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Operation of Ageing Reactors: Approaches and associated Research in the European Union

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PREFACE

This report was prepared before the Fukusima Daiichi tragic event. Without doubt this accident will have consequences on government decisions for the long term operation of operating reactors. Lessons need to be learned from the Fukushima Daiichi nuclear disaster that will have impact on the methodologies traditionally used in the safety evaluation of aged nuclear power plants.

EXECUTIVE SUMMARY

Plant Life Management (PLiM) of existing nuclear power plants in EU may consider longer term operability. This becomes an option with specific advantages and is under consideration in some Member States. It however unveils number of challenges that are closely related with extending the operational life of structures and components (SC) beyond the established operational time frame at the time they were designed. Safety related aspects of long term operations are obvious; for those SC important to safety that are selected for evaluation it is necessary to demonstrate that they perform the intended safety functions with sufficient safety margins for the entire period of operations. The ageing phenomena 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 with related human factor aspects. A broad and effective dissemination of related scientific results is a further objective.

The European Union, which sees a large diversity of nuclear plant types, needs a targeted investigation to upgrade knowledge on their objective safety levels. Research activities therefore concentrate on providing the scientific and technical knowledge in relation to safety important issues needed for Community policy support and for helping to enhance nuclear safety in EU and beyond. The European Commission launched within the EURATOM framework programme FP7 a research and support programme related to PLiM issues under progress at Joint Research Centre and involves partners from nuclear industry and Technical Support Organizations through several dedicated networks and projects.

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.

The IAEA initiative to launch an International "Generic Ageing Lessons Learned" (IGALL) project underlines importance of a coherent approach on ageing management in Member States operating nuclear power plants. The IGALL will provide a common internationally agreed basis on what constitutes an acceptable ageing management programme, as well as knowledge data base on ageing management for design of new plants, design reviews, etc. and will serve as a roadmap to information on ageing degradations and respective ageing management programmes. The IGALL will be an important input to safety reviews in addressing degradation mechanism for Structures, Systems and Components for different nuclear power plant designs.

The present report also discuses several current challenges, and shows some examples how the research is supporting / or can support the safety assessment of ageing nuclear power plants in the European Union.

LIST OF ACRONYMS

APSA	Ageing Probabilistic Safety Assessment
CLB	Current Licensing Basis
ENER	Directorate General Energy
ETSON	European Technical Support Organization
EU	European Union
FSAR	Final Safety Analysis Report
GALL	Generic Ageing Lessons Learned
IET	Institute for Energy and Transport
IAEA	International Atomic Energy Agency
IRS	Event Reporting System, operated by IAEA/NEA
JRC	Directorate General Joint Research Centre
HELB	High Energy Line Break
LR	License Renewal
LRA	License Renewal Application
LTO	Longer Term Operability / Long Term Operation
MR	Maintenance Rule
NPP	Nuclear Power Plant
OEF	Operational Experience Feedback
OECD/NEA	Nuclear Energy Agency
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Review
SC	Structures and Components
SCC	Stress Corrosion Cracking
SSC	Structures, Systems and Components
SNE TP	Sustainable Nuclear Energy Technology Platform
TLAA	Time – Limited Ageing Analysis
WENRA	Western European Nuclear Regulators Association

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1 OVERVIEW

1.1 Background

Nuclear safety of the operating nuclear installations has to be in the core of the challenges posed by the electricity market liberalization and plant life management of the plants which have to be operated safely and reliably. European Countries involved in nuclear energy are spending their efforts in improving safety of operating plants and of those under construction, which is in accordance with the EURATOM Treaty obligations. Referring to the IAEA's wording in "Requirements for Operation of Nuclear Power Plants", these priorities are identified as the following: Maintenance, Testing, Surveillance and Inspection (MS&I) programmes, ageing management for safety related components, thermal hydraulics analysis supporting plant improvement and modifications, engineering programmes supporting operation, plant safety assessment, operating procedures and human reliability aspects (including among others, human factors, safety culture, organisational aspects, organisational design and operation feedback).

The optimisation of these programmes requires a large effort for the development of new techniques and models, particularly in the field of component qualification, use of probabilistic assessment methods and risk-informed techniques, etc... In the same time the European integration in the nuclear industry is becoming a reality which increases the need for sharing best-practices and harmonizing guidelines among the EU Member States. Furthermore one of the consequences of the Fukushima accident is that also European regulatory bodies are becoming increasingly in favour of harmonised regulations.

The potential role for an EC action in the coordination of the effort among the European Countries can further improve the safety of European installations, in addition to national initiatives. In fact, both the development and the implementation of optimised techniques in these fields require the availability of component data, well assessed probabilistic techniques, complex case studies, collection of data that would benefit from an integrated European approach. Moreover, the development of new standards and norms for component qualification and inspection, and safety review also suggests full coordination at the European level.

In order to address specific issues of nuclear power plant operation, JRC-IET has launched a Plant Operation Safety (POS) action which aims at facing both technical and organisational issues related to the safe operation of the European nuclear facilities, both existing and under construction, in an integrated research approach, providing ready-to-use, validated methods, models and recommendations for procedures. The priorities defined above well address the needs of power plants considering the development of a programme for ageing management and adaptation to evolving regulatory rules. Design and construction of new Gen III plants is also largely benefiting from this research, as state-of-the-art engineering features and operational procedures are put in place since the earliest stages of the plant life. In fact scientists involved in POS are and will be invited to review the safety of present reactors with main focus on design and operation aspects, in line with the research priorities just mentioned. In some specific cases the competences in this field may also be well used in assessment of operational experience feedback.

The Action focuses on the following strategic goals:

- Support long-term EU policy needs on operational nuclear safety of the existing installations, and optimization of the safety of advanced nuclear energy systems through exploitation of the JRC competence in nuclear safety assessment methods and techniques.

- Provide a basis for harmonization of European best practice and approaches regarding operational safety of nuclear installations.
- In developing the European Research Area, integrate the research efforts with the on-going efforts implemented by the nuclear utilities and plant designers, through development of suitable networks and collaborating with other EC-General Directorates and international organizations.

With regard to Ageing Management, the overall objectives of this research action, to be implemented through analyses of current practices, development of new methods and benchmarking, are the following:

1) Support a convergence of the time-limited ageing analyses: develop knowledge, advanced methods and tools in support of harmonised European best practices for effectiveness and convergence of component ageing management. (In-house network APSA and SENUF and participation to the DG-RTD partially funded networks or action: NULIFE and LONGLIFE).

2) Support a convergence for Inspection reliability which is becoming a central issue in Ageing Management and is addressed as well when Gen-II and Gen-III are compared: develop in service-inspection programmes and strategies for the reliability of the NDT systems applied; develop knowledge, advanced methods and tools in support of harmonised European best practices in this field. (In-house network ENIQ).

3) Support a convergence of Plant Safety Review targets and policies (In-house network SENUF)

Some international activities are explicitly planned in the framework of the Enlargement and Integration policy of the JRC for candidate Countries, Associated Countries, Neighbour Countries, Russia, Ukraine and Armenia, using the support of the JRC-IET Unit.

1.2 Purpose and scope of the report

This report has been prepared in the framework of the JRC-IET support to long-term EU policy needs on operational nuclear safety of the existing installations. It is also a deliverable of the network SENUF as decided in its Steering Committee of November 25th 2009. It provides a basis for harmonization of European best practice and approaches regarding operational safety of nuclear installations.

Harmonization of safety requirements for the EU nuclear installations is a vital part for the future development of nuclear energy. The European Council has adopted Directive 2009/71/EURATOM in June 2009 [1], which objective is to establish a Community framework in order to maintain and promote the continuous improvement of nuclear safety and its regulation, and ensure that Member States provide for appropriate national arrangements for a high level of nuclear safety to protect workers and the general public against the dangers arising from ionizing radiations from nuclear installations. This Directive recognizes the IAEA Fundamental Safety Principles and Nuclear Safety Standards to constitute a framework of practices that Member States should have regard to when implementing this Directive.

This EC Directive sets minimum requirements on nuclear safety; however, provisions in this Directive do not prevent the Member States from taking more stringent safety measures if they deem appropriate. Members States shall ensure that their national framework for nuclear safety is maintained and improved when necessary considering lessons learned, operating experience, and insights from analysis, assessment of nuclear safety, and research and development.

A convergence of ageing management and related safety assessment methodologies should be of vital interest for all stakeholders. A common framework setting minimum requirements for the implementation of best practices at the national and European level seems to be necessary. Public acceptance for nuclear power generation is being built on trust in the competence of nuclear operators and safety authorities. Converging on common approaches to safety and arriving at common practices should largely enhance this trust.

The Fukushima accident is providing the energy policy in Europe with a renewed frame: (1) safety assessment of the nuclear reactors should be more transparent for any countries in the EU and their neighbours; (2) closing reactors in short term may come in conflict with targets on CO_2 reduction and contribute to other kinds of insecurity. The correct answer to this has been found with an EU-wide safety assessment of the reactors as decided by the European Council of March 25th 2011. Under such frame it might be recognised and accepted that some selected reactors may be operated beyond their initial time frame, and that for them a (perhaps limited) LTO will be chosen.

Purpose of the report is to provide an overview of different periodical safety assessment methodologies adopted by different utilities in EU countries. Special attention is given to discussing existing regulatory framework when LTO is considered as well as requirements set for LTO in the corresponding IAEA safety reports and safety guides. A comparison of Licence Renewal Rule and Periodic Safety Review as a tool for assessment of SSC is provided too. Finally, this report discuses different elements in LTO approach, and shows some examples how the research is supporting / or can support the safety assessment of ageing nuclear power plants in the European Union.

1.3 Organization of the report

Section 1 describes purpose, as well as background information for this report.

Section 2 discusses necessary activities to be implemented before entering LTO

Section 3 provides an overview of the current (regulatory) framework for LTO, as well as description of existing approaches used for LTO in USA and EU.

Section 4 discusses harmonization of LTO practices.

