Plant Life Management Activities for Long Term Operation of the Argentinean Water Cooled Reactors

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Abstract. The Comisión Nacional de Energía Atómica (CNEA) –National Atomic Energy Agency of Argentina– is a Sate-owned Research and Development (R&D) institution that has among its functions the responsibility of keeping up to date, and available to the Utilities, all nuclear related technologies in order to ensure the highest performance of the plants in terms of safety and production. Within the last years CNEA has developed a working group focused in the aspect related with Plant Life Management for Long Term Operation. In this work a brief review of the activities that are being carried out in this group are presented, which include development of methodologies and procedures for Ageing Managements Program, R&D activities in Ageing Related Degradation Mechanisms, and technical assistance activities for the Argentinean NPPs.

1. INTRODUCTION

The Comisión Nacional de Energía Atómica (CNEA) –National Atomic Energy Agency of Argentina– is a Sate-owned Research and Development (R&D) institution that has among its functions the responsibility of keeping up to date, and available to the Utilities, all nuclear related technologies in order to ensure the highest performance of the plants in terms of safety and production. In 2005 CNEA and Nucleoléctrica Argentina Sociedad Anónima (Na-Sa) –Argentinean National Utility– have formed a joint working group to develop Plant Life Extension (PLEX) methodologies to be applied in the Argentinean CANDU-6 plant "Central Nuclear Embalse" Refurbishment Project. Training and supervision have been provided by Atomic Energy of Canada Ltd. (AECL). As a result, a solid group of engineers is currently working in the PLEX division of the plant, and has finished the first stage of the project that consists in evaluating the current condition of the major equipment of the plant, in order to make the business case for the refurbishment. In the other hand, CNEA has continued to develop its own group to cope with all Long Term Operation (LTO) management issues. Several experimental activities are being carried out in the corrosion and cable degradation areas; the emphasis is put on the prediction of the future behavior of the materials, based on their current condition and on accelerated ageing tests. It is planned for the near future to set up a Loss of Coolant Accident (LOCA) test facility to study the behavior of the materials in LOCA and post-LOCA conditions. Other experimental activities have been the development of suppliers qualification and associated tests. It is worth mentioning that one of the Team objectives is being achieved throughout these activities; where the experimental facilities and expertise of the Research & Development Institution are combined with the operational and In-service experience from the plant personnel. Beside these experimental activities, from the methodological point of view, the PLIM-PLEX division of the Comisión Nacional de Energía Atómica is currently developing an unified PLIM program for the Long Term Operation of all current and future Argentinean reactors.

A brief synthesis of the group activities is presented in this work, together wit some R&D associated activities and the actual state of the PLIM Project for the Argentinean Water Cooled Reactors.

2. METHODOLOGICAL ACTIVITIES

2.1. Development of an integrated PLIM Project for Argentinean Water Cooled Reactors

The PLIM division has as one of its most important tasks, the development of an integrated and unified methodology for managing the effect of ageing in all Argentinean reactors, including nuclear power plans and experimental reactors. The experience gained during the Embalse Refurbishment Project is to be applied and expanded to design a single and comprehensive program. Proper procedures are being developed for each part of the unified program according to the guidelines provided ref.

[1],[2],[3] and according to local standards as ref.[4],[5] . The integrated program can be divided into the following stages.

- **Stage I: Design Review and Screening of major System, Structures and Components (SSCs)**

In the first part of the program; it is necessary to fully understand the design bases and operational conditions of the plant, in order to determine the major components/group of components that are going to be covered by the LTO program. Once the scope of the program is established, selected SCCs should be grouped to set up specific Ageing Management Programs (AMPs).
This stage of the program has been started designing the flow information path required for the establishment of the Plant Life Management Program (Figure 1) and developing a Screening and Scoping Procedure. This procedure will be reviewed by IAEA experts within the frame of ARG/4/093 project.

