JRC TECHNICAL REPORT

ANALYSIS OF AGEING RELATED EVENTS

A summary report from the European Clearinghouse

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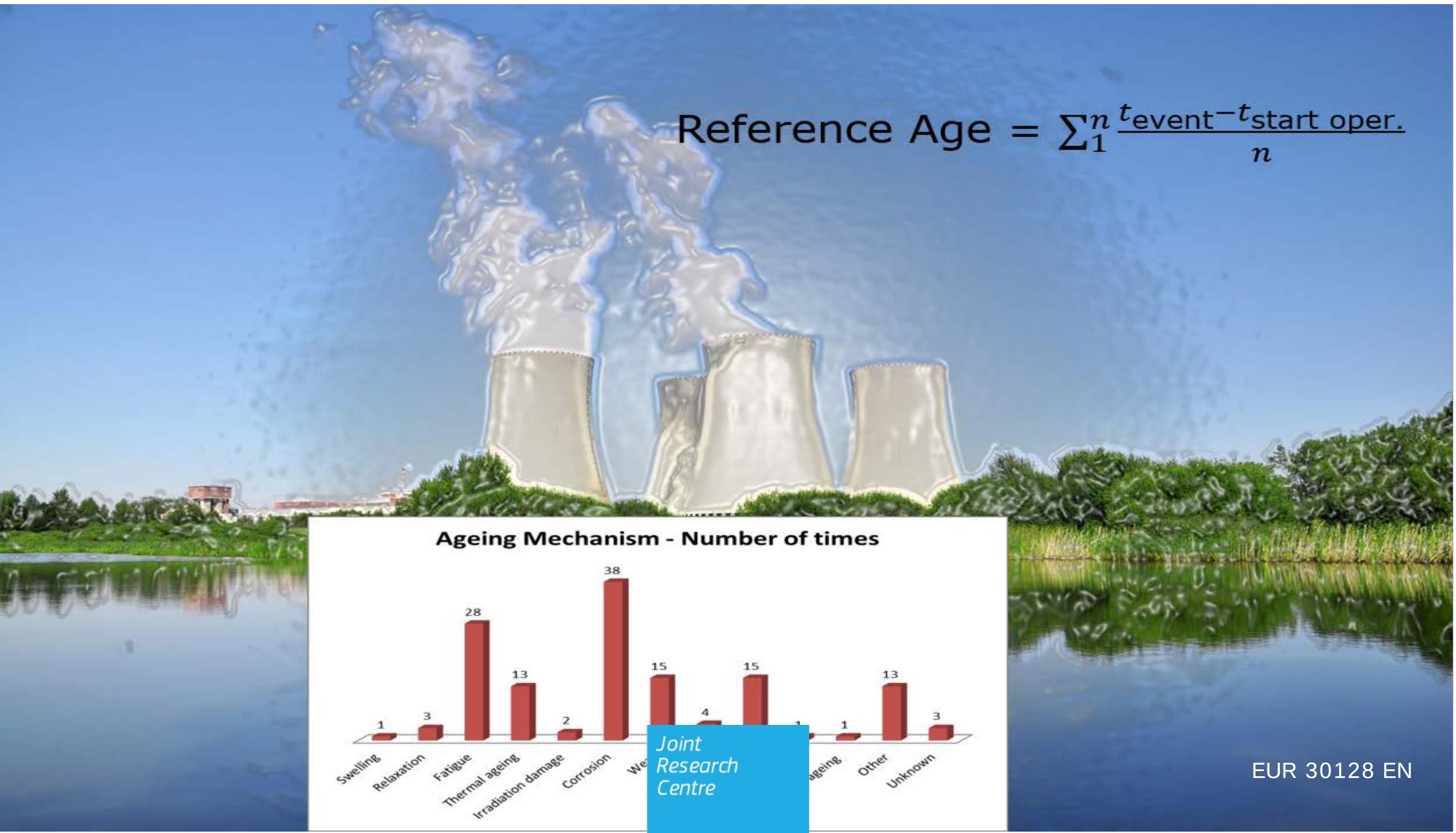
2020



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Abstract

This report presents a summary of the results of a review of available recent international operating experience on ageing events reported by nuclear power plants. Event reports retrieved from IAEA IRS database are characterised and used to derive insights and lessons learned. These lessons learned cover issues such as hidden deficiencies in design visible in aged components only after many years of plant operation, deficiencies in ageing and maintenance programmes, accelerated ageing or the adequacy and effectiveness of the inspection and monitoring methods. The findings of this study aim to support the licensees to improve the safe operation of nuclear power plants and the regulatory authorities to exercise their oversight role.

