Policy is adequate and effective and whether the policy is being correctly implemented".* Maintenance schedules should be audited to ensure that all significant items have been captured, reviewed and inspected by the schedule. Section 4.5 states, *"The Audit should audit the Reliability Centred Maintenance (RCM) work sheets to confirm the review process was thorough. If possible the original RCM analysis carried out at the introduction into service should also be reviewed and changes analysed".* Section 4.7 states, *"The availability and correct analysis of maintenance data is essential to identify ageing trends and this was recognised in the review into the loss of the RAF Nimrod MR2 XV230".* The available data should be adequate and the audit should review the methods used to determine the maintenance requirements. *"The Audit should establish what the data trends are being compared with; are there established targets or is the trend simply an historical comparison, are new failures captured and added to the data collection*

Reference: A-134 [AAPWG-010]

requirement? The Audit should also determine whether the PT participates in any data sharing with other users of the same aircraft type".

Trend data from across the audit areas should be available to review, this should link back to the initial RCM and a Failure Modes Effects and Criticality Analysis (FMECA) reviews. There should also be a Failure Reporting Analysis and Corrective Action System (FRACAS) in place.

Section 4.12 refers to the Statement of Operating Intent and Usage (SOIU). The paper considers the likelihood of the aircraft usage differing from the original intent. Examples are of operating for longer periods or at higher temperatures than first anticipated. This can correspond directly with any plant item whose design/operating parameters may have changed over time or may now be exceeded.

"The Audit should include a review of the latest edition of the SOIU and confirm that it is reviewed annually with a full review every 3 years".

<u>Check</u>

Section 4.15 states, *"The Audit should review the process for Designer and Service modifications (SMs) to confirm the process for identifying, controlling, classifying and embodying modifications is robust".* This section also considers the design of modifications by third parties and how these are controlled by the design organisation.

Section 4.17 (fault analysis) states, *"An AAA should review procedures used to analyse defects to determine how the collected information is applied to maintenance schedules and for possible modifications to improve reliability and maintainability and establish whether trends are identified and acted upon".* Links between fault investigation and modifications should be reviewed, where items have a high rejection rate the reports should be examined.

Section 4.18 considers the use of civilian contracts for maintenance purposes. The paper states here that the AAA does not want to repeat any approval processes however some areas should be investigated in more detail, these are:

1. The process for ensuring the competency of staff including training and authorisation, in particular it should focus on tasks where extra training and specific authorisation is required such as Zonal Surveys.
2. The Organisation's Quality System and any oversight by the contracting authority should be examined.
3. Where a contract is spare inclusive the process for obtaining components and piece parts, and what measures are in place to ensure the provenance and traceability of parts.

Section 8 describes the Condition Survey and refers back to the RA5723 document and the statement regarding an *"independent physical examination of the condition and husbandry standards",* this is known as a condition survey (CS).

8.1 states, *"CS is a method of examining elements of structures and systems not generally covered by standard maintenance. It has been found that although training and maintenance should be sufficient to detect 'expected' forms of wear and tear, degradation due to ageing extends beyond that range of subject matter and experience".*

The CS section describes a framework for the structural and system condition surveys. *"The survey extent and depth described are based on that experience and considered essential for an As Low As Reasonably Practicable (ALARP) condition, cognisant of practicality and cost".*

Reference: A-134 [AAPWG-010]
Section 8.2 considers the ageing factors and how the audit should recognise factors such as: 1. Ageing degradation can start at manufacture and occur before an AAA is due and propagate in places outside the boundaries of scheduled maintenance. 2. Repairs SI (T)s etc. may induce factors that cause or exacerbate degradation. 3. Component protection effective life can be reduced by human and environmental factors, resulting in significant and unexpected degradation before an AAA becomes due. The aim of the survey is to understand and confirm the actual condition of the equipment and compare against the records. The condition survey will aim to: 1. Identify any inconsistencies between the physical aircraft and its documentation suite 2. Identify inconsistencies and deficiencies in the scheduled maintenance regime, with respect to maintenance, ageing degradation, or environmental exposure, etc. 3. Depth Bay Maintenance or Overhaul/Reconditioning maintenance efficacy with respect to ageing degradation and in conjunction with material types and threats to integrity The outcomes in the form of recommendations should consider: 1. Recovery considerations 2. Changes to improve the effectiveness of the maintenance regime 3. Trends and material degradation considerations <u>Understanding</u> Section 4.22 states, *“Environmental Damage (ED) is the term used to describe the physical degradation of material properties as a direct result of interaction with the climate or the environment. ED includes corrosion, erosion and the degradation of surface finish and composite material properties. ED is not selective and will affect all parts of an aircraft therefore an AAA should address ED measures on structure, systems and the propulsion system”.* This section looks at the types of environmental issues like corrosion and its effects, stating that corrosion is the most significant form of ED. Also added here is the consideration of extreme environments and other systems, it states, *“Through either extreme environments or adjacent systems, the strength of composite structural or system components can be adversely affected by excess heat and moisture uptake and can also suffer degradation by fuels, oils, lubricants and ultraviolet light if left unprotected”.* Section 9 describes the different types of materials and the degradation mechanisms the audit should examine for. Some examples of these are: 1. Metals – “*Metals can suffer unobserved/unknown changes to their properties as a result of ‘ageing’ that an Audit Team should look to explore”*. These may include the following: a. Changing from corrosion resistant, to susceptible, or from ductile to brittle. b. Corrosion