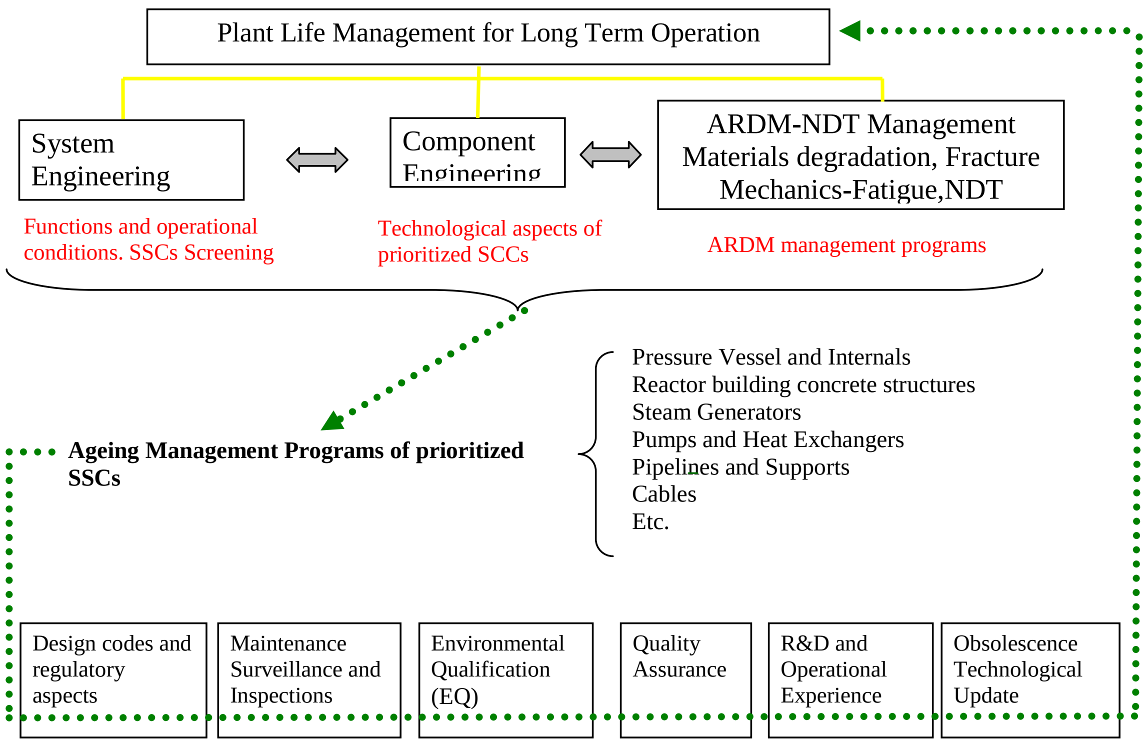


Fig. 1. Design of the of the information path flow in the PLIM program

The following chart summarizes the Scoping and Screening process.

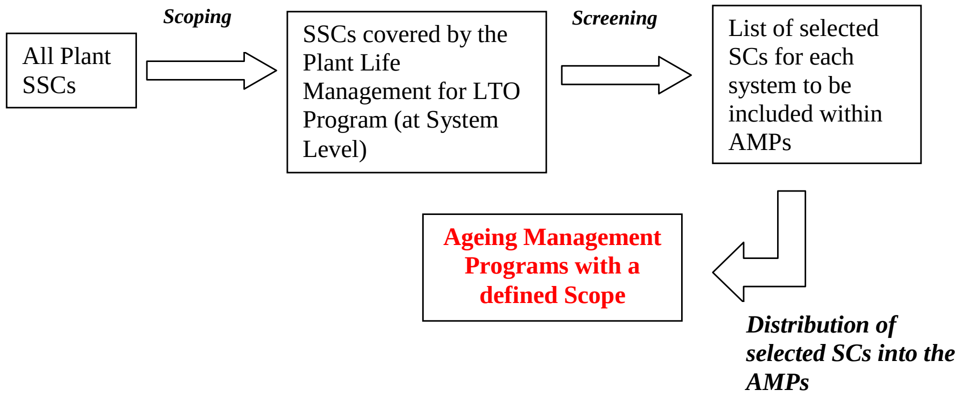


Fig. 2. Scoping and screening process

- **Stage II: Development of a Generic Ageing Database**.