Acknowledgements

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1. INTRODUCTION

Nuclear safety of the operating nuclear power plants (NPP) has to be in the core of their life management. NPPs have to be operated safely and reliably. European Countries involved in nuclear energy are spending their efforts in improving safety of the operating plants and of those under construction, which is in accordance with the Euratom Treaty obligations. To this respect, the IAEA requirements for the safe operation of nuclear power plants identify, among others priorities, Maintenance, Testing, Surveillance and Inspection programmes and Ageing Management of safety related components.

Recognising the importance of peer review mechanisms in delivering continuous improvement to nuclear safety, the amended Nuclear Safety Directive [1] introduced a European system of topical peer reviews (TPR). The subject 'Ageing Management' was chosen in 2017 as the first TPR exercise on the basis of the age profile and the potential long term operation of European NPPs. The national assessment reports [2] prepared under this first TPR gave numerous examples where operating experience (OPEX) has been used to inform ageing management. There are many existing fora for sharing OPEX. For example, the IRS and IGALL managed by the IAEA , the CNRA and CSNI under the OECD-NEA, and the European Clearinghouse on Operating Experience Feedback of the JRC of the European Commission.

2. AGEING AND LONG TERM OPERATION

The original design life of structural, mechanical and electrical components, particularly those that technically limit the power plant operation (e.g. reactor pressure vessel, containment, 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 during the initial design. While economical feasibility falls into operating organization competence, a decision regarding the plant safety level depends on country's regulatory requirements. Generally, a thorough technical assessment of the plant physical condition is needed, so that to identify safety enhancements or modifications, and the impact of changes to NPP programmes and procedures necessary for continued safe operation.

Long term operation (LTO) of nuclear power plants offers numerous benefits. For instance, it is economically advantageous compared to other power sources. This is because it requires a much lower capital investment cost, leading to low investment risks for investors and capital markets, and lower consumer costs. Furthermore, it reduces the EU’s energy import dependency on, primarily, fossil fuels and provides reliability to the grid.

As mentioned in the communication from the European Commission COM(2017) 237 on the Nuclear Illustrative Programme (PINC) [3], many operators in Europe have expressed the intention to operate their nuclear power plants for longer than envisaged by their original design. From a nuclear safety point of view, continuing to operate a nuclear power plant requires two things: demonstrating and maintaining plant conformity to the applicable regulatory requirements; and enhancing plant safety as far as reasonably practicable. Depending on the model and age of the reactor, national regulators assume that granting long-term operation programmes will mean extending their lifetime by 10 to 20 years on average.

3. AGEING OF THE EUROPEAN FLEET

The lack of new build over the last 25 years or so has resulted in a switch within the industry. It has moved from design, construction and the development of new systems to the strengthening of safety systems, both through engineered safeguards and the implementation of rigorous safety assessment and the life extension of existing reactors, where ageing management of structures, systems and components plays a central role.

There are 125 nuclear power reactors in operation in the European Union. The age distribution of current nuclear power plants is showed in Figure 1. Major part of the EU reactors are between 30 to 43 years old. Hence, from both the safety and security of supply viewpoints, ageing of these power plants is of increasing concern to European policy makers, citizens and utilities. The possibility of extending the life of the existing plants is very attractive to utilities, especially given the public opposition in several European countries to construct new NPPs.