Reference: A-134 [AAPWG-010]
c. Fretting d. Fatigue e. Overload cracking 2. Composites – “*Careful management and recording of repairs to composite structures and components is also necessary to ensure strength is retained. Audit Teams should carefully review methods in place to manage the exposure of composite structure to environment elements and the system in place for managing and recording repairs to composite structure. Where it is possible composite structure/components should be subjected to a sampling programme”.* Composites can degrade due to: a. exposure to heat, moisture, fuels, oils and UV light *b.* Low level impacts such as dropped tools leading to fibre damage and delamination <u>Other</u> Section 4.19 states, *“All aircraft should have in place an Obsolescence Management Strategy … The Audit should examine the effectiveness of the strategy by selecting specific examples of replacement parts and material and examining how any changes were made and approved”.* The procedure, approval and use alternative parts should also be reviewed. The obsolescence theme is continued in section 4.20 where considerations for the use of certain substances in construction and maintenance may cause an obsolescence issue due to changing legislation.
Document Relationships & Referencing In addition to RA 5723 this document references more of the RA documents, specifically RA5720 and RA5721, these relate to the sub-audits (Structural and System). Further RA guidance such as RA 5724 and 5725 may be of use, these refer to the life extension and out of service date extension of aircraft.
Applicability to Beyond Design Life Expectations This paper builds on the content within RA5723 with a more in depth look at additional checks such as the condition survey. Section 8 (The Condition Survey) may prove useful when considering the scope of an audit/assessment.
Applicability to the ONR SAPs The material section (9) gives some short statements on the degradation mechanisms for metals (EMC) and non-metals (ENC) which may add to the understanding of such materials and the types of testing required.
Future Considerations N/A
Additional Notes N/A

Reference: A-135 [AAPWG-011]
Document Title/Version Number: Ageing Aircraft Programmes Working Group - Guidance on the Conduct of Aircraft Zonal Hazard Analysis (ZHA)
Date of Issue: September 2016
Summary: This working group paper concentrates on the Zonal Hazard Analysis (ZHA) of aircrafts. This is used mainly to support new aircraft certification, therefore is less appropriate for older aircraft platforms. The paper considers the options for ZHA alongside other maintenance tasks to aid the discovery, understanding and mitigations required for ageing. " Under Regulatory Article (RA) 1210 Duty Holders (DH) are required to identify and assess the risk to life (RtL) on platforms they are responsible for and demonstrate that these risks are Tolerable and ALARP. For zonal hazards, demonstrating this has proved difficult because many aircraft entered service before zonal hazard analysis (ZHA) became an established technique or earlier analyses conducted may have been invalidated due to modification or other changes of use. To address this requirement, Duty Holders (DH) therefore need to develop a strategy to assess the risk posed by zonal hazards for the platforms they are responsible for. However, in practice the derivation of an appropriate strategy is influenced by life-cycle position, the availability of design information and the degree of change the aircraft type has been subject to."
Key Themes <u>Section 1, Description, definitions and requirements.</u> Para 1.3: A zonal hazard is a form of common cause failure (CCF) that can be described as an unsafe interaction between one system and another arising as a consequence of their relative spatial separation. Zonal hazards my also cross into other zones creating a “Cross zonal hazard”. A cross zonal hazard is defined as “A hazard cause initiates in one zone but the hazard interaction with a different system or structure occurs in another zone”. Para 1.4: ZHA’s are used to provide the Duty Holder (DH) with a better understanding of the hazards present. The paper states that the methods used for system safety analysis such as Failure Mode and Effect Analysis (FMEA) and Fault Tree Analysis (FTA) use assumptions about the systems and that these models do not take into account the influence of CCF. *“If these models are not adapted to include the influence of CCF, including zonal hazards, then the subsequent quantitative calculations of risk may be underestimated and the associated safety claims flawed”.* Para 1.5 lists some benefits of an independent and systematic ZHA and refers to an ALARP evaluation process which can help sustain airworthiness by: 1. The initiation of design changes. 2. The issue of Special Instructions SI(T), pending more permanent actions being taken. 3. The amendment of maintenance policy. This includes informing the development of the platform Reliability Centred Maintenance (RCM) based maintenance schedule. 4. Provide a basis for reviewing a platform hazard log to ensure its completeness.

Reference: A-135 [AAPWG-011]

5. Inform other sustainment activities, such as the scope of an Ageing Aircraft Audit.
6. Help validate the existing aircraft document set (ADS).

Section 2, Zonal hazard strategy

Para 2.3 considers the selection and effects of the zonal analysis strategy and give a list of objectives:

1. The installation should be checked against the design and installation requirements
2. The effect of failures on other systems and structures should be considered
3. Maintenance errors and poor maintenance practices and their effects

The paper describes instances where compliance with a standard or set criteria was taken to mean that there was no further requirement for safety consideration, this issue was therefore considered not able to contribute to a failure. *"compliance with standard or other criteria does not mean that conditions for a hazard to exist cannot arise".*

Regarding testing by the manufacturer or Design Organisation (DO) the paper has found that the checks done show very low non compliances and interferences between systems. The paper states that while they may be well informed by the qualification and testing data this may allow for some interactions to be missed. *"This trend could reflect that the DO have made optimistic assumptions about how a given system will behave in-service…".*

A change of usage of an aircraft is considered once one of the following has occurred:

1. Modification
2. Change of environment
3. Increased loads
4. Changes to maintenance policy

"If an aircraft has been subject to any of the above changes, then elements of any existing ZSA (Zonal Safety Analysis) *may no longer be valid".*

Many of the assessments see by the authors of this paper do not assess how or if the modification can interfere with any items beyond the 'zone' of the modified part. Has the modification created any cross zonal hazards?

Justification of further analysis may also come from a lack of evidence or an understanding of the evidence and assumptions made by the DO/Manufacturer.

Section 3, Aircraft ZHA process.

This section shows a process flow containing 5 phases:

1. Preparation and planning
2. Zonal hazard identification
3. Zonal hazard risk assessment

Reference: A-135 [AAPWG-011]

4. Reporting

5. ZHA results exploitation (this feeds the Life extension programme).

This section gives a detailed breakdown of each phase.

Within Phase 1 this paper recommends aligning the ZHA areas with the those used during regular maintenance, this avoids any confusion as to any areas of concern. "*This zonal scheme should be used as far as possible in the ZHA"*. Also mentioned here are the Suitably Qualified and Experienced Personnel (SQEP) requirements. The ZHA should be carried out by experienced system safety engineers, *"as the identification and analysis of zonal hazards requires a certain amount of engineering judgement…"*.

Changes of use and configuration changes should be taken into consideration when reviewing earlier assessments.

Phase 2 (A&B) considers zonal hazard identification and zonal hazard risk assessment.

The paper suggests that the identification of cross zonal hazards should be done after all of the zonal hazard surveys are complete. This is the 'optimal time' to carry out the survey as the hazards in each zone should have been captured.