The objective of this stage is to have a single and periodically updated database of the recommended Maintenance, Surveillance and Inspections (MSI) practices within the different AMPs. This will allow for a continuous revalidation of the Plant Programs. This stage of the program has been started developing a series of aging management guidelines customized for Argentinean NPPs These guidelines detail the materials used in the main SSCs, the relevant ARDMs, and the detection and mitigation methods in use or potentially applicable in Argentinean NPPs. Beside the theoretical information, an extensive operational experience database of mayor SSC is under developing gathering the available information in the Argentinean NPPs and the external operational experiences provides by others programs or institutions. As this regard, CNEA is participating in the IAEA activities related to the International Generic Ageing Lessons Learned Database and the Stress Corrosion Cracking and Cable Ageing Project (SCAP) project of the OECD/NEA.

- **Stage III: Analysis and /or design of specific AMPs**:

In this part of the program, detailed procedures for the MSI activities included in each AMP have to be established. It is important to point out the different strategies to be followed when AMPs for a new reactor are designed; or existing plant programs for a working reactor are re-assessed. However, in any case, the adequacy and fulfillment of the programs has to be compared against international standards and good practices (summarized in the previous stage - Generic Ageing Database).

- **Stage IV: Determination of measurable Program Performance Indicators**

For each AMP it is essential to establish proper indicators allowing for a periodic evaluation of the effectiveness of the program. Temperature values, pressure drops, bearing replacement rates, heat exchangers tube plugging rates and corrosion rates, among others, are parameters that could be followed to evaluate the AMP effectiveness. The selection of proper indicators requires a case by case analysis and strongly depends on the particularities of each AMP.

- **Stage V: AMP evaluation and feedback**

Not only the selected indicators are to be evaluated, but also field experience and any other relevant data have to be collected and analyzed in order to improve the effectiveness of the AMPs. The permanent re-evaluation of the program allows for an optimization of the resources assigned to the MSI activities of each AMP.

2.2. Specific Ageing Management Programs development

The PLIM division of CNEA has started the development of a specific Cables Ageing Management Program. The main goal of this task is the development of an unified Cable AMP for all Argentinean Reactors. In the fist stage of the project, only the case of Atucha II NPP was considered, it is important to point out that the AMPs for this NPP has some particular features due to the delay in the construction of the NPP. The long term storage, and the associated ageing effect must be taking into account in the baseline data of the AMP. In Atucha II, most of the cables were storage in good conditions and some of them were installed. Environmental Qualified Safety related cables will be purchased. A brief description of the tasks that are being developed within the scope of this program is given in the following paragraph.

- Screening of cables involved in systems and components relevant for the Long Term Operation. This task is being carried out along with plant personnel.
- Stored cable condition assessment based on original standards. Several studies are being carried out. These studies include material characterization, mechanical properties, thermal stability, etc. The methodology and acceptance criteria of theses studies are based on the original standards qualification for cables (DIN-VDE) [6],[7],[8].
- Determination of Aging Related Degradation Mechanisms effects.
- Data collection of baseline for aging management program (including Activation Energy).
- Development of master curves of elongation at break at different temperature and correlation of elongation at break with non destructive testing properties.
- Condition monitoring and in service inspection procedures elaboration and implementation.
- The Environmental qualified cables and EQ maintenance program is currently under development. This program includes the following stages:
- Qualified life determination and Initial qualification assessment.
- Sampling location determination.
- Sample testing procedures elaboration and implementation

3. Research and development associated activities

3.1. Cable and polymers components ageing

First efforts were made on literature review (using as main guideline ref [9]), IAEA experts experience consulting, material characterization techniques, stressor identification and aging related mechanism research. After that the main focus was in accelerated aging test. There are two main types of accelerated ageing: accelerated thermal ageing and accelerated radiation ageing, depending in the environment and the main ageing mechanism associated. For accelerated thermal ageing it is accepted the Arrhenius model to make a prediction to determinate the life cycle. It is used the elongation at break as parameter to determine the ageing points and make the curve.
Some tests were performed on aging assessment for cables from an operating NPP. Some cables are installed in harsh environment (high dose rate). Based on its function, end of life criteria was determined. It is commonly used the 50% absolute of elongation at break as a severe end of life criteria. Accelerated aging was carried out in order to determinate the life cycle. Regarding thermal aging accelerated aging are being carried out in order to asses predictive methods in PVC.