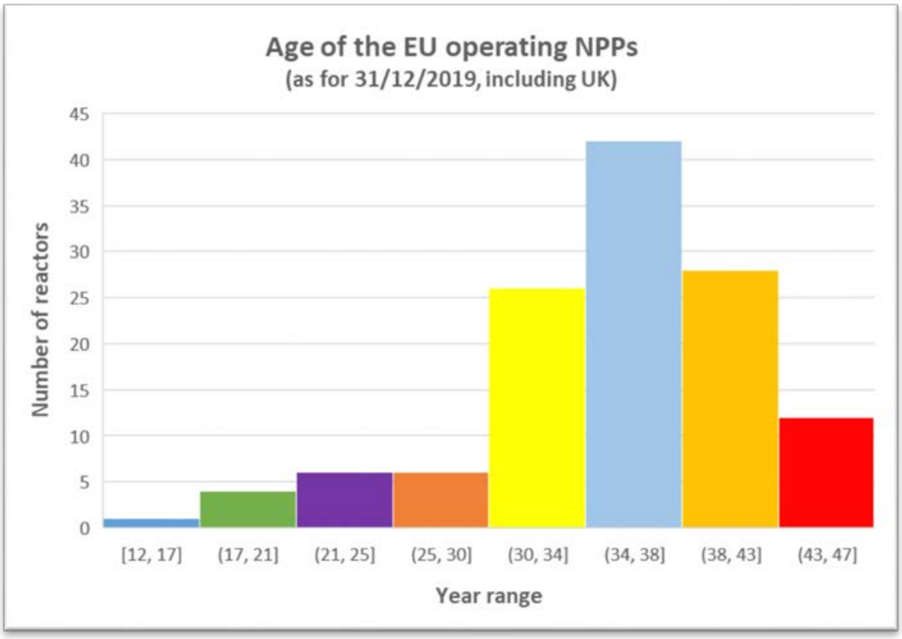


Figure 1: Age distribution of the EU operating nuclear power reactors

4. THE EUROPEAN CLEARINGHOUSE

The European Network on Operating Experience Feedback (OEF) for Nuclear Power Plants [4], or European Clearinghouse, was established in 2008 by European nuclear safety regulators. The aim was to promote the regional sharing of operating experience, the dissemination of lessons learned from NPP operation, and the understanding of the role of OEF systems in the safe and reliable operation of existing and new build NPPs. The centralised office of the European Clearinghouse is operated by the Joint Research Centre (JRC) of the European Commission at Petten (NL) site. Figure 2 shows the main tasks carried out and deliverables issued in support of the Clearinghouse network members.

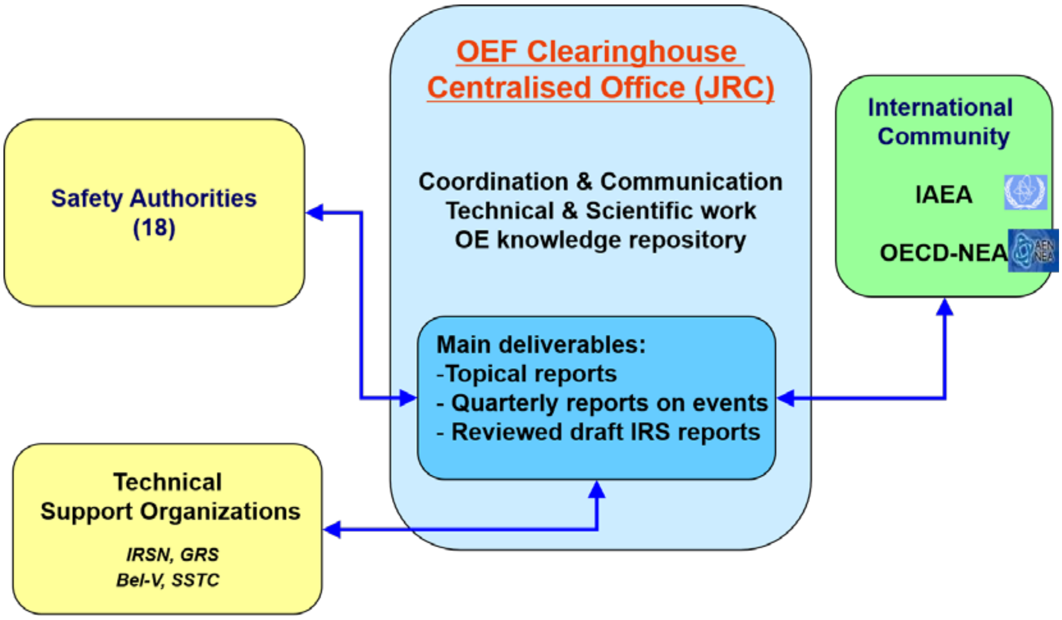


Figure 2: Participants and deliverables of the European Clearinghouse

The European Clearinghouse regularly carries out in-depth analyses of events related to a particular topic (the so-called "topical studies") in order to identify and disseminate the lessons learned aiming at reducing the recurrence of similar events in the future. The Clearinghouse Steering Committee requested in 2017 to update the topical study on Ageing (previously issued in 2011) with the objective to draw generic and case-specific lessons making them available to the members of the European Clearinghouse. A summary of methodology used and the results obtained in the new study on Ageing [5] is presented in the following sections. The lessons are derived from the analysis of ageing related events occurred in NPPs in the last 10 years, reported between 01/01/2008 and 30/06/2018 in the IAEA IRS database.