Some examples are given of the probability data gathering sources, these are:

1. In service maintenance data

2. Safety occurrence reports

3. Condition survey reports

4. Anecdotal information such as OPEX, training and interviews of personnel

Phase 3; Reporting, states, *"It is important to have in place an effective reporting framework for the ZHA undertaken. This will aid communication between the organisations involved in the ZHA, help manage identified project risks, enable any significant safety issues identified to be promptly dealt with and ensure that the ZHA product produced by the ZHA Delivery Organisation meets the TAA needs with respect to providing suitable evidence to argue that the ZHA Goal has been satisfied"*.

It is recommended here that as a minimum the following should be included in the final report:

1. The Goal of the ZHA

2. The ZHA Scope, Exclusions and the Assumptions used.

3. A method statement, describing the hazard identification and analysis approach adopted.

4. A list of the zonal hazards identified and the related risk assessments.

<u>Section 4, ZHA results exploitation</u>

The overview states, *"The implementation of an effective ZHA Strategy undertaken by the TAA should ensure that a DH has sufficient evidence to support a safety case claim that the risk from zonal hazards on the aircraft they are responsible for is acceptable. However, if the results of ZHA are managed effectively they can be also be used to inform the overall understanding of risk present on an aircraft, initiate risk reduction measures and help sustain the airworthiness of that aircraft"*.

Reference: A-135 [AAPWG-011]
Regarding the understanding of aggregate risk, the paper refers to a Regulatory Article (RA1230) which gives design safety target criteria. It is required that the *"cumulative probability of the loss of the aircraft they are responsible for and the cumulative probability of a technical fault leading to the death of any aircrew or passengers should be of the order of at least 1x10-6 per flying hour (and 1x10-7 per flying hour for passenger carrying aircraft)".* The authors state that the ZHA ca be used to inform the preventative maintenance policy. The ZHA can ensure that inputs to the Reliability Centred Maintenance (RCM) process are representative. This can be used as part of the continuous review process to: 1. Ensure that the criteria used for determining significant candidates for RCM analysis is relevant. 2. Validate that the extant RCM analysis has identified all the credible failure modes and effects for each asset being considered. 3. Validate the extant probability of occurrence used for the individual asset failure modes considered in the RCM process. The paper finishes section 4 with some examples of finds by the authors and a statement regarding the review of the Haddon-Cave Nimrod review.
Document Relationships & Referencing This paper is part of the AAPWG series of papers. As part of this project, and in addition to this, Papers 010, 012 and 013 have been reviewed. RA5723 Ageing Aircraft Audit is referenced in this paper. This has been reviewed as part of this phase of the project. Many other Regulatory Articles (RAs) are referenced in this paper, along with some Defence standards. Many of which are not considered relevant to this project.
Applicability to Beyond Design Life Expectations This document contains useful insights into how another high-hazard industry examines their safety systems for ageing effects. Many of the aircraft platform examples given in the paper can be overlaid with issues on plant items and the maintenance practices and attitudes are also very similar.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-136 [AAPWG-012]	
Document Title/Version Number: Ageing Aircraft Programmes Working Group - Understanding the Corrosion Threat to Ageing Aircraft	
Date of Issue: December 2015	

Summary:

"With many military aircraft platforms being required to operate past their original out of service date, there is increasing concern that structures and systems may be experiencing an increased airworthiness risks from corrosion. This Paper has been commissioned to capture the full extent of corrosion issues in the long-term Ministry Of Defence air fleets. It is suggested that the information presented in this Paper should be used to assist in focusing the MOD's Research and Development Corrosion Programme on key remedial requirements".

This paper contains the following sections:

1. Introduction
2. Information gathering
3. The nature of corrosion
4. Findings: HA&C
5. Findings: FJ&T
6. Findings: RW
7. Regulatory Articles
8. Contact with other organisations
9. Discussion
10. Conclusions
11. Recommendations

Examples of some of the significant issues identified are as follows:

1. The poor availability and serviceability of aircraft washing equipment and base washing facilities and an increase in reports of corrosion damage occurring to armament equipment
2. Widespread cadmium corrosion on electrical wiring connectors
3. The effect of runway de-icer fluid on landing gear and carbon brake packs on both FJ&T and HA&C aircraft
4. A lack of preparation for the impact that the Regulation, Evaluation and Authorisation of CHemicals) (REACH) will have on the supply of materials for EDPC protection on both FJ&T and HA&C aircraft fleets

Three particular issues were identified:

Reference: A-136 [AAPWG-012]

1. A lack of Environmental Damage Control Plans
2. The meaning and intent "of the recovery procedure following an "exposure incident""
3. A lack of clarity as to the Project Teams (PT's) responsibility with regard to training requirements

Key Themes

Introduction

Para 1.5 states, *"The key principles in avoiding corrosion are the correct selection of material at the design stage, early identification and rectification of any in-service degradation and the commitment to maintain corrosion protection systems to a high standard throughout the items service life".*

Section 3, The nature of corrosion.

Para 3.1.1 lists the consequences of corrosion which has been left untreated:

1. A reduction in static strength
2. The conditions to promote stress corrosion cracking
3. A reduction in the fatigue life
4. Seizure or failure to operate of mechanical, electrical, hydraulic and gaseous systems

Para 3.1.3 considers the material selection and the compromises made when selecting materials. Also recognised here are the platforms in use which have materials that, at the time of manufacture, were deemed suitable but have since been found to be susceptible to corrosion.

The remaining parts of section 3 describe the different types of corrosion.

Sections 4, 5 and 6 concentrate on the effects of corrosion on specific airframes and give examples of where those were found.

Section 7 reviews the Regulatory Article 4507 and also lists some of the other RA's.

Section 9 describes the tables provide in the annex, tables 7, 8 and 9 list corrosion issues under the following headings for each aircraft type:

1. Design issues
2. Corrosion protection
3. Husbandry
4. Training
5. Beneficial practice
6. Dual classification
7. Not classified

Para 9.8.1 through 9.8.5 describe the above findings in more detail.