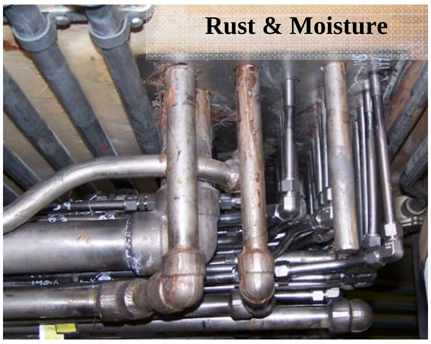
4. TECHNICAL ASSISTANCE TO NPP

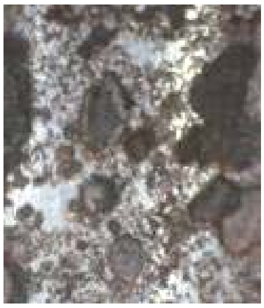
4.1. Failure analysis

Several failure analyses have been performed within the frame of the PLIM for LTO programs. Most of the failures have been discovered while doing scheduled walkdowns or by performing inspections suggested as a result of an Ageing Assessment process. In the following paragraphs two examples of failure analysis are briefly described.

4.1.1. Non containment penetration.

The failure has been found on a non-containment mechanical penetration, where several pipes pass from the top of a reactor building room to the floor of the contiguous one. The leaking pipe was an AISI-304 pipe belonging to a D_2O leakage collection system. The penetration is formed by two carbon steel plates. Stainless Steel pipes are welded to the upper plate and ilmenite sand is used as filler and as a shielding element. This sand was found to be contaminated with Cl^-, F^- and $SO4^{--}$. The average temperature ranges from 55 ºC to 65 ºC. The fluid contained in the pipe was D_2O from the leakage collection system. The failure was detected during a scheduled plant walkdown.
After the detection of failures, several samples were taken, during the preparation and cleaning of the samples, the first finding was the presence of pits in the outer surface of the pipes and a relatively smooth surface in the inner part. This difference suggested that the aggressive agent was not the fluid itself but the external contamination of the sand. A picture of the surfaces is shown in Figure 3






Outer surface: Pits Inner surface: No damage

Fig. 3. Detail of the penetration and the inner and outer surfaces

The metallographic analysis has shown typical transgranular and branched cracks. As a conclusion, the failure of the pipe was due to Stress Corrosion Cracking (SCC) produced by the anions found as contamination in the ilmenite sand. Along with the aggressive anions, two other conditions should be met to develop SCC: a) Susceptibility of the material and b) Tensile stresses. AISI–304 Stainless Steel is susceptible to SCC in presence of the above mentioned anions. The tensile stresses may have been produced by the welding process of the pipes. Despite the service temperature of the pipe was close to the threshold temperature for developing SCC; the morphology of the crack has confirmed the failure mechanism of the pipe.

4.1.2. Corrosion of Electronic equipment

In a normal inspection to electronic equipment of the Embalse NPP, several failures in welded connections were detected. The failure was detected in the welding between cables and terminal connectors, the welding was made by soldering using standard Pb-Sn alloy. Welding was covered by polymeric protection. Ender this protection there was a green deposit and under the deposit several cracks were found. The equipment is in a controlled room at 18-20°C and a 40-60 % of relative humidity.
The failure analysis consisted in a characterization of some failed connector by SEM. The welded connection was grinded at different deeps in order to evaluate de crack size and morphology. A characterization of the green corrosion product, the materials of cable insulator, and the polymeric protection was also carried out. Both, the cable insulation and the cover were studied by FTIR and the corrosion product was characterized by XRD and EDS. A walkdown was also performed.