5. LESSONS LEARNED FROM AGEING EVENTS

5.1 Events screening in the IRS database

The International Reporting System for Operating Experience (IRS) is an international system jointly operated by the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency of the Organisation for Economic Cooperation and Development (OECD/NEA). The IRS was established as a simple and efficient system to exchange important lessons learned from operating experience gained in nuclear power plants of the IAEA and NEA Member States. The IRS database contains about 4000 event reports with detailed descriptions and analyses of the event's causes that may be relevant to other plants.

The screening of ageing related events was carried out in two steps:

- Step 1: The query capabilities of the IRS database are used to retrieve an initial list of potentially relevant events.
- Step 2: The reports obtained from the previous step are briefly reviewed to confirm their relevance. Even if apparently relevant, a report could be screened out if it is insufficiently detailed or if its quality is too low to be useful for the purposes of the study.

The query result in the IRS database for the period 01/01/2008 - 30/06/2018 was a list of 173 ageing event reports (step 1), which were reviewed to confirm their relevance. After detailed analysis of the 173 event reports (step 2), only 113 reports were considered as relevant.

5.2 Reference age

It was possible in this work to calculate the average age of the nuclear power plant when the event occurred. This can be expressed by:

$$\text{Reference Age} = \sum_{1}^{n}(t_{\text{event}} - t_{\text{start op.}})/n$$

where,

n = final number of selected ageing events

t_{event} = time when the event happened

$t_{\text{start op.}}$ = time when the plant started operation

The analysis provides a Reference Age of 28 years (331 months) with a standard deviation of 10 years (123 months). In other words, on average, ageing related events occur after 28 years from the start of reactor operation.

5.3 Analysis of events

The event reports were characterised according to the following defined criteria: plant status when the event happened, detection means of the event, affected systems, affected components, direct cause, root causes, ageing mechanisms, consequences and corrective actions. This section highlights several relevant findings.

The distribution of root causes is given in Figure 3. A maximum of three different root causes was attributed to each event. Deficiencies in maintenance or surveillance is the most important root cause, followed by deficiencies in design and in ageing management programmes (AMP). To this respect, we infer that the establishment of an effective AMP, as early as possible in the lifetime of the plant, will significantly contribute to preventing events and the resulting consequences.

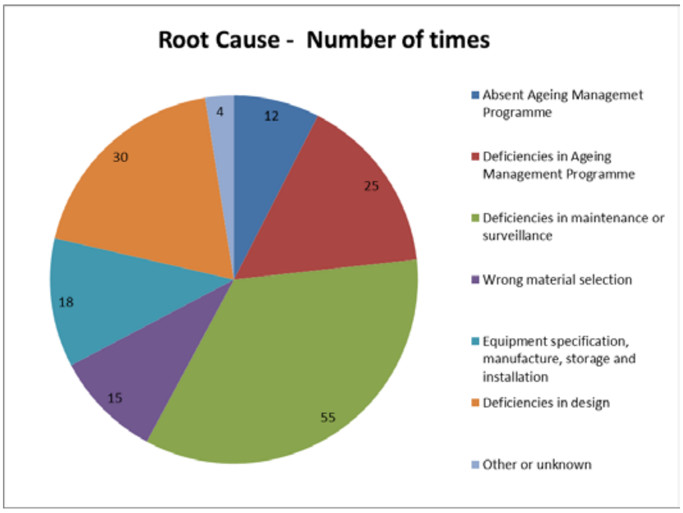


Figure 3: Distribution of root causes

Figure 4 shows that corrosion (38 times) is the main cause of failure, followed by fatigue (28 times). Other important contributions are coming from thermal ageing, wear and electrical ageing. Many events only appear after a long period of operation of a component or material, and the main cause was a deficiency in the consideration of ageing effects in the life design. Figure 5 sheds some light on this issue and illustrates that fatigue is the main degradation mechanism in relation to hidden deficiencies in design.