Reference: A-136 [AAPWG-012]
Section 10, Conclusions. 10.1.1, Design issues states, *"There are two significant factors identified in this category, the original choice of materials and damage arising in-service. Both of these can be managed by a robust maintenance policy"*. 10.1.3, Husbandry states, *"A number of problems with aircraft washing were identified. These related to equipment, materials and facilities. A further concern was the poor condition that some equipment had been found in when removed from storage containers. The problems were aggravated by lack of cleaning prior to storage and possible deterioration while in storage. The loss of trained personnel for the task was also a possible contributory factor"*. 10.1.4, Training refers to training of Environmental Damage Prevention and Control (EDPC). *"RAF training staff reported that EDPC husbandry was perceived as a secondary task at many units. The situation was made worse by reports that many such tasks were being deferred until Depth maintenance"*. 10.1.5, Beneficial practice looks at the good work done by the Typhoon project team (PT) and the Chinook EDPC plan which could be used as a template for other PT's. 10.1.6, MAA regulation. Of all of the PTs one had published an ED plan and one other had a post specifically tasked with managing the EDPC. *"Many PTs stated that they found some of the regulatory requirement poorly defined while other parts were considered to be not their responsibility"*. Section 11 gives a list of 32 recommendations based on the findings, a selection of which are listed below: 1. It is recommended that all ED susceptible materials used on a platform be identified within the ADS (Aircraft Documentation) 2. It is recommended that the maintenance policy for any identified susceptible materials is reviewed for its effectives at protecting and detecting ED 3. It is recommended that prior to any life extension programme for a platform that the life of EDPC products is taken into account 4. It is recommended that the consequence of any identified life expiration is taken into account at subsequent platform maintenance schedule reviews 5. It is recommended that CSs results are reviewed at EDPC/SIWG meetings to establish trends and to provide a lessons-learned analysis so that EDPC management might be better focused
Document Relationships & Referencing This paper is part of the AAPWG series of papers. As part of this project, and in addition to this, Papers 010, 011 and 013 have been reviewed. Section 7 focuses on the EDPC Regulatory Article 4507.
Applicability to Beyond Design Life Expectations The conclusions and recommendations sections highlight many issues that can be addressed for any SSC exposed to these sorts of degradation mechanisms.
Applicability to the ONR SAPs N/A

Reference: A-136 [AAPWG-012]
Future Considerations N/A
Additional Notes N/A

Reference: A-137 [AAPWG-013]
Document Title/Version Number: Ageing Aircraft Programmes Working Group - Continuing Airworthiness Management its Contribution to Identifying Evidence of Ageing in Aircraft
Date of Issue: June 2017
Summary: *"The UK MOD policy for ageing aircraft centres round carrying out an Ageing Aircraft Audit (AAA) 15 years after a type's in-services date or at the mid-point between the declared ISD and the initial planned Out of Service Date (OSD) whichever is soonest. Repeat audits should be conducted at 10 year intervals thereafter. However, it is recognised that ageing is a progressive process that commences from manufacture and an in-service programme of monitoring ageing would be advantageous. The responsibilities of both a Type Airworthiness Authority (TAA) and a Continuing Airworthiness Management Organisation (CAMO) include data collection and associated analysis, functions which are recognised as essential tools in identifying potential ageing in aircraft".* This paper consists of 5 sections: 1. Introduction 2. CAMO regulation and policy 3. The CAW culture 4. CAMO/TAA responsibilities 5. Conclusions *"This Paper concludes that the tasks carried out by the Military CAMO include a number that could make a significant contribution to identifying ageing in individual aircraft."*
Key Themes <u>Introduction</u> Para 1.1 states, *"The adverse effects of age may be described as the cumulative exposure to the threats to Integrity these encompass overload, fatigue, environmental/accidental damage, the loss of configuration control and maintenance/supply errors, and the risk of them interacting increasing with time and usage. Additionally, calendar-based ageing mechanisms such as the effects of environmental ageing and degradation can compromise Integrity".* Section 2 gives a view of the civilian approach (2.1.1) and the MOD policy (2.2.). <u>Section 3, The CAW (Continuing Airworthiness) culture</u> This section contains the relationship and responsibilities of the Type Airworthiness Authority (TAA), the Military and the Continuing Airworthiness Management Organisation (CAMO), in Para 3.1 it describes this relationship and provides a flow diagram to show the 'Airworthiness culture'. Para 3.1 states, *"During the operation of the aircraft the CAMO will feed back to the TAA the experiences and any problems encountered operating the aircraft and much of this information will be derived from the analysis of data collected, sources of which could include:*

Reference: A-137 [AAPWG-013]
1. *Occurrence Reports* 2. *Changes to the Maintenance Programme* 3. *A request for modification or repair information.* 4. *A request to change the operating profiles* 5. *Information gleaned from the CAMO's technical data collection programme".*   Section 4, CAMO/TAA Responsibilities Para 4.1.1 refers to the usage of the fleet of aircraft. The paper gives examples of changes which may have ageing implications, some of these are: 1. Increased utilisation 2. Change of usage in terms of fatigue 3. Changes to the normal operating environment Para 4.1.2 states that, *"The number of repairs, their frequency across the fleet and whether they are repetitive may be indicative of an ageing problem".* Para 4.1.3 considers the data collection. This also refers to trends, as above, here the paper provides a list of sources to which the CAMO should have access. Examples of these are maintenance and fault data and occurrence reports. Para 4.1.4 states, *"Maintenance Data is perhaps the most useful data in detecting trends that might indicate the onset of ageing in a system or structure".* One of the findings in this area, found during the Ageing Aircraft Audits (AAA), recognised that there is a reluctance to use data to identify issues and this collection and analysis of data is not being carried out effectively. Section 5, Conclusions *"The introduction of CAMOs into the MAE* (Military Air Environment) *and the resultant requirement to monitor the continuing airworthiness of individual aircraft presents an opportunity to progressively monitor ageing of an aircraft through the analysis of in-service data".* The conclusions also suggest that the most important tasks when identifying ageing effects are monitoring usage and analysis of maintenance data.
Document Relationships & Referencing This paper is part of the AAPWG series of papers. As part of this project, and in addition to this, Papers 010, 011 and 012 have been reviewed.
Applicability to Beyond Design Life Expectations N/A
Applicability to the ONR SAPs N/A