Section 5 provides overview of current research activities to support LTO.

Section 6 provides conclusions related to this report.

Section 7 provides a list of technical documents and publications relevant to LTO.

2 BASIS FOR LTO

Forecasting for the energy mix of the EU sometimes considers longer term operation (LTO) of existing nuclear power plants as an option with specific advantages. Depending on the safety requirements at the time of the licensing, the existence or not of periodical improvements related to safety and on actual safety regulation frame and content for the time for which LTO is considered, this option can be accepted or not. It anyway unveils number of challenges that are closely related with extending the operational life of Structures and Components (SC) beyond the initially established operational time frame. Safety related aspects of long term operations are obvious; for those SC important to safety that are selected for LTO it is necessary to demonstrate that they perform the intended safety functions with sufficient safety margins for the entire period of operations. Moreover since the regulation frame has evolved it might be desirable to consider if and how the new safety targets can be met.

According to IAEA definition LTO means "Operation beyond an established time frame set forth e.g. by licence term, design limits, standards, and/or regulations etc., which has been justified by safety assessment considering life limiting processes and features for system, structures and components". LTO means a complex process that requires multidisciplinary engineering approach. It should start in appropriate time before entering LTO so that to perform an engineering evaluation to demonstrate that SSC in LTO scope will fulfil their intended safety functions considering in service ageing for the period of operation.

The original design life of structural, mechanical and electrical components, particularly those which technically limit the power plant operation (e.g. reactor pressure vessel, containment structure, electrical cables, etc.) was originally estimated to be around 30-40 years, considering anticipated operational conditions and ambient environment, under which they are operated. In reality, the plant operational conditions and ambient environment parameters are below the limits established for SC during the initial design. Moreover, using operational trends and limits lower than actually allowed by the plant Operational Limits and Conditions (OLC) is a regular practice in most of NPPs; this approach ensures the environment and stressors have less effect for in service ageing of SC. This is a very important factor for assessment of actual component conditions, i.e. whether the actual equipment ageing degradation for particular SC is equal, slower or faster than anticipated.

2.1 LTO Process

The LTO process has already been described in number of International publications, e.g. [2], [3]; the following sections therefore highlight its important elements. The detailed description of each element scope is provided in Section 3.

2.1.1 Feasibility study

Before entering LTO, there are two very important questions to be answered for making a decision whether to proceed with LTO; the first question relates to economical and technical feasibility, and reflects strategic elements such as needs for electrical power and supply diversity issues, and second, probably even more important, whether the current safety level of the nuclear power plant is adequate or should be substantially changed. This is applicable especially for the plants built according to earlier design.

While economical feasibility falls into operating organization competence, a decision regarding the plant safety level depends on country's regulatory requirements. Generally, thorough technical assessment of the plant physical condition may be needed so that to identify safety enhancements or modifications, and the impact of changes to NPP programmes and procedures necessary for continued safe operation. This also involves re-assessment of the environmental impact for the period of LTO.

Besides that, the operating organization will have to demonstrate that certain time limited assumptions initially used for SSC remain valid for the period of LTO. In some cases, depending on the safety relevance, a comprehensive re–analysis of the ageing process may be required so that to set a new time limit of reliable and safe LTO.

LTO typically starts with feasibility study which forms a basis for a decision whether to proceed with LTO or not. The decision mainly depends on two aspects, economical feasibility and compliance with safety requirements for extended period of operation, i.e. demonstration that the NPP can be operated safely for the period of LTO.

2.1.2 Preconditions

A decision to continue NPP operation for extended period of time is also based on evaluation of the past operating practices and experience. The plant practices and programmes that have been implemented in the course of established operational time frame are important for the extended operation too.

LTO activities are built on the past performance of the plant SSC as well as lessons learned from operational experience feedback. Actually, not that much is going to be changed in the LTO as one could expect; although a lot of analysis is required before entering the LTO, but once LTO has been approved, the plant operates as before. In addition to standard plant programmes and practices, special provisions are being made on managing the ageing effects of SSC that are important for maintaining the plant safety and reliability. These provisions are implemented through ageing management programmes.

The following plant practices or programmes from among the existing plant programmes are essential in developing the foundation for a successful LTO programme.

1) Existing plant programmes
    a) In-service inspection
    b) Maintenance
    c) Equipment qualification
    d) In-service testing
    e) Surveillance
2) Quality assurance, and configuration management;
3) Original Time Limited Ageing Analysis (TLAA);
4) Updated Final Safety Analysis report (FSAR).

Above plant programmes and practices may be modified for the period of extended operation. In addition, new ageing management programmes may be needed to complement existing plant programmes.

Most of the plants that consider LTO have implemented a plant life management programme (PLiM), which could be considered as LTO precondition. PLiM provides technical and economical consideration to ensure the plant reliable operation, while the Ageing Management is one of the PLiM elements.

According to [4] the Plant Life Management means: "the integration of ageing Management and economic planning to:

- Maintain a high level of safety;
- Optimize the operation, maintenance and service life of systems, structures and components;
- Maintain an acceptable performance level;
- Maximize return on investment over the service life of the nuclear power plant;
- Provide operating organizations and owners with the optimum preconditions for achieving long term operation.

Plant Life Management (PLiM), is a methodology "whereby all expenses are optimized to favour commercial profitability and competitiveness, while safe and reliable supplies of electric power are being produced [4]".

Typically, a scoping and screening, which is an important element of the plant ageing management programme is not required for the PLiM because it considers the plant as a whole. The scoping and screening exercise is however required for two plant programmes, the maintenance programme and the ageing management. The maintenance programme involves a broader scope; it includes both active and passive SCs, as well as those needed for emergency operating procedures. On the other hand, the ageing management programme typically includes only passive and long lived SCs that are safety-related or may impact on safety functions if they fail. The goal of maintenance programme is to maintain the overall plant performance, while the ageing management goal is to maintain SC functions at component level.

2.1.3 Assessment

As it will be shown in Section 3, there may be different approaches used for LTO assessment and approval, e.g. the US Licence Renewal Rule, and the Periodic Safety Review. Whatever approach is applied; there are typically four main elements in LTO assessment process:

i. Scoping and screening which is used to identify the SSC in the scope of LTO,

ii. Ageing management review which identifies whether all known degradation mechanisms for the given component material and environment have been identified,

iii. Review or development of new ageing management programmes so that to check their effectiveness in detecting and mitigating the ageing effects, and

iv. Evaluation and re-validation of time limited assumptions for specific SC.

Set of specific guidelines for assessing the available methods and approaches to implement activities for each element is described in Section 3, and the detailed considerations associated to each element are provided in Section 4 of this report. The new IAEA extra budgetary programme on International Generic Ageing Lessons Learned (IGALL) that was recently launched will cover topic (ii) and (iii) in greater details.

3 CURRENT REGULATORY FRAMEWORK FOR LTO

Granting LTO for nuclear power plant may be done through the License Renewal (LR), Periodic Safety Review (PSR), or other approach that is accepted/required in a member state country.

The licence renewal approach pursuant US 10 CFR 54 is followed particularly in USA when the operating license is granted for fixed operational term, while PSR is normally set for 10 year cycle. The Licence Renewal typically grants operating license for current operational term plus 20 years, PSR requires demonstrating the safety with ageing prediction for another 10 year cycle.

Regardless the approach (or combination of both) is chosen, both the License Renewal and PSR approach have common elements i.e. to perform comprehensive ageing management review and re-validate safety analysis using time limited assumptions in order to demonstrate SC fitness to service for the period of LTO.

In the following section, the License Renewal and PSR elements are discussed in detail.

3.1 The US Licence Renewal Rule

3.1.1 Analysis by the Licensee

The License Renewal Rule is applied at NPPs under the jurisdiction of US NRC, as well as in other countries (e.g. Spain, Belgium) that operate US design NPPs. It is based on 10 CFR Part 54 [5], and 10 CFR Part 51 Implementing National Environmental Policy Act. The US NRC published the original license renewal rule in 1991; it had a broader scope (i.e. active and passive components), dealt with "unidentified" ageing degradation mechanisms unique to license renewal, and had an industry demonstration project.

NRC amended the rule in 1995; it reduced the scope to passive, long-lived structures, and components, dealt with plausible ageing effects and ageing degradation mechanisms, and required the implementation of the Maintenance Rule (MR), because MR primarily focused on active systems and components.

The main principle of License Renewal is that the regulatory process is adequate to ensure safe operation of the plant taking into consideration the detrimental effect of ageing, and that current licensing basis must be maintained and carried forward into the period of extended operation in the same manner and to the same extent, as it was before.

The applicant must prepare and submit a license renewal application in accordance with [6], which contains the following activities: Scoping and Screening, Integrated plant assessment, which is in fact the ageing management review, review of time limited ageing assumptions, updating Final Safety Analysis Report (FSAR), and Environmental report. The following sections briefly describe each of the LTO elements.

3.1.1.1 Scoping

Scope of LR Rule involves all safety-related SSC that maintain integrity of the reactor coolant pressure boundary, ensure capability to shut down and maintain a safe shutdown condition, and prevent or mitigate offsite exposures; as well as non-safety related SSC whose failure could prevent safety-related functions. Besides that, it also involves SSC relied upon for compliance with regulations for fire protection, environmental qualification, pressurized thermal shock, anticipated transients without scrams, and station blackout. SSC satisfying above criteria are identified through the **"scoping"** process. A complete list of safety functions and SSC relied upon for compliance with specific regulations is provided in [5].

3.1.1.2 Screening

A list of the SC subject to ageing management review (AMR) is identified through the **"screening"** process. Methods used in the screening process to identify SC subject to AMR must be properly documented and justified. Typically, the SC subject to AMR are passive, long-lived components (mechanical, electrical, and structures) while the active components are covered in the Maintenance Rule, surveillance testing, diagnostics, etc. Besides that, the plant maintenance programmes (predictive, preventive, corrective) are in place to ensure component fitness to service and its reliability, i.e. if a degradation of active component elements is observed through its degraded operational characteristics, it is being either repaired or replaced. It is possible to say, that the original properties of the active component are re-established.