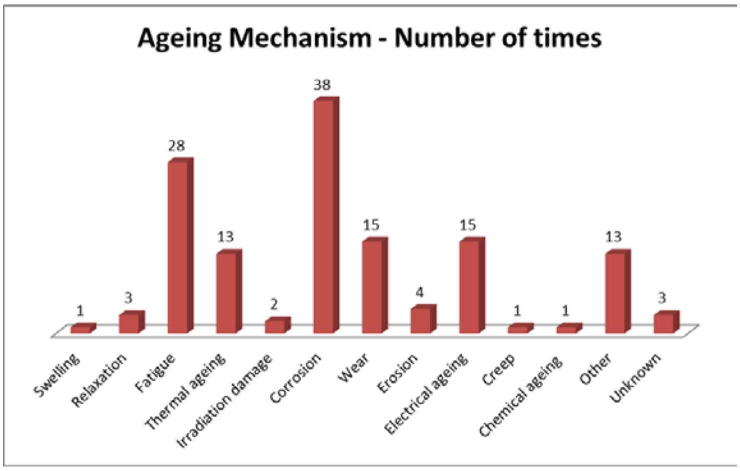


Figure 4: Ageing mechanisms present in the events

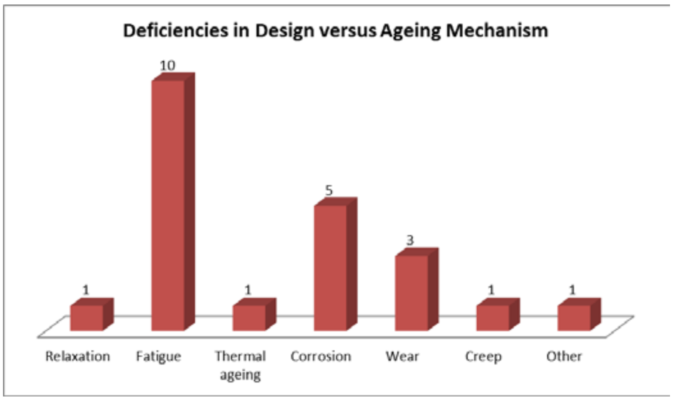


Figure 5: Deficiencies in design vs. ageing mechanism

The analysis performed allows us to correlate deficiencies (or absent) in ageing management programme with the ageing mechanism. In this case, electrical ageing is the most relevant contributor to failure. This indicates the need for improvement of the ageing management programmes of electrical and I&C components.

Figure 6 illustrates the corrective actions. A maximum of three corrective actions were allocated to a single event. As expected, the main corrective action was the replacement or repair of equipment. Changes in maintenance programme was the second most usual corrective action followed, in this order, by monitoring or inspection improvement, design modification and changes in ageing management programme.

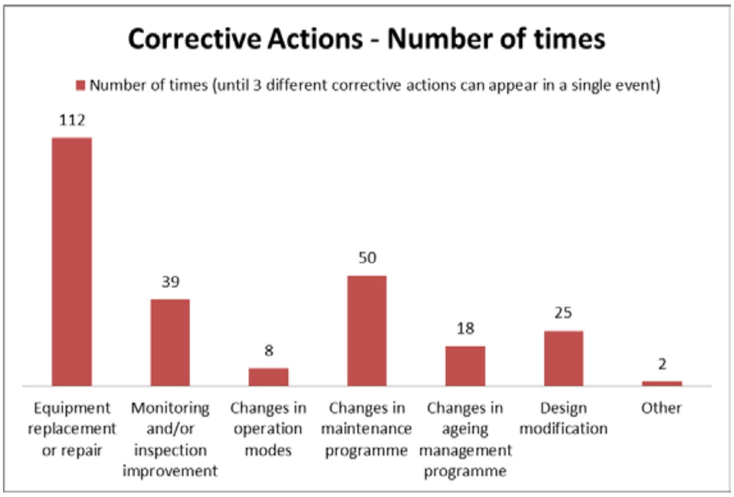
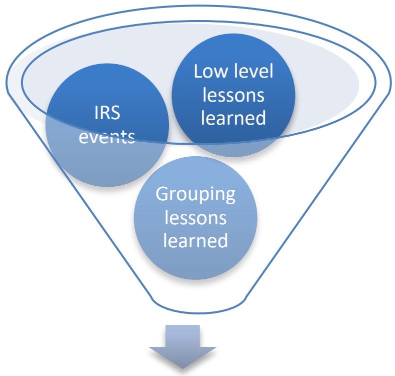


Figure 6: Distribution of corrective actions

5.4 High level lessons learned

The extraction of the lessons learned from the operating experience was completed in two steps. First (step 1), low level lessons learned (LL-LL) were retrieved from the IRS database, or developed in some cases, for a large number of the 113 analysed events. A total of 110 low level lessons learned were obtained. They are given, together with a short summary of the events in [5]. Several lessons were allocated to the same event in many cases. These low level lessons learned are very specific, so that they would have a too limited applicability. To address this issue, the low level lessons learned were grouped under similar topic or underlying key message to get a high level lesson learned (step 2). A total of 10 high level lesson learned (HL-LL) were developed [5]. In order to restrict the length of this report and just give a flavour of the work performed, only several high level lessons learned are presented in Figure 7.