Reference: A-137 [AAPWG-013]
Future Considerations N/A
Additional Notes N/A

Reference: A-139 [HSE-2009]
Document Title/Version Number: Guidance on management of ageing and thorough reviews of ageing installations
Date of Issue: 2009
Summary: This information sheet provides guidance for asset managers, safety managers and safety engineers in the offshore industry on taking account of ageing of the installation during thorough review, which is required by the Offshore Installations (Safety Case) Regulations 2005 (SCR05). This information sheet considers the 5 yearly thorough review from the perspective of ageing.
Key Themes Objectives of the thorough reviews are: 1. To confirm that the safety case, with any necessary updates, is still adequate, and is likely to remain so until the next thorough review. 2. Compare the case against current standards, HSE guidance (such as APOSC, GASCET, offshore safety case guidance) and industry practice for new installations; to evaluate any deficiencies; and to identify and implement any reasonably practicable improvements to enhance safety. 3. Identify design parameters, ageing processes, changes in operating conditions and hence performance standards that may limit the life of the installation, or of its safety critical elements. 4. Check that the management of safety is adequate, in particular that performance standards and key performance indicators (KPIs) are relevant and effective. Regarding ageing, this guidance suggests that those carrying out the thorough review should refer to this and other documents such as the ‘Guidance on fire and explosion hazards associated with ageing offshore installations’ and ‘Structural integrity management of ageing installations.’ <u>Plan</u> *“Systems and procedures should be in place to identify and rectify issues arising from ageing by means of*: *1. Inspection* *2. Planned maintenance* *3. Change control procedure (modifications)* *4. Operational risk assessment (e.g. in the event of failures)* *5. Incident investigation”* Some considerations for the scope of the thorough review are: 1. Design and operational parameters of the structure and plant, together with actual operational experience and projected operational status

Reference: A-139 [HSE-2009]

2. Maintenance, inspection and testing experience of safety critical elements (SCEs) and consideration of whether test intervals are adequate given the testing history
3. Modifications to the installation or plant including SCEs to ensure that the installation hazard profile remains tolerable and as low as reasonably practicable (ALARP)
4. New knowledge and understanding
5. Changes in safety standards

Management of asset life extension can raise several additional hazards, some examples listed are:

1. Design and operational issues relating to integration of new plant, processes or materials with old
2. Degradation of emergency equipment and facilities
3. Equipment obsolescence leading to substitution, modification or plant outage
4. The need for detailed knowledge of the current state of the structure

"It is best to plan in advance for any future life extension of the installation. Any reduction in maintenance regime in anticipation of end of life requires careful consideration as it will make any subsequent life extension more difficult and costly. Any change from a programme of scheduled maintenance to a regime of "on-condition" maintenance will require the necessary design changes to enable the required level of condition monitoring. This includes adequate plant access for monitoring and robust models of wear rates".

A list of items which are important to the management considerations for ageing plant are given, some examples of these are:

1. Ageing and deterioration
    a. Wear and tear
    b. Corrosion
    c. Structural fatigue
2. Modifications
    a. Process equipment
    b. Staff levels
3. Obsolescence
4. Advances in knowledge and technology

"The effective management of ageing installations entails the effective application of inspection and maintenance strategies and structural analysis techniques. This also requires competency in the wide range of activities essential to the structural integrity management process and the importance of this cannot be overstated".

A section on Structural Integrity Management (SIM) is included in this guidance along with a table containing SIM processes and the associated life extension issues.

<u>Do</u>

Reference: A-139 [HSE-2009]

Some options for evaluation and implementation are given for equipment where ageing/degradation mechanisms have been established:
 	
1. Evaluate
  a. Assess the overall condition and performance
  b. Determine if a viable strategy can be developed without the equipment or with reduced long term performance
  c. Compare its life expectancy with the estimated life of the facility
 	
2. Implement
  a. Scrap and decommission the equipment, with or without replacement
  b. Revise the role and live with the reduced performance for the remainder of the lifecycle
  c. Provide alternative means to fulfil the equipment role
  d. Monitor the component to ensure that the revised performance standards are achieved in the long term and to identify any terminal decline before it becomes critical.
 	
"The course of actions needed usually depends on the role and criticality of the system, nature of the damage, economic factors associated with the operation and repair/replacement of the equipment and the costs of assessment and monitoring".
 	
<u>Understanding</u>
Regarding the understanding of ageing, OPEX is an important tool when considering the life extension of any plant/equipment. As part of the SIM section within this guidance the authors touch on this by stating, *"The understanding of structural and materials performance is an ongoing activity. As platforms age, the industry needs to make use of the information that becomes available to improve knowledge and current practices and assessment procedures. The inspection of decommissioned structures would provide particularly valuable information on structural and materials performance for all types of component but particularly for components which cannot normally be inspected".*

Document Relationships & Referencing Several references to RR509 are made throughout this guidance, this document has been reviewed as part of this project (Ref: A-038).
Applicability to Beyond Design Life Expectations N/A
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Reference: A-144 [RA-5723]
Document Title/Version Number: Ageing Air System Audit (AAA), Regulatory Article 5723
Date of Issue: November 2019
Summary: This Military Aviation Authority (MAA) Regulatory Article identifies that the risk to airworthiness due to the ageing of aircraft in service is partly mitigated by Integrity Management in accordance with RA 5720, RA 5721 and RA 5722. However, the insidious nature of degradation and the interaction of apparently unrelated ageing processes are often found only by an additional rigorous periodic audit of trend data, procedures and the aircraft's physical condition. This whole process is known as an Ageing Aircraft Audit and it is achieved by observing the regulation and guidance in this Regulatory Article. There are similarities between this type of audits and the Ageing Management Programmes reviewed as part of this project. This guidance breaks down the management of such audits into an Authority (TAA) and an AAA coordinator and stresses the need for independence. Also, the guidance refers to comparable programmes and the use of such, as long the programme can meet the requirements set out by the TAA and MAA.
Key Themes <u>Acceptable means of compliance.</u> An Ageing Air system Audit (AAA) should be initiated no later than the following: 1. 15 years after a type's declared In-Service Date (ISD). 2. The mid-point between the declared ISD and the initial planned Out of Service Date (OSD). 3. Where any member of a fleet, acquired under short-duration arrangements (i.e. a service provision contract), exceeds 50% of its cleared life (in any parameter). 4. In the case of the acquisition of a fleet which can already be regarded as ageing, an AAA should be conducted before ISD. The Type Airworthiness Authority (TAA) should: 1. Specify the areas to be covered by the Audit. 2. Identify the organizational boundaries of the Audit based on current issues. 3. Assess the safety consequences of potential failure. 4. Analyse information from all available resources. 5. Clearly state which Air System areas or Systems, if any, are to be excluded from the AAA and the rationale for their exclusion. 6. Submit requests for recognition of comparable programmes to the MAA (Military Aviation Authority) at least 12 months prior to the audit becoming due.