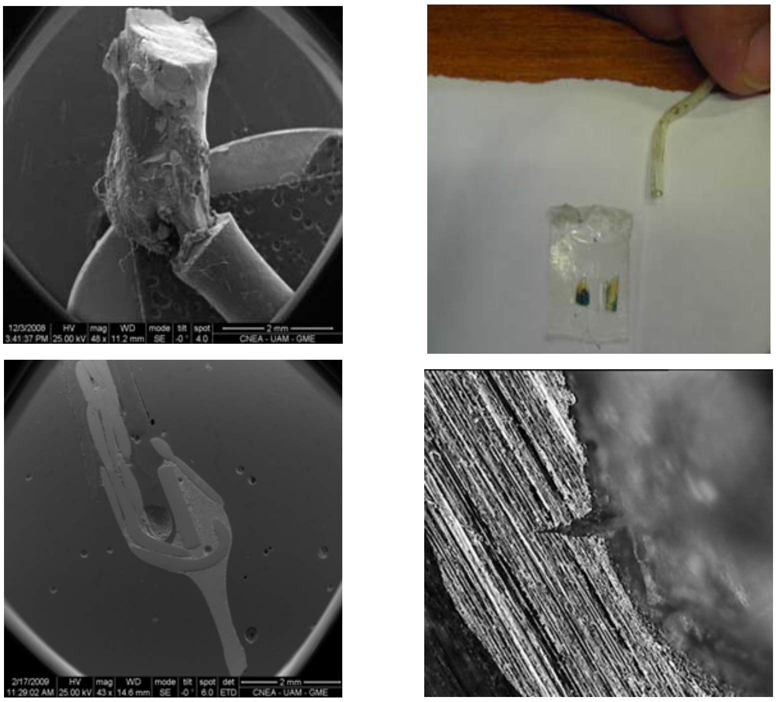


Fig. 4. Detail of cable, cover, and welded connectors

The analysis performed by FTIR demonstrates that cable insulator was made of crosslinked polyethylene and the cover was made of PVC and $CaCO_3$ added as filler.

XRD and EDS analysis on the corrosion product shown that it was manly copper carbonate, and that was an important presence of chlorine. This result, along with the fact that cracks and corrosion product were found only under the PVC cover; lead to the conclusion that the failure could be related to chlorine evolution due to some transient in temperature, or due to some migration process from the PVC. The main recommendation was changing the PVC for other polymer more resistant to thermal degradation or plasticizer migration.

4.2. Suppliers qualification.

The PLIM division has made several tests to qualified materials and supplies for Argentinean NPPs, like electronic components, thermal insulation, etc. As an example of these activities, a case study is briefly described.

A new material based on a silica aerogel reinforced with a non-woven glass-fiber batting, was proposed to replace the conventional stone wool blanket. The PLIM department has studied the radiation damage and the possible changes in radiological activity after the exposure of both materials to neutrons. The irradiations wee performed in the R.A 1 research reactor, radiological activity of the samples was measured in a multichannel detector Teletector FH FN3. The irradiated material was tested in compression under the guidelines of ref [10], also flexibility test were performed under the guidelines of ref [11]. Pictures of the mechanical test are shown in the following figure:

Fig. 5. Compressive test and flexibility of thermal insulator blankets

The main conclusion of this test was that radiological activity of aerogel after neutron exposure was lower than the stone wool and the mechanical properties of aerogel were not affected at the applied doses.

5. CONCLUSIONS

As a result of the efforts made by CNEA, a solid working group has being developed to cope with the different topics on PLIM for LTO. This group is developing several activities of R&D related with Ageing Degradation Mechanisms and Ageing Effects, integrating the experience and capabilities of different laboratories and providing technical assistance to the Argentinean NPPs. The main aspects covered up to date are: development of procedures and methodologies for Ageing Management, R&D in cables ageing, failure analysis, and suppliers qualification. Future work will be focused on the development of EQ test and on the application of recently developed procedures to design and implement specific ageing management programs for the different SSCs of Argentinean NPPs. For this task it is essential to continue enhancing the synergic cooperation between the NPP personnel and R&D institutions.

ACKNOWLEDGEMENTS

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[7] DIN VDE 0273, Crosslinked polyethylene insulted cables, nominal voltages: Uo/U 6/10, 12/20 and 18/30 kV.

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