For passive components such as piping, cables and connections, containment penetrations etc, the degradation process cannot be observed that easily; most of them cannot be repaired or replaced as quickly as active components. Some components may be considered as irreplaceable (e.g. reactor pressure vessel). In order to monitor potential ageing effects for long lived passive SC, a specific set of ageing management programmes that are able to detect the ageing of the long lived passive components should be developed and implemented so that to provide for timely detection and corrective measures to prevent the component failure.

Maintenance Rule 10CFR 50.65 for the active components allows failures (for example run to failure for certain component type); therefore the preventive maintenance programmes should be adapted for ageing management. Preventive maintenance programmes, if credited for ageing management should be based on the component level, and do not take any advantage of redundancy and defence in depth.

In order to help the industry to implement the LR rule, the Nuclear Energy Institute (NEI) developed a License Renewal Implementation Guideline, which provides a detailed guidance on how to perform scoping and screening of SSC [9].

3.1.1.3 Integrated plant assessment

Once the list of SC subject to AMR has been identified, an "**integrated plant assessment"** follows. This process is used to identify intended functions that a system, structure, or component must perform (i.e. electrical conductivity, insulation, mechanical support, containment isolation, etc.), and demonstrate that associated effects of ageing will be adequately managed so that the intended function will be maintained consistent with the Current Licensing Basis (CLB) for the period of extended operation. This integrated assessment is based on evaluation of the plant ageing management programmes. Its objective is to check whether the provisions contained in existing plant programmes provide reasonable assurance that the effects of ageing associated with a specific SC in the scope will be managed during extended period of operation.

In order to ensure a common approach in assessing the ageing management programme for SC in the LR scope, the US NRC has developed a Generic Ageing Lessons Learned (GALL) report [7] which is referenced as a technical basis document in [8]. The GALL Report identifies ageing management programmes, which were determined to be acceptable programmes to manage the ageing effects of SSC in the scope of license renewal. The GALL Report is split into two volumes. Volume 1 summarizes the ageing management reviews that are discussed in

Volume 2. Volume 2 lists generic ageing management reviews of SSC that may be in the scope of LR application and identifies ageing management programmes that are acceptable to manage the listed ageing effects. Revision 1 of the GALL Report incorporates changes based on experience gained from numerous NRC staff reviews of License Renewal and other insights identified by stakeholders.

The GALL report can be considered as a "reference book" of degradation mechanisms for the given system/component. This is very important because the applicant, during the ageing management review just follows the specific section in GALL that addresses the same system, compares the tables in GALL and in the AMR report, determines whether the ageing effects listed in GALL are indeed covered in the AMR report, and if not, he must determine the reason why it is not the case.

Another important aspect that the plant operator should carefully consider is that any plant programme, when credited for ageing management, shall 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.

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 GALL report also contains 37 Generic Ageing Management Programmes that address degradation mechanisms for specific component groups (mechanical, electrical and structural components). These generic AMPs are based on the 10-element criteria listed above to show how the plant programmes, if credited for management of ageing effect should be structured.

3.1.1.4 Time limited ageing analysis (TLAA)

As a next step in LR process is the **evaluation of TLAA**. The LR application must contain a list of TLAA that have been identified for the period of LTO. Typically, it contains all TLAA that have been originally envisaged for the plant, as well as new TLAA, that may be identified for LR (e.g. new High Energy Line Break (HELB) zoning, radiological criteria, etc.) TLAA are the plant specific safety analyses that are based on an explicitly assumed time of plant operation or design life (for example, aspects of the reactor vessel design, environmental qualification, etc.).

Sometimes, TLAA are considered as a component residual life assessment; this is however not a correct interpretation. TLAA is an assessment of an identified ageing effect (due to time–dependent degradation) on certain plant–specific safety analyses that are based on an explicitly specified length of plant life (e.g., 30 years). For LTO, once a TLAA is identified, an evaluation is performed to demonstrate that the component will meet its design criteria at the end of the plant life, and that at least one of the following criteria is applicable: the analysis remains valid for the period of long term operation, the analysis has been projected to the end of the period of long term operation, or the effects of ageing on the intended function(s) will be adequately managed for the period of long term operation.

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

a) Involve systems, structures, and components within the scope of LTO;
b) Consider the effects of ageing;
c) Involve time-limited assumptions defined by the current operating term;
d) Were determined to be relevant by the plant operator in making safety determinations as required by national regulations;
e) Involve conclusions or provide the basis for conclusions related to the capability of the system, structure, or component to perform its intended function(s);
f) Are contained or incorporated by reference in the current licensing basis.

In some cases, 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. This is performed in the framework of the LTO project. A typical list of TLAA includes the following:

- Reactor vessel embrittlement
- Environmental Qualification (EQ)
- Concrete containment tendon pre-stress
- In service flaw growth analysis
- Containment liner plate / penetration fatigue, etc.

The environmental qualification is a TLAA for which time limited assumptions must be revalidated. In IEEE Standard 323 for Qualifying Class 1E Equipment for Nuclear Power Generating Stations the basic requirements for qualifying Class 1E equipment and interfaces that are to be used in nuclear power generating stations are described. "The principles, methods, and procedures described are intended to be used for qualifying equipment, maintaining and extending qualification, and for updating qualification as required if the equipment is modified. The qualification requirements in this standard, when met, demonstrate and document the ability of equipment to perform safety function(s) under applicable service conditions including design basis events, reducing the risk of common-cause equipment failure".

Because the environmental qualification is based on time limited assumptions, the EQ programme as well as all relevant EQ documentation must be reviewed and its validity confirmed for the LTO. It may also require evaluation of the original EQ zone maps and conditions which were not originally considered. The acceptance criteria should be projected for the period of extended operation, i.e. 60 years, i.e. projection of 60 years estimated radiation dose as the input for demonstration of equipment qualification. The plant Equipment Qualification programme typically contains provisions to either replace the equipment before reaching its qualified life (40 years) or pre-qualify it for additional life (another 20 years) or re-evaluate the original qualification assumptions so that they remain valid for extended operation. It is a current EQ practice to replace the component after reaching its qualified life.

Full set of TLAA required for LR is provided in Table 4.1-2 and 4.1-3 of [8]. TLAA considerations may require updating the original plant licensing documentation; for example, (i) changes affecting CLB, (ii) supplement to FSAR, and (iii) changes to Technical Specifications.

3.1.2 Guidance to LR implementation

In order to help the licensee preparing the License renewal application correctly, the US Nuclear Energy Institute [1] has prepared a document NEI-95-10 "Industry Guideline for Implementing the Requirements of 10 CFR Part 54 the License Renewal Rule" [9]. This Industry Guideline has been reviewed by the NRC Staff, and recommended to US Licensees for preparing their License renewal application.

The process outlined in this guideline is founded on industry experience and expertise in implementing the license renewal rule. This guideline is intended to maximize the use of existing industry programmes, studies, initiatives and databases. NEI 95-10 is written to be consistent with GALL and the Standard Review Plan.

3.1.3 Inspection by NRC Staff

The NRC staff in order to review the licensee application for license renewal developed specific inspection requirements included in the Inspection Manual 71002. Purpose of this Manual is to verify: (i) the accuracy of the application, (ii) that plant procedures have been established to implement the AMP prior to entering into the renewal period, and (iii) verify that the plant design basis are retrievable and auditable. The entire LR review process is outlined on Fig.1; it can be seen that the review process is quite complex and besides the nuclear safety, it involves the environmental review too. The public is included in the LR review process as well.

The NRC staff typically performs several specific inspections on site; they may also perform optional inspections if needed.

Typical scope for specific inspection involves selection of one of the structure, system, or commodity group that is not identified as being within the scope of license renewal, interviews onsite staff for their knowledge and involvement in license renewal effort, and verification of whether operating experience was evaluated in determining ageing effects.

Optional inspections may involve a sample of plant modifications or any CLB changes since the date of the LR application (LRA) submitted, determining that the modifications/changes were

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[1] Nuclear Energy Institute, 17761 Street N. W., Suite 400, Washington, D C

included in an annual update, determine the status of the issues raised in early inspections, and determine whether the commitments have been loaded into a plant work tracking system.

For ageing management review the staff selects a structure or component that was in the scope of LR, but for which AMP was not required, and determines if the absence of AMP has a sound technical basis. It shall be proven that the GALL programmes are applicable to specific SC in terms of components, materials, environments and ageing effects/ageing degradation mechanisms. The review of ageing management programmes focus on verifying consistency with GALL report. The review may conclude consistency with GALL, but also deviations from GALL, In that case, the staff must ensure that there are adequate technical justifications for the deviations. The NRC staff uses the following guidance documents to perform the review:

- Standard Review Plan for License Renewal (NUREG-1800)
- Generic Ageing Lessons Learned (GALL) Report (NUREG-1801)
- Regulatory Guide 1.188, Format and Content for License Renewal Applications
- Nuclear Energy Institute Guideline 95-10

The Standard Review Plan for License Renewal [8] provides technical guidance to NRC staff reviewers, and documents staff's acceptance criteria and review procedures. With this regard, the staff's position is not a regulatory requirement, but is one of the acceptable methods.

The GALL Report contains a compilation of common ageing management programmes that have been reviewed by NRC and National Laboratory staff and which is acceptable to NRC staff. It is a technical basis document for the Standard Review Plan for License Renewal, however it shall not be considered as a scoping document.

The Regulatory Guide 1.188, Format and Content of a License Renewal Application provide guidance to applicants for the format and content of a license renewal application to ensure uniformity of the format and the level of technical content. Beside that, it endorses NEI Guideline 95-10, Revision 6 for implementing the license renewal rule.