Reference: A-144 [RA-5723]

7. Ensure that all audit activity is completed and a final AAA report, covering all Audits and detailing the closure plan for all resultant actions and recommendations, is issued within 2 years of the AAA initiation.

The Ageing Airworthiness system Audit (AAA) should:

1. Cover the Airworthiness and Integrity Management (IM) of the Air System
2. Include a detailed, independent condition survey to assess the condition and Husbandry standards of representative Air Systems (and, where appropriate, sub-systems) from the fleet.
3. Items managed by Commodity Delivery Teams (DT), where necessary. The Air System DT should take primacy in the Audit, seeking Commodity DT support as necessary.
4. Include an independent review of the continued applicability of Airworthiness procedures, management processes and interfaces between organizations providing aspects of the overall fleet delivery.

Periodic audits should be at no greater than 10 yearly intervals.

<u>Guidance Material</u>

<u>Background.</u>

"During the life of an Air System, cumulative exposure to the threats to Integrity (such as overload, fatigue, environmental/accidental damage, absence of configuration control, or Maintenance/supply errors), and the risk of them interacting, increase with time and usage. Additionally, calendar-based ageing mechanisms (such as the effects of environmental ageing and degradation) can compromise Integrity. The effects of ageing are not always comprehensively recognized or addressed by routine activities".

<u>The Aim of AAA.</u>

The aims of AAA are to:

1. Conduct a periodic, independent assessment of the Airworthiness management of the fleet, with consideration to ageing.
2. Consider individually and collectively the SI (Structural Integrity), SysI (System Integrity) and PI (Propulsion Integrity) activities, often carried out in isolation, to assess the effectiveness of the fleet's IM.
3. Undertake an independent review of the continued applicability of procedures, management processes, assumptions and documentation that are in place to ensure Airworthiness, integrity and functionality.
4. Undertake a detailed, independent condition survey of representative Air System from the fleet, unless an equivalent examination is conducted routinely.
5. Identify patterns or trends that suggest future Airworthiness or integrity issues.
6. Identify significant risks to the Airworthiness or integrity of the Air System that would threaten the achievement of its planned OSD (Out of Service Date).

<u>Timing of an AAA.</u>

Considerations for timing:

1. 15 years after In Service Date (ISD) when acquired from new, earlier if previously owned

Reference: A-144 [RA-5723]

2. Where evidence shows potential ageing issues an earlier audit activity should be considered
3. When under short duration arrangements AAA's are not usually required. Considerations should be made of the life of the fleet and any extensions to the agreement.
4. If the OSD is extended, then the AAA should be based upon the original OSD.

Use of comparable programmes.

RA5723 states here that the Air Systems may have comparable programmes in place which may fulfil the requirements of the AAA. A comparison between the documentation should be conducted. When accepting other programmes, the Type Airworthiness Authority (TAA) should consult independent specialists and the Military Aviation Authority (MAA).

Management of AAA.

The TAA may appoint an AAA coordinator or an independent audit company. If the AAA is carried out by the Design Organisation (DO), the OEM or any organisation already involved with the airworthiness of the fleet, additional measures are required to maintain independence.

Para 30 states, *"Advisors, DOs and OEMs, where contracted, may assist the TAA to interpret the AAA report and findings. The ADH* (Aviation Duty Holder) *needs to be informed of any Airworthiness risks to allow assessments to be made of the consequential RtL* (Risk to Life) *to ensure they are As Low As Reasonably Practicable (ALARP) and Tolerable".*

Para 31 states, *"The AAA can only be considered to be complete once the final AAA Report, covering all Audits and detailing the closure plan for all resultant actions and recommendations, has been produced by the DT* (Delivery Teams) *and accepted by the TAA. Additionally, the TAA may consider the benefits of producing a Lessons Identified (LI) report and participation in the MAA's Ageing Air System Programme Working Group (AAPWG) to spread best practice and Lis".*

Scope of AAA.

"Careful scoping of the AAA is essential and ought to be undertaken well in advance of AAA initiation to ensure that Audit activities are integrated in order to; properly focus the Audit, address all aspects and avoid nugatory work".

A list of areas to be considered by the audit are given as part of Para 32, some examples are:

1. Proximity to OSD: if nearing the OSD then the extent of the AAA will be set using a risk-based approach, while considering the possibility of OSD extension.
2. Continued validity of Life Extension Programme evidence where applicable.
3. Availability and veracity of usage data.
4. The Engineering and Asset Management System employed along with the associated Quality Audit arrangements for capturing tracked items.
5. Known or perceived repair or supply errors.
6. An assessment of the adequacy of procedures and Maintenance policies.

Reference: A-144 [RA-5723]

7. The effectiveness of Maintenance schedule reviews to ensure that technical documentation is up to date and consistent.
8. The existence, effectiveness and findings of any other ageing Air System programmes.

Para 33 states, *"Proposals regarding the scope of any aspect of the AAA cannot compromise the independence of the Audit team in achieving the AAA aims"*.

Structural Audit Scope.

Para 35 states, *"The TAA will need to consider MAA guidance when setting the scope of the Structural Audit"*. This para makes reference to the AAPWG Paper 10 (A framework for ageing aircraft audits) which has been considered as part of the additional reviews.

Some examples of additional requirements for the structural audit are:

1. Adequacy of all published structural information for the Type Design
2. Relevance, currency and results of structural monitoring and Individual Air System Tracking
3. In-service structural arisings and recovery programmes
4. Existence and effectiveness of the Structural Examination Programme
5. Susceptibility to Widespread Fatigue Damage (WFD) and the existence of programmes for corrective action.

