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Ageing at the TRIGA MK II research reactor of the University of Pavia: management and practical applications

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ABSTRACT

In the Laboratory of Applied Nuclear Energy (LENA) of the University of Pavia, a 250 kW TRIGA Mark II research reactor is in operation since 1965 without unplanned extended shutdown periods during which different activities took place. Ageing and its management, in a more than fifty years old facility, is a key point for both reactor safety and all its activities continuation. To mitigate ageing effects, several issues must be considered due to the time-dependent degradation of TRIGA and LENA structures, systems, and components (SSCs). Furthermore, the centre must deal with managements issues as documentation control, changes in mandatory requirements and staff turnover, that could lead to a loss of experience and know-how. During the past years, starting from an accurate assessment of SSCs conditions and the identification of ageing mechanisms, several activities were successfully carried out. In this field, LENA has implemented, since 2014, an ageing management system, continuously revised until its final transmission to the Italian control body. From the experience gained over these years, a new improvement phase has begun to identify the difficulties in the plan application and the opportunity to integrate changes to make it more practical and effective. In the present paper, an overview of the above-mentioned topics, and the forthcoming plans highlighting lessons learned and challenges, will be provided.

1 INTRODUCTION

LENA is an interdepartmental centre of the University of Pavia, and it is part of the Cravino Nuclear Pole, which includes the radiochemistry area, the sub-critical SM1 complex (1mW Power) and the environmental monitoring laboratory. The environmental monitoring laboratory (LMR) is classified as a low activity lab equipped with Liquid Scintillation Counters and chemical hoods. Its two main activities are focused on the continuous monitoring of environmental radioactivity for the Radioprotection Service of University of Pavia and on the research and development of new methods for the radiochemical identification and detection of radioisotope difficult to measure and reaching rapid analytical procedures in collaboration with Radiochemistry area.

At the LENA centre a TRIGA Mark II nuclear reactor, a 250kW light water moderated facility aimed for isotope production, training, and general-purpose research is present. [1] Moreover, LENA is equipped with a cyclotron IBA CYCLONE® 18/9, a Rx generator Gilardoni MT 350 / 6-12 and a Cobalt-60 2.91 TBq (78 Curie) source.

The University of Pavia is the operator of the nuclear reactor TRIGA MKII since its first criticality, that occurred on November 15th. In 2010, the board of the centre decided to implement a management system, in order to monitor issues as the obsolescence of documentation, the measurement traceability, and changes in mandatory requirements. Since 2014, to integrate the management system with ageing considerations, the centre adopted an ageing management program, revised until final transmission and acceptance to the Italian control body in 2019.

In the present paper it is described how the centre implemented the ageing plan in compliance with IAEA Safety Standards Series No. SSG-10, focusing on the importance of the management system to support the ageing considerations. [2]

2 MANAGEMENT SYSTEM

In 2010, to continuously improve the quality of reactor management and for the accomplishment of the stakeholder requirements (both under legal and commercial framework), LENA implemented an Integrated Management System (IMS) in accordance with International Standard ISO 9001. [3,4] This choice allowed to satisfy both national and international compulsory requirements and typical ISO 9001 requirements (as e.g., continuous improvement, users/stakeholders care and satisfaction) as well as complying with the IAEA GSR-3 “The management system for facilities and activities” [5] The experience in the application of IMS regarding maintenance and ageing problems resulted particularly helpful in the reactor operation management. The introduction of an IMS leads to the following main benefits:

- define a risk-based control plan to examine plant components and system to ensure operability and the respect of safety factors.

- establish a maintenance control plan to give the requirements for the frequency and the method of inspection and the acceptance criteria for measurement, so all instruments are under a documented metrological confirmation plan according with well-defined standards [6]
- revise documents and records to ensures the use of only up-to-date documentation avoiding the accidental use of obsolete documents, work instructions or diagrams. Indeed, well managed records ensure a proper process traceability as well as providing a database on the status of the individual components and systems.
- define the audit criteria, scope, frequency and methods to pave the way for the periodic management review. This review includes evaluations of improvement opportunities and the management of risk.
- implement a **s**upply chain: the control of supplies provides an accurate control of purchased products and their suppliers, ensuring adequate availability of spare parts and the implementation of a purchase plan that can compensate the obsolescence of components

3 AGEING MANAGEMENT PROGRAM

Based on the positive outcomes from the implementation of the IMS and for a better and more formal consideration of ageing, LENA, in 2014, implemented a formal **A**geing **M**anagement **P**rogram (**AMP**) following the IAEA guideline SSG-10. The AMP resulted in a set of organized policies, processes, procedures, and activities for managing the ageing of **S**tructures, **S**ystems, and **C**omponents (**SSCs**)**,** with the main purpose of ensuring reliability and availability of required safety functions throughout the extended life of the plant. In order to implement the ageing management program, the first task was to compare the IAEA guideline with the IMS in place. This process highlighted as the meeting point of the two systems was the well-known Deming Cycle allowing the continuous improvement of safety efficiency and effectiveness of the organisation (see Figure 1)**.**

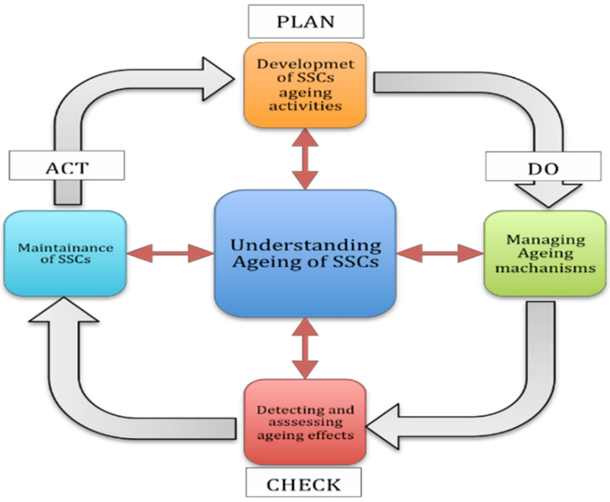

Figure 1: The Deming cycle, is a description of a four stages process described by the verbs Plan, Do, Check, Act. This cycle is the thinking-base of both IMS and AMP.