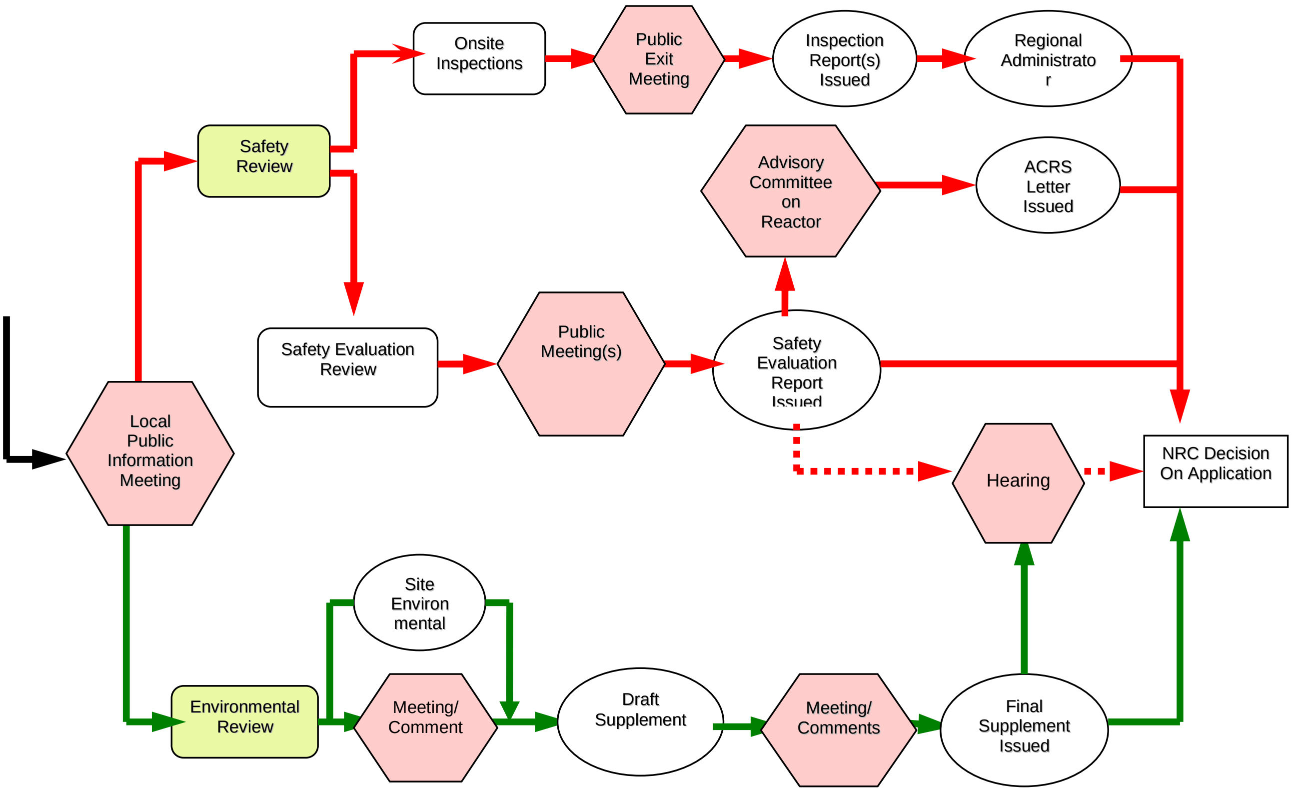

Fig. 1 NRC License renewal review process

The GALL report, SRP-LR, and RG 1.188 have incorporated lessons learned from the past LR reviews, with consideration of appropriate previous positions, operating experience from relevant age-related Licensee Event Reports, as well as NRC staff positions from finalized Interim Staff Positions (ISGs). Besides above guidance documents, the NRC staff refers to commonly used codes and standards, such as ASME Code Sections III and XI, ACI Codes and Standards, IEEE 323-71 Standard, NRC regulatory guides, NUREGs, and selected EPRI Publications.

3.2 Periodic Safety Review

The license renewal rule as described above is used in the USA as well as in other countries operating the US designed PWR (Westinghouse) or BWR (General Electric) nuclear power plants. This approach however requires a comprehensive (regulatory) framework with numerous regulatory and technical reference documents (Industrial standards, IPEE, EPRI, etc.) available. In general, this approach is not applicable "as is" in the EU countries operating nuclear reactors of other (European) vendors partly because the design basis and standards used are different from USA, as well as EU regulators have different regulatory approach.

Another aspect is that LTO in EU is just planning for some oldest nuclear power plants. The real experience with LTO in Europe is with the Russian Federation, which already extended the life time of several nuclear power plants with VVER as well as RBMK design. The operating license was however granted only for 5-10 years of extended operation.

Most of the European Countries use a Periodic Safety Review as a tool to assess the nuclear safety aspects of their nuclear power plants. PSR scope and level of details also depends on Country's specific regulatory requirements, but (typically) involves number of safety factors in the scope that are reviewed every ten years. The "Ageing of SSC" factor is included among these safety factors in the PSR scope. A regulatory acceptance of PSR report can grant continued operation of nuclear power plant for another 10 years; this may however vary among European countries.

Current European practice shows, that PSR regulatory framework normally does not limit number of PSR cycles; the licensee shall demonstrate the safety of the plant operation for the next PSR cycle with some safety margins. This approach is effective for PSR cycles within the period of an established timeframe set forth by license term, design limits, standards, or regulations.

3.2.1 PSR as a tool for LTO assessment

In accordance with recent practice in EU, the PSR focuses on cumulative effects of SC ageing, assessment of plant current status and modifications, operating experience, safety standards enhancement, and internal and external hazard evaluation.

A description of the license renewal process in the USA in section 3.1 showed that both the US NRC as well as industry has developed a comprehensive set of guidance documents that provide the licensee with detailed guidance to elaborate application for license renewal, and the regulator to perform a comprehensive review. This approach, which is US specific and sort of prescriptive is used in some European countries operating the US designed nuclear power plants (e.g. Spain, Belgium).

It appears that majority of EU countries prefers using PSR as an evaluation tool for the plant safety. While the US License Renewal rule is LTO specific, the PSR is used as a tool for the plant safety evaluation on regular basis, i.e. it is not LTO specific.

Currently, the requirements for conducting PSR of nuclear power plants are contained in the IAEA Safety Guide NS-G-2.10 "Periodic Safety Review of Nuclear Power Plants" [11]. The scope of PSR is defined in section 3.3. and identifies 14 safety factors for which a detailed evaluation shall be performed. These safety factors are:

1. Plant design,
2. Actual condition of SSCs,
3. Equipment qualification,
4. Ageing,
5. Deterministic safety analysis,
6. Probabilistic safety analysis,
7. Hazard analysis,
8. Safety performance,
9. Use of experience from other plants and research findings,
10. Organization and administration,

11. Procedures,

12. The human factor,

13. Emergency planning.

14. Radiological impact on the environment.

An overall assessment of plant safety is based on analysis and evaluation of all 14 safety factors. Based on this assessment recommendation for improvements are made. An independent external review should be conducted that includes international experts not associated with production tasks.

PSR activities are typically performed in several phases that involve (i) detailed planning and scheduling, (ii) evaluation of each safety factor, (iii) and elaboration of respective documentation, and (iv) an independent review.

Phase I objective is to establish a PSR scope, PSR organization and define the working relationship among project stakeholders as well as regulatory authority. This phase also includes: definition of the elements for review for each safety factor and a basic agreement with the regulatory body on these elements, development of technical guidelines and working procedures to be followed during the work of phase II and III. Another objective of phase I is to suggest a tentative format and content of the summary reports for each of the safety factors and also the format of the main report of the PSR.

Phase II objective is to perform detailed evaluation of each safety factor, collect all relevant information, justification cases, etc.

Phase III objective is to document the results of analysis and prepare the integral report summarizing the methods used for assessment, acceptance criteria, PSR findings, corrective actions, etc.

Phase IV objective is to perform and independent peer review, which should comment on correctness of the assessment approach, assumptions made and acceptance criteria that were used in the PSR. Depending on peer review results, the operating organization may correct the PSR documentation before submitting it to the regulatory authority.

In case the PSR is going to be used as a tool to demonstrate safe nuclear power plant operation beyond the established operational timeframe, the PSR must contain special provisions to demonstrate that time limited assumptions used in the design of certain SC would be valid for the period of extended operation.

PSR can be applied as an evaluation tool for LTO as well, however it should be considered some limitations to control changes and tendencies with an evolution time greater than 10 years, for which PSR is typically performed. Although a full scope PSR for life extension should be the same in principle there are some specific considerations on SC ageing that may limit the plant operational life time. Most likely, it would need elaborating the specific requirements to conduct the evaluation of time limited analysis (i.e. plant specific analysis that are based on an explicitly assumed time of plant operation or design life) that ought to be included in the scope of PSR too. TLAA evaluation must provide well documented evidence that:

(i) The analyses remain valid for the period of extended operation;

(ii) The analyses have been projected to the end of the period of extended operation; or

(iii) The effects of ageing on the intended function(s) will be adequately managed for the period of extended operation.

It may not be necessary to perform TLAA every ten year cycle; nevertheless, when approaching the end of SC design life, TLAA must be performed in appropriate time before entering the extended operation, in order to provide for a reasonable assurance that the effects of ageing on the intended function(s) will be adequately managed for the period of extended operation.

Another important issue, which is closely related to PSR applicability for LTO, is a presence of sufficient regulatory as well as technical guidance so that both the licensee and operating organization have an agreement on how to prepare application for life time extension based on sound technical basis and justification, and the regulatory authority have established a comprehensive review process on the basis of which it could grant the license for continued operation beyond an established timeframe.