Examples of High level lessons learned

- HLLL-1: Appropriate measures should be taken and design features should be introduced in the design stage to facilitate effective ageing management throughout the life of the plant.

- HLLL2: Ageing Management Programmes as well as maintenance programmes should be reviewed and updated to take into account modifications in the current licensing bases.

- HLLL-3: The adequacy and effectiveness of the inspection and monitoring methods should be periodically reviewed to maintain plant safety and to ensure feedback and continuous improvements of ageing management. The evaluation of technology and methods should consider the need for detection of unexpected degradation, depending on how critical the structure, system or component is to safety.

- HLLL-4: Adequate oversight by the licensee is recommended during all phases of design, procurement, testing, receipt inspection and installation to avoid events where wrong material is used. When a wrong or low performance material is already installed, the rate of material degradation can often be reduced by optimizing operating practices and system parameters.

- HLLL-5: The operating organization should ensure that Ageing Management Programmes (AMP) are reviewed on a regular basis and, if needed, modified to ensure that they will be effective for managing ageing. Where necessary, frequently as a result of reviewing operating experience, new AMPs have to be developed.

Figure 7: Some representative high level lessons learned

6. CONCLUSIONS

Ageing is a concern for the safe long-term operation of NPPs. In particular for the EU nuclear reactors, which are many of them between 30 – 43 years old. To this respect, operating experience from ageing events can contribute significantly to enhance nuclear safety.

The IRS database was screened to select relevant events related to ageing, which took place in the period 01.01.2008 – 30.06.2018. In total 113 events were analysed. The statistical analysis showed that the Reference Age of a nuclear power plant is 28 years. This amount represents the average age of a nuclear power plant when the event occurred. Deficiencies in maintenance or surveillance is the most important root cause, followed by deficiencies in design and in ageing management programmes. Corrosion is the main degradation mechanism, followed by fatigue. Other important contributions are coming from thermal ageing, wear and electrical ageing. Many events only appear after long-term operation of an aged component or material, and the main cause was a deficiency in design that was hidden.

110 low level lessons learned (specific for the events) and 10 high level lessons learned (generic) have been obtained in this study. They cover different areas, such as hidden deficiencies in design, the impact of ageing on maintenance and inspection, deficiencies or lack of ageing management programmes, use of wrong material, etc.

This study highlights that the continuous analysis of ageing related events and the efficient utilization of operational experience provides important insights for improving the quality of ageing management programmes and for preventing the occurrence of unusual events.

References

[1] Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom.

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2014.219.01.0042.01.ENG

[2] Topical Peer Review exercise on Ageing Management http://www.ensreg.eu/country-specific-reports

[3] Communication on a Nuclear Illustrative Programme (PINC).
https://ec.europa.eu/energy/sites/ener/files/documents/nuclear_illustrative_programme_pinc_-_may_2017_en.pdf

[4] European Clearinghouse on Operating Experience Feedback.

https://clearinghouse-oef.jrc.ec.europa.eu/

[5] Antonio Ballesteros Avila, *Analysis of ageing related events occurred in nuclear power plants*, 2019, JRC119082.

List of abbreviations and definitions

AMP	Ageing Management Programme
CNRA	Committee on Nuclear Regulatory Activities of the OECD-NEA
CSNI	Committee on the Safety of Nuclear Installations of the OECD-NEA
HL-LL	High Level Lesson Learned
IAEA	International Atomic Energy Agency
IGALL	International Generic Ageing Lessons Learned
IRS	International Reporting System for Operating Experience jointly operated by the IAEA and OECD/NEA
I&C	Instrumentation and Control
JRC	Joint Research Centre of the European Commission
LL-LL	Low Level Lesson Learned
LTO	Long Term Operation
NPP	Nuclear Power Plant
OECD/NEA	Nuclear Energy Agency
OEF	Operating Experience Feedback
OPEX	Operating Experience
PINC	Communication on a Nuclear Illustrative Programme
TPR	Topical Peer Review

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