System Audit Scope.

Some examples of requirements for system audits are:

1. Emergency systems and systems with a critical function
2. Mechanical systems
3. Secondary Power Systems
4. Systems whose failure could affect another system
5. Obsolescence issues
6. The changes in operational conditions and usage during the life of the Air System and how the differences have been, and plan to be, monitored and managed.

Propulsion Audit Scope.

Examples of the requirements for a propulsion audit are:

1. A documentation review confirming that all technical documents are up to date
2. Product usage assessment covering:
    a. Product used as intended
    b. Initial assumptions are still valid

Reference: A-144 [RA-5723]
3. A maintenance policy review 4. A component life review assessing the following: a. Life and usage monitoring systems are fir for purpose b. Adequacy and process of managing critical parts c. Assumptions of component life are still valid d. Tracking of part life 5. A review of operational statistics to identify trends and age related faults 6. A review of fault investigations since previous audit
Document Relationships & Referencing As part of the structural audit this guidance suggests that the TAA would need to consider relevant MAA guidance, here it refers to the AAPWG paper 10 which has been reviewed as part of this project. (Ref: A-134) Further RA guidance such as RA 5724 and 5725 may be of use.
Applicability to Beyond Design Life Expectations Useful guidance for audits and the types of considerations when dealing with ageing items. The scope of each of the three audits listed may add some value.
Applicability to the ONR SAPs N/A
Future Considerations N/A
Additional Notes N/A

Appendix E. Comparison of Themes Using Plan–Do–Check–Act Model

The items mirrored across the reviews are highlighted in yellow, while the additional high-hazard themes not included in the nuclear industry RGP (or to the same extent) are highlighted in blue.

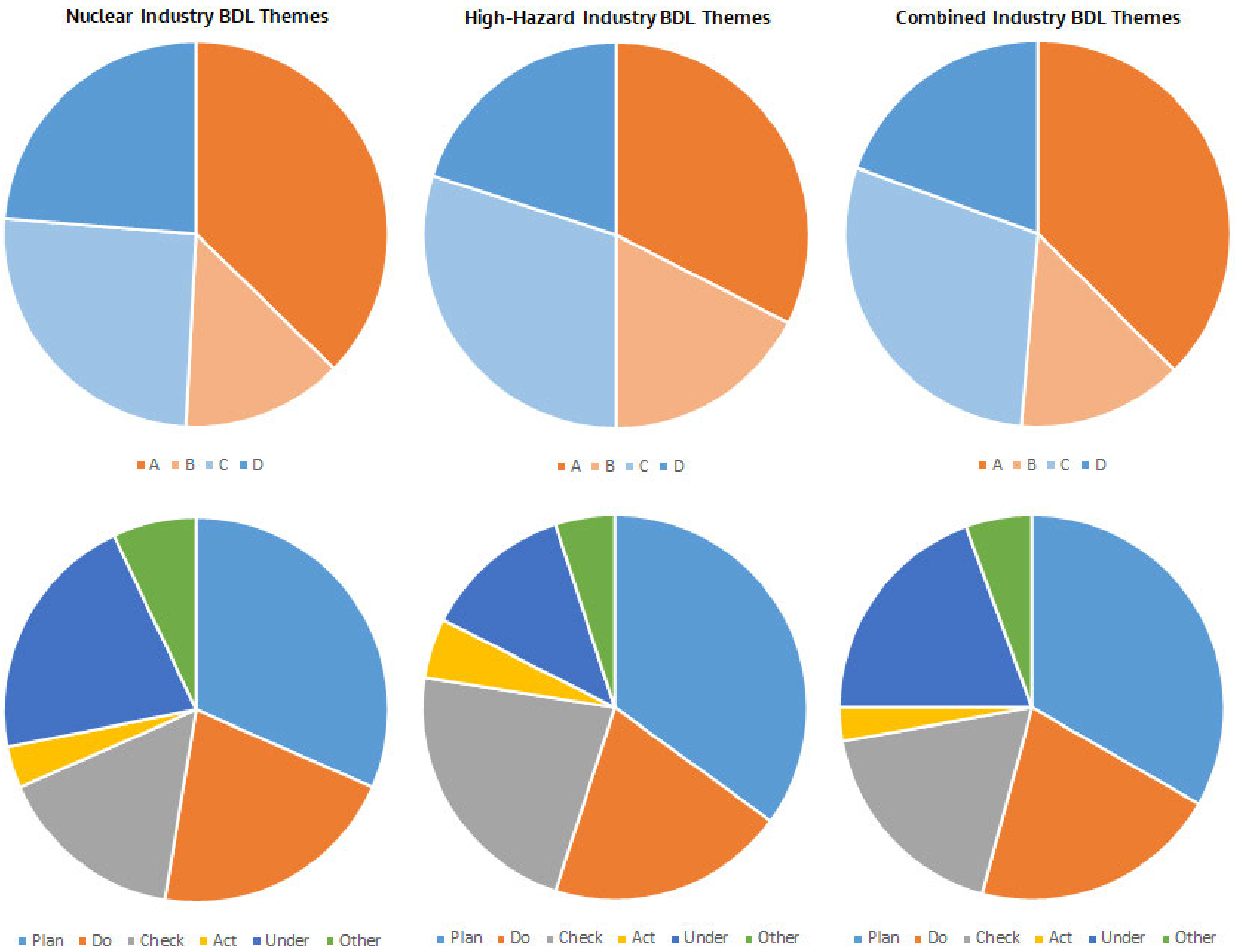
Nuclear Industry	Other High-Hazard Industries
PLAN	PLAN
> Ageing Management	> Ageing and Life Extension
> Ageing Management Programmes	> Ageing Management
> Asset Management	> Asset integrity management
> Capabilities & Resources	> Databases
> Data Recording & Availability	> Economic Optimisation
> Design Stage Considerations	> Human Factors
> Economic Optimisation	> Integrity Management
> EIMT	> Knowledge Management
> General Framework for AM & LTO	> Obsolescence Management
> Human Factors	> Organisational Factors
> Knowledge Management	> Planning and Implementation
> Lifetime/Life-Cycle Management	> Record Keeping
> Modifications to Existing Plant Programmes	> Safety Management Systems
> Performance Management	> Self-Assessments for Other AM or Life Extension Type Tasks
> Pre-Conditions for LTO	> Skills, Training and Competence
> RIM Programme	> Strategy
> Roles and Responsibilities for Operators and Regulators	> Workforce Involvement
> Safety Management	
DO	DO
> Equipment Qualification	> Data Management and Trending
> In-Service Inspection	> Integrity Assessment
> LTO Engineering Process	> Operational Programmes
> Operational Programmes	> Plant Ageing Questionnaires & Checklists
> Preventative/Predictive Maintenance	> Record Keeping
> Review & Update of Processes and Procedures for LTO	> Revalidation
> Reviews/Revalidate TLAAs	> Safety Cases and Reviews
> RIM Implementation & Documentation	> Scoping and Screening
> RIM Strategies (Performance of Strategies)	
> Scoping and Screening	
> Surveillance and Monitoring Programmes for TLAAs	