The IAEA is currently revising the PSR Safety Guide in order to reflect lessons learned from industrial and regulatory application since the safety guide publication in August 2003. The IAEA document DS426 is a draft revision of PSR safety guide, which is currently provided to MS for their comments. Changes that have been introduced in the revised PSR guide will further enhance PSR guidance and refers to the IAEA Safety Guides that have been developed to support implementation for some safety factors, e.g. ageing management and LTO. With this regard, this draft introduced a major change i.e. crediting the PSR process for LTO evaluation. In that case, if "PSR is used for long term operation or license renewal, the proposed new lifetime period should be evaluated as a whole, not only the next 10-year cycle. Furthermore, if the long term operation or licence renewal is approved, consistent with the guidance in this document, PSR should continue to be performed in a 10-year cycle after the approval of the new end of plant life".

A section “Review strategy and general methodology” replaced the previous section “Review strategy” emphasizing that during the assessment process a priority should be given to meeting the requirements contained in national safety standards rather than international ones. It also requires among the prerequisites to be satisfied before the review work is started, that the main prerequisite is to be an agreement established between the operating organization and the regulatory body on PSR Basis Document. There are also some recommendations on the scope and structure of such a document. This section became significantly bigger and it provides now more comprehensive approach to the review strategy.

A short summary what has been modified in the draft PSR Safety Guide is as follows:

- There are the same 14 safety factors recognized by both the present standard and the new one in the section “Safety factors in a periodic safety review”, but the structure of the safety function subsections is different. Instead of two units in each subsection (“Objective” and “Description”) there are now three ones in the new Safety Guide, such as “Objective”, “Scope and tasks” and “Methodology”. This provides clearer guidance on assessment of the safety factors.

- “Scope and tasks” now outlines more precisely the borders of an assessment of a specific safety factor.

- A “Methodology” unit provides recommendations to the safety factor assessment in a comprehensive manner including interrelations between some subsections like the subsection “Actual condition of systems, structures and components” and the subsection “Ageing”, etc. And now every safety factor has a methodology on how it is to be assessed.

- A global assessment became a section which contains more detailed explanation of the process including assessment of the risks associated with the findings during review of the particular safety factors. Consequently a section “Basis for acceptability of continued plant operation” was removed while its statements were included into the new section “Global assessment”.

- In the section “Roles and responsibilities” it is currently defined more precisely what should be reported by the operation organisation to the regulatory body, i.e “all safety significant findings” instead of “all significant findings” of the review, and when “by a date agreed with the regulator” instead of “as soon as they are available”. Also roles and responsibilities of regulatory body are specified in greater detail.

- Some changes were made in section “Review process” (former “Review procedure”). For instance the new standard specifies that “The schedule should take into account that the review of the safety factors is an iterative process and the interfaces between safety factors have to be taken into account”.

- Subsection “Activities of the regulatory body” now clearly states that the regulatory body should establish requirements for PSR as well as approve “Milestones and time frames provided by the operating organization”. The regulatory body should also approve “the PSR Basis Document provided by the operating organization” and “review the PSR reports and assess the findings submitted by the operating organization”. Besides that an additional "function": the regulatory body PSR project manager has been established so that “to prepare an integrated project report”. There are also new requirements for the format and content of that report as well as for the endorsement process with the operating organisation.

- Section “Post-review activities” contains some small changes: “corrective actions and/or safety improvements” were changed to the “safety improvements” and consequently the “programme of corrective actions and/or safety improvements” was changed to the “integrated plan for safety improvement”. It was added also that execution of the Periodic Safety Review and the implementation of safety improvements should result in the revision of design and operation documentation to reflect the current configuration of the NPP.

- Appendix A has extended its content from the old Appendix “Elements of the review” providing interfaces between safety factors (Safety Factors Interface Matrix) as well as inputs, outputs and references to review each Safety Factor.

3.2.2 PSR versus Licence Renewal

The requirements on the format and content of the application for LTO are typically given by regulatory framework. As it was discussed above, the licence renewal rule is generally applicable for the US designed plants, while the PSR approach is widely considered in the EU. Some countries may combine both approaches (e.g. Slovenia).

Nevertheless, whatever approach is chosen the evaluation of LTO should provide demonstration that the plant can operate reliably and safely for the period of extended operation.

The License renewal rule typically grants the extended operation for another 20 years, and the licensee may apply for the extension 10 years before expiration of the plant design life. When the license is granted, the licensee typically continues performing standard monitoring and inspection activities (operation, maintenance), besides that the licensee implements the ageing management programmes for another 20 years of operation.

On the other hand, the PSR approach, which is performed on a 10 year cycle, seems to provide for more frequent assessment of the entire plant conditions in the period of extended operation. It may provide several advantages, e.g. the plant operating experience and the results of ageing management programmes can be evaluated more frequently, and thus provide for important insights of any degradation that may need correction of the respective plant programmes.

4 HARMONIZATION OF AGEING MANAGEMENT PRACTICES

There are three different types of LWRs from different vendors, currently operated in the EU. These are boiling water reactor (BWR), pressurized water reactor (PWR) and VVER type reactors. Although these plants use different design arrangement and construction materials (e.g. RPV, primary coolant systems, containment structure, etc.) the ageing phenomena are mostly the same.

Identification and assessment of degradation mechanisms of SC (i.e. mechanical, electrical and I&C, and structures) in the scope of LTO appears to be a key element of the effective ageing management. The plant should therefore review / modify the existing plant programmes to credit them for ageing management, or develop new ageing management programmes so that to ensure that effects of ageing for SSC in the LTO scope will be managed.

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. A number of existing plant practices and programmes have already some attributes of ageing management programmes. What is needed is to evaluate these plant programmes whether they can be credited for ageing management of SC in their scope, i.e. if they are able to detect the ageing effects, have acceptance criteria, and provide for corrective measures.

Crediting the existing plant programmes for ageing management may have some limitations which are important to know. For example, the ageing management programme is typically oriented to long-lived passive SC that are safety-related or may impact safety functions if they fail. The objective is to maintain SC functions at component level. On the other hand, maintenance programme, which is typically used for active components have broader scope. They include both active and passive SC as well as those needed for emergency operating procedures. The overall goal of maintenance procedures is to maintain overall plant performance. Therefore, if maintenance programme is credited for ageing management, it must be modified so that to include: a defined programme scope, preventive actions, parameters monitored or inspected, and detection of ageing effects, monitoring and trending, acceptance criteria, corrective actions, confirmation process, administrative control and operating experience.

Currently, there is no common approach in the EU that would set up the requirements on format and content of the plant ageing management programme, similar to that one published in GALL; the advantages of a common harmonised approach in the ageing management field is obvious. It may be potential action at EU level to develop it so that it will satisfy common principles and requirements from safety authorities and utilities. Good ageing management approach is to start since the beginning of operation. This is not because the SC would require immediate ageing attention, but the data collection is vital for monitoring and trending, as well as performance of time limited ageing assumptions

There is also another aspect that would benefit from common EU action, i.e. generic ageing lessons learned. In EU currently 143 nuclear power units are in operation with average age of 27 years. Similarly to US approach, it may be possible to develop a comprehensive database of ageing related effects applicable to SC different materials, and environments. The information on ageing are currently scattered through out the industry, operating organisations, TSO and research institutes. One possible way to integrate ageing lessons learned for different type of reactors operating in EU could be to develop an international generic lessons learned report. This way it could be possible to identify as many SC degradation mechanism/ageing effects as possible and prepare effective safety strategies and practices for inspection and techniques. Such an action has been recently launched by the IAEA in the form of the Extra-Budgetary

Programme on International Generic Ageing Lessons Learnt (IGALL) with participation of 22 countries and of the EC-JRC as international organisation.

Harmonization of safety requirements for the EU nuclear installations is vital part for the future development of nuclear energy. The European Council has adopted Directive 2009/71/EURATOM in June 2009, which objective is to establish a community framework in order to maintain and promote the continuous improvement of nuclear safety and its regulation, and ensure that Member States provide for appropriate national arrangements for a high level of nuclear safety to protect workers and the general public against the dangers arising from ionizing radiations from nuclear installations. This Directive recognizes the IAEA Fundamental Safety Principles and Nuclear Safety Standards to constitute a framework of practices that Member States should consider when implementing this Directive.

This EC Directive sets minimum requirements on nuclear safety; however this Directive does not prevent the Member States from taking more stringent safety measures if they deem appropriate. Members States shall ensure that their national framework for nuclear safety is maintained and improved when necessary considering lessons learned, operating experience, and insights from analysis, assessment of nuclear safety, and research and development. This is generally applicable to all stages of nuclear power plant operation, including LTO.

In what follows an insight on regulatory and technical reference documents that are currently available to support LTO in European countries is given.

4.1 WENRA[2] Reference Levels

The WENRA Reactor Harmonization Working Group has developed a set of Reference Levels [10] with the aim to continuously improve safety and to reduce unnecessary differences between the countries. The Reference levels published in [10] are divided in 18 topical areas, and establish high level requirements for each topical area.

A major strength of the Reference Levels is their foundation in a framework of recommendation and guidance that is already widely accepted, the Safety Standards drawn up by the IAEA, in cooperation with its Member States. It should be understood that the purpose of reference levels was however different than to provide for a detailed guidance on addressing each of safety factor.

4.2 IAEA Safety Standards

The IAEA developed series of Safety Guides that provide detailed guidance for performing safety evaluation of the nuclear power plants, ageing management and LTO.

As discussed in previous section, the Safety Guide on Periodic Safety Review [11] provides a general guidance for performing the overall safety review of nuclear power plant, carried out at regular intervals, typically of ten years. This PSR Safety Guide provides guidance on how to evaluate each of the 14 safety factors that are included in the scope. Many EU countries have adopted this safety guide in their regulatory framework for setting the requirements for conducting the PSR of their nuclear power plants.

The IAEA, after publishing PSR Safety Guide in 2003, continued its effort in addressing specific topics of interests, like ageing management and LTO. The PSR Safety Guide has been

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[2] Western European Nuclear Regulators' Association.

supplemented by number of related safety guides, safety reports or other technical documents addressing in detail the ageing management and LTO. For example, requirements for safety factor "Ageing" were developed in greater details in the Safety Guide Ageing Management for Nuclear Power Plant [12] and Proactive Management of Ageing for Nuclear Power Plants [13]. LTO related aspects that are not explicitly addressed in the PSR Safety Guide are contained in the SALTO Final report "Recommendations on the Scope and Content of Programmes for Safe Long Term Operation of light water reactors" [14] and Safety Report "Safe Long term Operation of Nuclear Power plants" [15].