On the other hand, to incorporate the ageing concept in a management system, the safety categorization of SSCs played a central role in the definition of the AMP. This categorization lead to the identification of Safety System (SS) or Safety Related System (SRS). Furthermore, it was necessary to identify for each SSC how ageing affects the components and materials that were used, procedure known as the Ageing Mechanism. Linking this information to operation complexity and frequency and to the requested records, it was possible to obtain the identification of the ageing management plan, that satisfies the practical aspects of AMP.

3.1 SCCs' categorization

Following IAEA guidelines, firstly a complete screening of LENA SSCs was done to identify the safety critical points. Based on the screening results, SSCs was analyzed in detail to pinpoint the most relevant activity areas not already included in the IMS. The SSCs not considered in in the periodic maintenance and registered as important to safety were highlighted in Table 1, and for each SSC was planned the corresponding activity subjected to management program.

LENA SCCs' categorization was presented at the European Nuclear Safety Regulators Group (ENSREG) on Topical Peer Review "Aging Management", with the purpose to define a national standard for the ageing management of working reactors, an activity that was part of the regulatory body "Topical Peer Review 2017 Ageing Management National Assessment Report". [7]

Table 1: identification of important to safety SSCs and description of the planned activities necessary to counteract ageing effects.

SSC	Planned activities
Pool structure and vessel	Visual inspection with underwater camera, development of procedures and definition of acceptance criteria. Assessment of results
Core structure	
Reflector	
Shielding	
Beam tubes	
Linear	
Fuel assembly and storage in reactor pool	
Primary	Efficiency monitoring by online data acquisitions and real time parameters evaluation. Trending of data to assess conditions. Periodic result evaluation
Biological shield	Efficiency of shielding of gamma and neutron dose to be tested every 5 years
Ventilation: emergency	Improved maintenance and controls on the rotating equipment. Definition of procedures
Control Console (LOG channel, SCRAM loops)	New channel refurbishment. Updating of the documentation, management of spare parts. New calibration procedure
Cabling (control console internals and interconnections replacements)	Step by step cable
Shielding	Visual inspections. Definition of tests to be carried out on periodic base.
Beam tube lines	

3.2 The Ageing Mechanism

To determine the ageing mechanism, according to IAEA guidelines for each SSC was indicated a code from 0 to 10:

1. change of properties due to neutron irradiation;
2. change of properties of materials due to operating temperatures;
3. mechanical stresses or cracks due to temperature/or operating pressure;
4. fatigue phenomena, material consumption due to thermal cycles, mechanical load, flow, induced vibrations;
5. corrosion;
6. chemical processes;
7. erosion;
8. technology change;
9. regulatory changes;
10. documentation obsolescence.

The corresponding internal codification was selected referring to the technical nature of the SSC, keeping in mind experience, publications, and past activities results; LENA identified several mechanisms as the more relevant to ageing and they were the subjects considered for the implementation of the AMP (see Table 2).

Table 2: principal ageing mechanism of LENA SSCs highlighted during the initial screening. This codification was used to determine the following activities to counteract the corresponding ageing mechanism

Ageing mechanism	Code (IAEA SSG 10)
Changes of properties due to neutron irradiation	1
Motion, fatigue or wear (resulting from cycling temp., flow, vibrations, etc.)	4
Corrosion	5
Chemical processes	6
Changes of technology	8
Obsolescence of documentation	10

3.3 The Ageing Management Plan

All the considerations, classification and screenings done in the previous paragraphs were improved to achieve a practical document, crucial for both ordinary maintenance program and plant management. The Ageing Management Plan, jointly with a risk-based thinking, allowed a complete planning of the site activities over the years. At LENA, this plan included more than 40 identified SSCs with the corresponding description of the activity, check needed, or maintenance required to counteract the ageing effects. Due to its practical nature the document was implemented, for each SSCs, with the corresponding complexity replacement, the frequency of the activities required, and the registration needed. Each activity was fully documented and reported to the Regulatory body. An accurate maintenance plan, followed by specific operating instructions, was established in accordance with the Surveillance program and with License Prescription. The integrated Management System allowed the systematic review of activities and documents of the plant and was used as input for the Periodic Safety Reviews. This process lead to confirm whether ageing and wear-out mechanisms have been correctly considered and to detect unexpected issues. As the AMP, the ageing management plan was approved by the Italian regulatory body in 2019.

During 2021, a review of AMP was done, in order to include staff turnover as a new SSC; moreover, registration and work instructions for staff turnover control were implemented to avoid know-how loss and to ensure the centre regular work-flow.

4 CONCLUSIONS

Ageing management in a more than fifty years old facility turns out to be a key point in the ordinary planning of the activities. In the present work, the time-line process that allowed the centre to achieve in 2019 the approbation of its management program was shown. The overall result was a combination of the already existing management system with ageing concepts as ageing mechanism and safety classification of structures, system, and components. Indeed, a practical document was prepared to improve both maintenance and surveillance program, to counteract ageing effects. The ongoing improvement of the Ageing Management Program is needed to ensure the reviews of all interested documents and the efficiency of the Ageing Plan.

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