Nuclear Industry	Other High-Hazard Industries
<u>CHECK</u> > AMP Review > EIMT > In-Service Inspection > LCM Self-Assessment > Periodic Safety Reviews > Performance Monitoring & RIM Updates > Preventative/Predictive Maintenance > Reviews/Revalidate TLAAs > Surveillance and Monitoring Programmes for TLAAs	<u>CHECK</u> > Change, Audit & Review > Data Management and Trending > EIMT > Examination Policy > Monitoring, Audit and Review > Process integrity > Revalidation > Safety Cases and Reviews > Self-Assessments for ALE > Self-Assessments for Other AM or Life Extension Type Tasks > Skills, Training and Competence
<u>ACT</u> > Maintenance > Refurbishment/Replacement	<u>ACT</u>
<u>UNDERSTANDING</u> > Ageing/Degradation Mechanisms > Ageing/Degradation of SSCs > Capabilities & Resources > Design Life > Identification of Reliability Targets > RIM Strategies & Uncertainties > Licence Management > OPEX > Periodic Safety Reviews > Regulatory Oversight > SSC Safety Classification > System and Data Management	<u>UNDERSTANDING</u> > Ageing/Degradation Mechanisms > Corrosion > Definition of Ageing > Mechanical Integrity > Non-Metallic Materials > OPEX > Pipelines > Plant Ageing Questionnaires & Checklists > Skills, Training and Competence > Structural Integrity > Structures
<u>OTHER</u> > Decommissioning > Early approaches to AM or LTO superseded or evolved into SSG-48 > Indirect Aspects of AM & LTO > LTO Submissions or PSR to Demonstrate Safe Operation > Obsolescence > Regulatory Approach to LTO	<u>OTHER</u> > Decommissioning > Fire and Explosion > Obsolescence > Safeguards

Appendix F. Summary of BDL Expectations

NI & HH BDL Themes	A	B	C	D	Plan	Do	Check	Act	Under	Other
• Ageing Management	1				1					
o Ageing Management Programmes			1		1					
o AMP Review		1					1			
• Ageing/Degradation Mechanisms				1					1	
• Asset Management	1				1					
• Data Recording & Availability	1				1					
o Databases	1				1					
o Data Management and Trending		1	1		1		1			
o Record Keeping			1			1				
• Decommissioning		1		1						1
• Design Life				1					1	
• Design Stage Considerations			1		1					
• Economic Optimisation	1				1					
• EIM&T	1		1		1		1			
o In-Service Inspection		1		1		1	1			
o Maintenance				1				1		
o Preventative/Predictive Maintenance		1		1		1	1			
o Refurbishment / Replacement				1				1		
o Surveillance and Monitoring Programmes for TLAAs		1		1		1	1			
• Equipment Qualification				1		1				
• General Framework for AM & LTO	1				1					
o Organisational Factors	1				1					
o Workforce Involvement	1				1					
• Human factors	1				1					
• Knowledge Management	1				1					
o Capabilities & Resources		1	1		1				1	
o Skills, Training and Competence			1				1		1	
• Licence Management	1								1	
• Lifetime / Life-Cycle Management	1				1					
o LCM Self-Assessments			1				1			
• LTO Engineering Process			1			1				
• LTO Submissions or PSR to Demonstrate Safe Operation	1									1
o Periodic Safety Reviews	1	1					1		1	
• Modifications to existing Plant Programmes	1		1		1	1				
• Obsolescence	1			1						1
o Obsolescence Management	1				1					
• Operational Programmes			1			1				
• OPEX			1						1	
• Performance Management			1		1					
• Pre-Conditions for LTO	1				1					
• Regulatory Approach to LTO	1									1
o Roles and Responsibilities for Operators and Regulators	1				1					
• Regulatory Oversight	1								1	
• Review & Update of Processes and Procedures for LTO	1		1			1				
• Reviews / Revalidate TLAAs				1		1	1			
• RIM Programme	1				1					
o Ageing/Degradation of SSCs				1					1	
o Identification of Reliability Targets				1					1	
o RIM Strategies (Performance of Strategies)			1			1				
o RIM Strategies & Uncertainties				1					1	
o RIM Implementation & Documentation			1			1				
o Performance Monitoring & RIM Updates		1					1			
• Safety Management	1				1					
o Safety Cases and Reviews		1	1			1	1			
• Self-Assessments & Audits for AM or Life Extension Tasks	1		1		1		1			
o Plant Ageing Questionnaires & Checklists			1			1			1	
• Scoping and Screening			1			1				
• SSC Safety Classification			1						1	
• System and Data Management	1								1	
Nuclear Industry Totals	22	8	15	14	18	12	9	2	12	4
High-Hazard Industry Totals	13	7	12	8	14	8	9	2	5	2
Totals	27	10	21	14	24	15	13	2	14	4

Key:
- Items that could be assessed via PSR
- Items that could be assessed via BDL Submission
- Themes mirrored in HH and Nuclear Industries
- Themes identified in HH Industries not covered in Nuclear Industry (or to the same extent)



Key (as discussed further in Section 5.2.7)

A – Programmes assessed as part of the PSR;
B – Global assessment of SSCs assessed as part of the PSR;
C – Programmatical elements associated with the SSCs assessed as part of the BDL submission;
D – Justification for SSCs extended operation within the BDL submission.