Similarly to US License renewal, the safety Guides [12] and [15] in particular, provide detailed guidance for the development and implementation of effective ageing management programme, and set the minimum requirements for LTO for nuclear power plants. What is currently missing in the chain of EU regulatory and technical reference documents for ageing management and LTO, it is a guidance document that would provide a compilation of common ageing degradation mechanisms for the structures and components used in variety of EU reactor designs (PWR, BWR, VVER, CANDU, GCR, etc.) as well as set of generic ageing management programmes, and corresponding technical basis documents.

4.3 The scope of SSC for LTO

Current practice shows that the selection of the plant SSC for LTO is a crucial element of LTO evaluation process. The list of SSC for LTO is typically more comprehensive than for example for ageing management. Although references [9,15] provide quite detailed methodology and criteria that can be generally applied for selecting the SSC for LTO, it also depends what is the country specific regulatory framework, whether it provides sufficiently detailed guidance and requirements for LTO that operating organization could follow. In any case, it is the operating organization which must develop the LTO approach specific to their NPPs while respecting the country's regulatory framework.

SSC for LTO are identified throughout the scoping and screening process based on selection criteria. This involves SSC important to safe operation as well as those SC not important to safety whose failure could compromise safety functions, and which should be subject to ageing management review.

The question asked by every NPP starting LTO evaluation is: Which SSC should actually be included in the scope of LTO? The outcome of the selection is basically given by selection criteria which may differ country by country. At the beginning of the scoping process, the plant engineers have the system and equipment master list from which they start selecting the systems important to safety, or supporting systems that if fail may compromise safety functions. The result of this first stage is a list of systems with active and passive components.

The IAEA also provides guidance on scoping and screening of SSC for LTO that can be used by both, regulator and operating organizations. There may also be a country specific guidance including a review concept to verify completeness of the list of SSC for LTO. The following are a few points for performing scoping and screening review [15]:

1) All SSC important to safety that ensure the integrity of the reactor coolant pressure boundary;

2) All SSC important to safety that ensure the capability to shut down the reactor and maintain it in a safe shutdown condition;

3) All SSC important to safety that ensure the capability to prevent accidents that could result in potential off-site exposure or that mitigate the consequences of such accidents;

4) Other SSC within the scope of LTO are those whose failure may impact upon the safety functions specified above.

All SC within the scope of LTO and not subject to replacement based on a qualified life or specified time period are identified and included for further reviews for LTO.

Some national regulations also require that all SSC that are credited in a safety analysis to perform a function that mitigates certain types of events also be included in the scope of reviews for LTO. Such events are:

(i) Fires and floods;

(ii) Extreme weather conditions;

(iii) Earthquakes;

(iv) Pressurized thermal shock;

(v) Anticipated transient without scram;

(vi) Station blackout.

As a consequence of the Fukushima Daiichi accident, it is expected that national regulatory bodies require a reinforcement of safety analysis to be performed for the above mentioned events.

Identifying SSC for LTO is the first activity that involves evaluation of dozen plant systems and thousands of plant components whether they should be included in the LTO initial scope. The final list of SC for LTO will be populated based on the results of a comprehensive ageing management review (also called integrated plant assessment).

Some countries do not perform the scoping and screening of SSC, because they have a list of SC which is approved by regulatory body, and SSC included in that list are automatically considered important to safety. Nevertheless, the operating organization is advised to perform the scoping and screening of SSC for LTO, because the original predetermined list may be either incomplete or too long. The scoping and screening process as outlined in [9,15] provides for a systematic guidance to ensure that all SSC will be in the scope.

The result of scoping process is a list of SSC, including all active and passive components. This list is subject to a screening process to select SC to be subject of ageing management review. The screening criteria will apply to identify active and passive components for which ageing management review will be performed. Typically, it involves passive, long-lived SC, some of those may already be included in the ageing management (if such programme has been already implemented at the plant).

The active components are also considered in the scope of LTO however active components are typically in the scope of maintenance programmes. Maintenance or repair normally restores original component properties, e.g. by replacement of worn out parts. It may be necessary to review the plant maintenance programme for its completeness before entering LTO.

Some active components may be subject to both, maintenance and ageing management programmes. In this case, the active part is managed by the maintenance programme, while the passive part may be subject to ageing management programme. Typical example of that arrangement is a reactor coolant pump, emergency core coolant pump, etc. While the active part is subject of surveillance testing and maintenance programme, the passive part is subject of ISI Programme, boric acid programme, bolt integrity programme, or another relevant ageing management programme.

Long lived passive components and structures are typically covered by the ageing management programmes. There may be programmes to address certain degradation mechanism, the environment, or a component group.

The active and passive components that are replaced or refurbished on specified time interval e.g. those that already have defined their "design life" or are located in harsh environment and are subject to Equipment Qualification (EQ) programme are also in the scope for LTO. The EQ programme is a kind of ageing management programme too. In fact, the EQ programme is TLAA for which time limited assumptions must be revalidated; therefore the EQ programme as well as all relevant EQ documentation must be reviewed for the LTO. The EQ equipment is automatically included in the scope for LTO, although it may be treated separately (e.g. within the EQ programme which has its own equipment master list).

The results of scoping and screening process are the initial list of SC that is to be subjected to a comprehensive ageing management review. An independent review of the list of SC for LTO is often required to ensure its completeness. A reviewer should familiarize himself with the methodology used to select SSC and focus his attention on the review procedure in each section. The reviewer should also use Process & Instrumentation Diagrams (P&ID) as the tool to determine where the system boundaries are. For example, the NRC Standard Review Plan for LR [6] addresses scoping and screening review in Chapter 2. Specifically, Table 2-1-1 in the SRP-LR provides sample listing of potential information sources. Table 2-1-5 lists all typical SSC that are in the scope of license renewal. Section 2.2.3.1 provides some examples of SSC that may not be identified as within the scope of license renewal and use them to test the adequacy of the applicant’s scoping and screening methodology.

5 RESEARCH ACTIVITIES TO SUPPORT LTO

When extending the life of structures and components, how far can we go to be still safe? This is a fundamental question that comprises both the economical and safety aspect. Regarding the safety, for SSC important to safety it is necessary to demonstrate that they perform the intended safety functions with sufficient safety margins for the entire period of extended operations. Especially, time limited ageing analysis are typical candidates for research activities. Specific research programmes are already in progress that supports life time evaluation of the nuclear power plant structures and components important to safety. The ageing phenomena 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.

5.1 IAEA

As mentioned in section 4.2, minimum requirements for LTO for nuclear power plants have been defined by the IAEA. The presently missing guidance document that would provide a compilation of common ageing degradation mechanisms for the structures and components used in variety of EU reactor designs with a set of generic ageing management programmes, and corresponding technical basis documents are currently under preparation through the IGALL Programme.

In 2010 the IAEA launched an Extra Budgetary Programme (EBP) which objective is to develop the "International Generic Ageing Lessons Learned Document (IGALL)". This IGALL report will provide a roadmap to ageing mechanisms and effects based on research results and operational experience accumulated to date, and an overview of ageing management programmes for typical plants' components, structures, materials, and environments. The Programme scope will include PWRs, BWRs, VVERs, CANDUs reactors. The EBP IGALL programme is a complementary activity to the previous activities carried out under SALTO (Safety Aspect of Long Term Operation) extra budgetary programme, in which the Institute of Energy and Transport of JRC was actively involved, and significantly contributed to the programme implementation.

The EBP will be implemented under three Working Groups: Mechanicals and Material; Electrical and I & C; Structures; a Technical Coordination Group and a Steering Group. After completion of the IGALL report, the IAEA will have a set of Safety Guides each addressing the LTO specific element, such as the (i) Scoping and screening of SSC, (ii) Ageing management review, (iii) Ageing management programmes, and (iv) evaluation of TLAA.

5.2 OECD/NEA activities on LTO

The OECD/NEA just finalized a project that tackled two important subjects for ageing management of nuclear power plants, i.e. stress corrosion cracking (SCC) and degradation of cable insulation, called the SCC and Cable Ageing Project (SCAP) [16]. The project was financed through a Japanese voluntary contribution to the OECD/NEA.

In the SCAP project 14 OECD/NEA member countries joined in 2006 to share knowledge and three more countries joined during the course of the project. The International Atomic Energy Agency (IAEA) and the European Commission participated as observers.

The objective of this project was to share the corporate knowledge and operating experience to understand the failure mechanisms and identify effective techniques and technologies to effectively manage and mitigate active degradation of SSC in nuclear power plants.

During the project start it was realised that in the limited time available ageing management could not be addressed in detail over a large range of topics. SCC and cable ageing has been recognized as important issues. Cable ageing has been identified in recent years as an area requiring more attention from both the regulators and the industry. The operational experience feedback shows that incidents in these areas often occur and draw both regulatory as well as public attention. These two topics were therefore chosen for specific study in the project as examples of an area in which ageing management has been applied for many years and one in which ageing management still needs to be developed in an internationally coordinated study which could yield greater insights into the management of these failures.

The specific objectives of the project were to (1) Establish a complete database with regard to major ageing phenomena for SCC and degradation of cable insulation through collective efforts by NEA members, (2) Establish a knowledge base in these areas by compiling and evaluating the collected data and information systematically, (3) Perform an assessment of the data and identify the basis for recommendable practices which would help regulators and operators to enhance ageing management.

The SCAP Report summarizes the SCAP work and shared knowledge from all participants as a result of 4 years of technical interactions. This report collects the recommendable practices identified during the project that are intended to strengthen technical approaches to optimize ageing management in the areas of SCC and cable ageing. The SCAP SCC, cable data, and knowledge bases provide extensive information that may be of interest to designers, manufacturers, operating organizations as well as regulatory authorities. It also provides commendable practices applicable to new reactors.

The working process of SCAP has also provided an important example to demonstrate how such a challenging task can be effectively addressed and therefore could be used as a basis for other topics in ageing management. Vital elements of the working process have been the identification of priority items of common interest, the assignment of a dedicated project coordinator, chairperson and clearinghouse with expert knowledge and lead organizations providing input to start the discussion and giving orientation. More details on SCAP results can be obtained in [16].

5.3 International Forum for Reactor ageing Management (IFRAM)

While reviewing past programs on AM/LTO US NRC and Pacific Northwest National Laboratory (PNNL), Richland, WA, USA discovered that there is quite an overlap between existing national programs, and that it is too challenging for one (or two organisations respectively) alone to review all the existing work on AM/LTO. At this stage it was felt that an international network involving a larger number of nuclear organisations around the world would be beneficial, not only in reviewing past and existing national or international programs related to AM/LTO, but also to bring together experts who exchange information on operating experience, best practices and emerging knowledge.

It was proposed to establish the “International Forum for Reactor Ageing Management (IFRAM)” [17]. It is intended to be an international network (umbrella) to consolidate the present knowledge on AM/LTO and to keep this knowledge available for the next generation of nuclear staff. Information and knowledge on AM/LTO of the various countries could be shared. It is however recognised that concerns about intellectual property (IP) may limit this exchange. IFRAM should also identify open gaps for AM/LTO and prioritize the necessary R&D work to fill these gaps. IFRAM is also seeking to avoid the duplication of efforts since the human and financial resources available for AM/LTO are limited.

The first step in establishing IFRAM was the Asian Engagement Workshop, organised in Seoul, Republic of Korea from 11th – 13th October 2009. In total 36 experts from Japan, Republic of Korea, the Peoples Republic of China, Taiwan, India and the USA participated in this event. The aim of the workshop was to discuss the idea of IFRAM and how such an international forum could be established, what are its objectives and what are the benefits for its members.

The Asian Engagement Workshop was followed by the European Engagement Workshop organised in Petten, the Netherlands from 25th – 27th May 2010. In total 29 persons from 13 European countries, the USA, IAEA and the European Commission (EC), General Directorate Joint Research Centre (JRC) participated in the European Engagement Workshop. The aims of this workshop were the same ones as for the Asian Engagement Workshop. In addition to the establishment and objectives of IFRAM also scientific and technical issues on AM/LTO for 60 years were discussed.

The sessions with individual presentations of the workshop participants was followed by a panel discussion on the establishment of IFRAM, i.e. need for an international forum on reactor ageing management, benefits for the members, structure & organization, relationship with national and international organizations, intellectual property issues, etc. The following four larger topics were discussed, although there was no strict separation between them:

- Topic A: Define the Benefits of the International Forum—what are the likely returns for those who participate?
- Topic B: Describe ways national programs could be linked to the International Forum—how to leverage so that benefits are greater?
- Topic C: Describe the best ways for International Forum to share and exchange information—Recommended “next steps” for cooperation.
- Topic D: Develop matrix of individuals/organizations technical programs—who is doing what?

At the end of the workshop the participants agreed on the following symptomatic concrete steps for the further establishment of IFRAM.

- A matrix/report on past and on-going projects related to AM/LTO will be issued. It should be a living document and updated regularly.
- IFRAM should be a network with unlimited duration, not a project with a fixed closure date. It should serve as a communication platform where participating organisations can exchange ideas and knowledge on materials degradation, AM and LTO of NPPs. Contributions to IFRAM are done in-kind. For the establishment and smooth running of IFRAM the experience from previous European Networks, e.g. AMES, ENIQ, NESC, etc., should be used. Strong links with IAEA and NULIFE should be established.
- Member organisations of IFRAM can form individual working groups for collaboration on specific (scientific) issues. These projects should have a limited duration with fixed dates for deliverables (decided by the Steering Committee). The output of these projects will only be distributed to the participating organizations in the project.

On 4th and 5th August 2011 IFRAM had its kick-off event in Colorado Springs, CO, USA. 40 persons attended the IFRAM kick-off event: 15 from Asia (Japan: 6, Republic of Korea: 7, PR China: 1, Taiwan: 1), 10 from Europe (Czech Republic: 2, Finland: 1, France: 3, Germany: 2, Sweden: 1, EC-JRC: 1), 14 from the USA and 1 from the IAEA. Three focus groups were established during the kick-off event on the following topics/tasks: (1) Handbook on reactor ageing management (best practice document), (2) identification of research issues for reactor ageing management and (3) technologies for monitoring ageing and materials degradation. For the handbook on reactor ageing management an IAEA common research project (CRP) is seen as the best mechanism to perform such a task. Another outcome of the kick-off event was that most participants agreed that a list of on-going and planned research projects on reactor ageing management is the most immediate need. IFRAM is currently working on establishing the three focus groups and define their work programs. A sole session on IFRAM for the 3rd IAEA PLiM Conference in Salt Lake City in May 2012 is foreseen. JRC-IET is currently making attempts to establish links between IFRAM and NULIFE/NUGENIA (see below).

5.4 SNE-TP Technical Working Group Gen II / III

The European Commission launched the Sustainable Nuclear Energy Technology Platform[3] (SNE-TP) which aims at coordinating Research, Development, Demonstration and Deployment (RDD&D) in the field of nuclear fission energy [18]. It involves stakeholders from industry (technology suppliers, utilities and other users), research organisations including Technical Safety Organisations (TSO), universities and national representatives. Considering advantages and challenges of LTO, members of SNE-TP proposed a R&D programme to support life time extension of Light Water Reactors (LWR) up to 20 years. The objective of this R&D programme is to develop new methods for prevention and mitigation of the plant ageing and optimization of operating methodologies and practices in EU. It is expected that specific R&D activities to support life time extension will start soon under the Technical Working Group for Gen II/III reactors (TWG Gen II/III).

This TWG shall establish the roadmap and priorities of the R&D to be performed or initiated from 2010 to 2020 in the area of Gen II and III reactors and under sponsorship of the industry. The selected topics are: LTO and harmonisation of justification methodology, performance improvement, and harmonisation of methodology to assess new features of Gen III reactors, fuel cycle, harmonised codes & standards. The prioritisation list of topics provided related to LTO is: European harmonised plant design and safety justification methodology, integrity assessment, ageing mechanisms of Structures-Systems-Components, ageing monitoring, prevention and mitigation of ageing, pre-normative research, codes and standards, safety issues in instrumentation & control and electrical systems. Clearly some of these prioritised topics are covered by the IAEA EBP on IGALL and the research will not be doubled by the TWG Gen II/III.

Outside of LTO a strong consensus was reached on the following topics: employee dose reduction, human resources availability and knowledge management, operational lessons learned and improved design, power upgrade, fuel performance, external factors, waste and decommissioning. On the contrary dissensions were found in ranking the urgency of research related to the following topics: man system interface, quantification and advantages of supercritical water reactor, public acceptance.

Taking the above into consideration the TWG will concentrate on four areas from which research project proposals will be generated: i) LTO, ii) advanced technologies for components, iii) Cross-cutting safety, iv) Fuel & fuel cycle optimisation. Due to obvious synergies with other established networks dealing with currently operating reactors, in particular NULIFE (= European network on reactor ageing and structural integrity of NPP components; see below) [19] and SARNET (= European network on severe nuclear accidents) [20], these two network are merged with the TWG Gen II / III of SNE-TP in November 2011 to create one sole European network / working group on Gen II / III reactors.

[3] Sustainable Nuclear Energy Technology Platform was launched in Brussels in September 2007.

5.5 Life prediction of NPP structural components for LTO

The European Commission Joint Research Centre (JRC) has been established by EURATOM treaty in 1957 to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies support implementation of EU polices community research, independent of special interests, private and national. JRC comprises seven institutes that are located in five different EU countries.

The Institute for Energy and Transport located in Petten, the Netherlands, focuses in its nuclear energy related units on material research, and support of life prediction of materials used at nuclear power plants. It operates several networks, e.g. ENIQ on effectiveness and efficiency of ISI programmes and strategies and inspection qualification, and participates to Nuclear Plant Life Prediction (NULIFE) Network of Excellence that is successor of former SAFELIFE network (that included research programmes on NPP component integrity, life time extension, in-service inspection, etc.).

The NULIFE network of Excellence aims at creating single organisational structure capable of working at European level to provide R&D and harmonised understanding in the area of lifetime evaluation methods for structural components to the nuclear power industry and the relevant safety authorities. It has been established in 2006 and comprises 10 EU contractors. NULIFE is co-financed by EC-RTD budget and the coordinator is VTT, Finland. The SNE-TP recognizes NULIFE as an instrument to implement current and future LWR issues of Strategic Research Area (SRA) relevant to LTO.

The NULIFE work plan involves the following pilot projects that focus on (i) development of a guideline for the development of high quality stress corrosion crack growth data, (ii) thermal fatigue analysis, (iii) recommendations on good practice approach for assessment of dissimilar welds, as part of an overall Leak before Break (LBB) concept, and (iv) unified procedure for life prediction of VVER components.

In addition, several projects jointly financed by NULIFE partners and EC have been prepared to support LTO related ageing analysis for NPP components, e.g. prediction of the effects of radiation for reactor pressure vessel and in-core materials using multi-scale modelling for extrapolation to 60 years plant lifetime, (ii) identification of the realistic failure modes relevant to the ageing and lifetime management of pressure boundary/pressure circuit components in LWR and VVER systems as well as gas-cooled reactors, (iii) treatment of long term irradiation embrittlement effects in RPV safety assessments for long term operation up to 80 years, and (v) nuclear plant life management training scheme. The VERLIFE project that focuses on harmonization of life extension practices for VVER reactors has been launched as part of NULIFE. The main goal of the VERLIFE project is the preparation, evaluation and common agreement on a unified procedure for life assessment of components and piping in VVER type NPP. This procedure is based on former Soviet rules and codes, as VVER components were designed and manufactured in accordance with requirements of these codes and from prescribed materials. Critical analysis of the possible application of some approaches used in PWR type components is being performed, and such approaches are incorporated into the prepared procedure as much as possible with the aim of a harmonization of VVER and PWR codes and procedures.

Beside the projects mentioned above, which are mainly dealing with metallic NPP components, recently also projects focusing on non-metallic NPP components (concrete containment, I&C) or on other issues relevant for safe operation of NPPs, in particular ISI / NDE and human factors (man-machine interference) have been initiated. This trend is in agreement with the establishment of one sole network / organisation on Gen II / III. In November 2011 the major European networks / working groups on Gen II / III, i.e. NULIFE, SARNET (severe nuclear accidents) and the TWG Gen II / III of SNE-TP, have been merged to one single (legal) organisation on Gen II / III, called NUGENIA. The inclusion of the “European Severe Accidents Research Network (SARNET)’ is the result of the Fukushima-Daiichi accident. NUGENIA will have the following main working areas:

1. Plant safety and risk assessment,
2. Severe accidents,
3. Core and reactor performance,
4. Integrity assessment and ageing of SCC,
5. Fuel & waste management and dismantling of NPPs,
6. Innovative Gen III design and
7. Harmonisation

Working programs for all these working areas are currently in preparation.

5.6 Operational experience feedback and LTO

The nuclear power plant operational experience has been used for many years to improve the safety of nuclear facilities throughout the world. The operating experience feedback is extremely important for the plant ageing management and LTO.

In the European Union, in order to support the Community activities on evaluation of NPP operational events, a centralized regional "Clearinghouse" on NPP operational experience feedback (OEF) [21] was established in 2008 at the JRC-IET, on request of nuclear Safety Authorities of several EU Member States, in order to improve the communication and information sharing on OEF, to promote regional collaboration on analyses of operational experience and dissemination of the lessons learned among the participants.

One of the technical tasks of the European Clearinghouse consists in performing in depth analysis of families of events ("topical studies") in order to identify the main recurring causes, contributing factors, lessons learned and to disseminate and promote recommendations aiming at reducing the reoccurrence of similar events in the future. The topics that were selected for the 2010 topical studies that were proposed by participating countries involve, among others the events related to ageing which underlines the importance of ageing related lessons learned for LTO of nuclear power plants.

Currently, EU Clearinghouse is preparing a Topical Operational Experience Report (TOER) on ageing related events of the nuclear power plant SSC. A list of events that involve ageing related issues will be populated as a result of screening the international operating experience. The event list will be further analysed in order to identify events involving component failures due to ageing, and provide an overview of the most common ageing related events, components involved, and associated ageing degradation mechanism / ageing effects.

5.7 JRC Networks in relation with LTO

In frame of the JRC-EURATOM FP7 programme two additional networks are operated on the topics of maintenance and of Ageing Probabilistic Safety Assessment (PSA). PSA as tool is widespread and used. Attempts are made to take into account ageing models or data in the PSA methodology. The APSA network [22] is currently developing recommendations for using ageing generic data and interpretation of them with the aim of applying Ageing PSA methodology on passive components.

The APSA Network was initiated within the framework of the JRC FP6 Institutional Project "Analysis and Management of Nuclear Accidents" (AMA) and it was decided to continue these activities in the frame of new FP7 programme. Since 2009 the activities of the Network are performed in the frame of JRC-IET Institutional Project “Plant Operation Safety” POS.

Reason why to use the PSA for ageing evaluation comes from the requirement to accomplish the safety goals during the whole lifecycle of the nuclear installation (including the extended lifetime). For the units which approach the end of initial design lifetime and especially for those which plan to extend the lifetime, it has to be demonstrated that the plant safety level will remain in accordance with this target until the end of operation, and to do that, it is necessary to evaluate the effects of ageing phenomena on the plant performance. On system availability level, ageing can induce the modification of system success criteria, can increase the CCF probability for highly redundant systems, the occurrence of inter-systems CCF, and can change the list of contributors into system unavailability and overall plant risk. Additional argument to use the PSA for ageing assessment proceeds from the significant limitations of the deterministic approach and from the need to prioritize the ageing management or LTO actions to maintain established safety goals.

A primary motivation for the APSA Network is the fact that current standard PSA tools do not adequately address important ageing issues, which could have a significant impact on the conclusions made from PSA studies and applications, especially in case of plants in advanced age operation or LTO. Main differences between a standard PSA and a time-dependent PSA are as follows:

- Time-dependent PSA could explicitly models ageing effects in component failure rates, which generally cause the failure rates to increase with age, while a standard PSA assumes that component failure rates are constant.
- Time-dependent PSA could explicitly model the effects of test and maintenances in controlling the ageing of components while a standard PSA does not.
- Standard PSA neglects the components that have small failure probabilities, not taken into account the fact that these probabilities could suffer dramatic changes in time; passive components are not included in the models
- Time-dependent PSA could explicitly calculate the ageing effects and age dependence on the core damage frequency and system unavailability, while a standard PSA does not and, instead, it calculates constant values for the core damage frequency and system unavailability.

Currently, activities related to ageing evaluation are performed in the frame of the following programmes:

- Periodic Safety Review,
- Ageing Management,
- Maintenance Optimization,
- Long Term Operation.

Accumulated knowledge from APSA should help PSA developers and users to incorporate the effects of equipment ageing into current PSA tools and models, to identify and/ or develop most effective corresponding methods, to focus on dominant ageing contributors and components and to promote the use of PSA for ageing management, LTO activities and for risk-informed decisions.

Benefits from the APSA Network are in particular the European wide dissemination of information related to a better understanding of important issues in modelling of ageing phenomena in PSA applications, increased knowledge on use of different approaches and methods to include ageing effects into PSA models, new experience based on particular case study evaluations and feasibility studies as well as information on the effort involved when applying different APSA related methods.

The SENUF Network [23] was founded in 2003, after an organizational meeting of the interested parties held in Petten on July 3-4, 2003. The Working Group on "Safety of Nuclear Facilities in Eastern Europe dedicated to Nuclear Power Plant Maintenance", was founded with the following objectives:

- Review and identification of the open (generic/specific) maintenance related issues
- Promote well designed and prepared maintenance plans for SSCs
- Support the implementation of advanced maintenance approaches, including implementation of preventive (condition based) maintenance as well as preventive mitigation measures
- Evaluate advanced risk informed maintenance approaches and provide assistance on its implementation
- Maintain a database (link) on operation experience in relation to maintenance

Work programme includes:

- Monitoring the effectiveness of maintenance program through the use of MPI (Maintenance Performance Indicators). Comparison of engineering and operational practice, analysis of support tools.
- Benchmarking of optimised approaches to maintenance. Special emphasis was given to equipment reliability approaches, plant life management models, value based maintenance (asset management) models.
- Addressing the management of spare part and obsolescence; of outsourcing and contracting; of knowledge management in relation to the maintenance program; identification of needs, and suitable tools for training of maintenance personnel.

Additionally SENUF may answer specific request from EU nuclear organisations for organising workshops with the aim of favouring exchange of experiences. This allows progressing toward harmonized approaches in the EU in the management of safety related issues. As an example a two day workshop has been organised in late 2010 where EU utilities, joined by one regulator, exchanged their experience (difficulties and recommended approaches) about preparation of Periodic Safety Review. The workshop gathered specialists of 10 countries representing all reactor types operated in the EU (except BWRs).

Both networks gather nuclear energy stakeholders of the EU with more participation of Engineering specialists in SENUF and more TSO specialists in APSA.

6 CONCLUSIONS

The Fukushima accident demonstrated the necessity of having strong safety assessments, reliable defence in depth and strong regulatory bodies. In the EU one of the consequences of this accident has been a stronger will in promoting harmonized regulatory approaches, a domain where Member States remained long time concentrated on their national rules. In view of the EU's target of reducing CO_2 emission by at least 20% in 2020 nuclear will continue to play a significant role for reliable power generation. Therefore, activities at JRC EURATOM programme aim at providing the scientific and technical knowledge - especially in safety important issues needed for Community policy support and for helping to enhance safety in general.

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.

Operation of ageing nuclear power plants also requires a strong research support to address key issues relating to ageing and life prediction of SSC. 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.

JRC will continue to develop its actions promoting harmonised approaches in specific issues like exchange among licensees about their way of conducting Periodic Safety Reviews, upgrading safety for mitigating fire events, addressing I&C evolution and associated risks, addressing the way the lack of baseline data for old reactors can be compensated etc. Most of the time these topics are treated in frame of workshops where licensees or regulatory bodies experts exchange their experiences

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Abstract
Plant Life Management (PLiM) of existing nuclear power plants in EU may consider longer term operability. This becomes an option with specific advantages and is under consideration in some Member States. It however unveils number of challenges that are closely related with extending the operational life of structures and components (SC) beyond the established operational time frame at the time they were designed. Safety related aspects of long term operations are obvious; for those SC important to safety that are selected for evaluation it is necessary to demonstrate that they perform the intended safety functions with sufficient safety margins for the entire period of operations. The ageing phenomena 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 with related human factor aspects. A broad and effective dissemination of related scientific results is a further objective.

The European Union, which sees a large diversity of nuclear plant types, needs a targeted investigation to upgrade knowledge on their objective safety levels. Research activities therefore concentrate on providing the scientific and technical knowledge in relation to safety important issues needed for Community policy support and for helping to enhance nuclear safety in EU and beyond. The European Commission launched within the EURATOM framework programme FP7 a research and support programme related to PLiM issues under progress at Joint Research Centre and involves partners from nuclear industry and Technical Support Organizations through several dedicated networks and projects.

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.

The present report also discuses several current challenges, and shows some examples how the research is supporting / or can support the safety assessment of ageing nuclear power plants in the European Union.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

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