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Screening and selection of structures, systems and components to be considered in Ageing Management and Periodic Safety Review of the TRIGA IPR-R1 Reactor

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1. Introduction

Ageing management programs for research reactors should be aimed at identification and implementation of effective and appropriate ageing management actions and practices that provide for timely detection and mitigation of ageing effects in systems, structures, and components (SSCs) [1]. Several approaches can be incorporated in an ageing management program, including not only those techniques based on analysis of operating experience or experts judgments, but also probabilistic techniques. Although all these techniques utilize different methods, they have a point of intersection: selection of SSCs important to safety and sensitive to ageing degradation.

A research reactor has a large number and variety of SSCs, some of which are more important to safety than others. Besides, distinct SSCs could present considerable differences in the extent to which these SSCs are susceptible to ageing degradation. It is neither economically practicable nor necessary to evaluate and quantify the extent of ageing degradation in every individual SSC. A systematic approach should therefore be applied to focus resources on those SSCs that can have a negative impact on the safe operation of the reactor and that are susceptible to ageing degradation.

In this work, a qualitative approach for selection of SSCs for TRIGA (Training, Research Isotopes, General Atomics) IPR-R1 reactor cooling system is presented. TRIGA IPR-R1 research reactor has been commissioned in 1960 and belongs to Centro de Desenvolvimento da Tecnologia Nuclear (CDTN). Since then, it was used in many researches, such as radioisotope production, neutron activation analyses, neutronic and thermohydraulic experiments, etc [2]. The main idea of the present study is to categorize SSCs related to the cooling system operation that are sensitive to ageing whose failures could have a significant adverse effect on facility safety in order to provide a screening of components that should be considered in aging management and periodic safety review of the reactor.

1.1. Description of TRIGA IPR-R1 cooling system

The TRIGA IPR-R1 reactor is a typical TRIGA Mark 1 light-water and open pool reactor. The Cooling System is currently licensed to operate with a maximum steady state power level of 100 KW. It consists of two circuits: primary (containing a water purification system) and secondary. The reactor core is cooled by natural convection of demineralised water from the pool, but the primary circuit is connected to cool the pool water from 1 kW on. In this condition, the hot water collected at the bottom of the reactor pool is cooled as it passes through the shell of a heat exchanger and then returns to the pool above the point of the outlet [3]. A purification system is connected to the primary system in order to fulfill three basic functions: **(i)** keep the conductivity of the pool water lowest than $\leq 2\mu S/cm$ to minimize corrosion of the reactor components, particularly fuel elements; **(ii)** reduce the level of radioactivity in water by removing suspended particles and soluble impurities; **(iii)** keep the optical transparency of the water [3]. The components of this system are the demineraliser, based on ion exchange resins, in addition to filters, pumps, and monitoring equipment (flow meters, temperature, radiation, and water conductivity).

The water in the secondary circuit, after circulating through the internal tubes of the heat exchanger, is cooled by atmospheric air in the external cooling tower. Two pumps, one of them located in the primary circuit and the other one in the secondary circuit, are responsible for flows in the cooling system. More details can be found in [3]. Although the main components for the mechanical system operation are the heat exchanger, pumps, a cooling tower, and a resin system ion exchange for water purification, the whole cooling system was analyzed for completeness, which includes electrical and instrumentation components as well.

2. Methodology

A functional block diagram has been developed to illustrate the entire operation and interrelationships between functional items of the cooling system as defined in the Final Safety Analysis Report (FSAR) [3]. For that matter, the BlockSim software [4] was used and the block diagram can be seen in Fig. 1. Secondly, SSCs important to the reactor safety that are sensitive to ageing were evaluated in order to identify their possible ageing failure, failure effects, and the ageing mechanisms. Regarding the cooling system of the TRIGA IPR-R1 reactor, it has been done examining technique information taken from similar systems, manufacturer manuals, and articles [5, 6, 7]. Therefore, a screening of each mechanical, electrical, and instrumentation items containing their respective ageing failure modes and ageing mechanisms was developed.

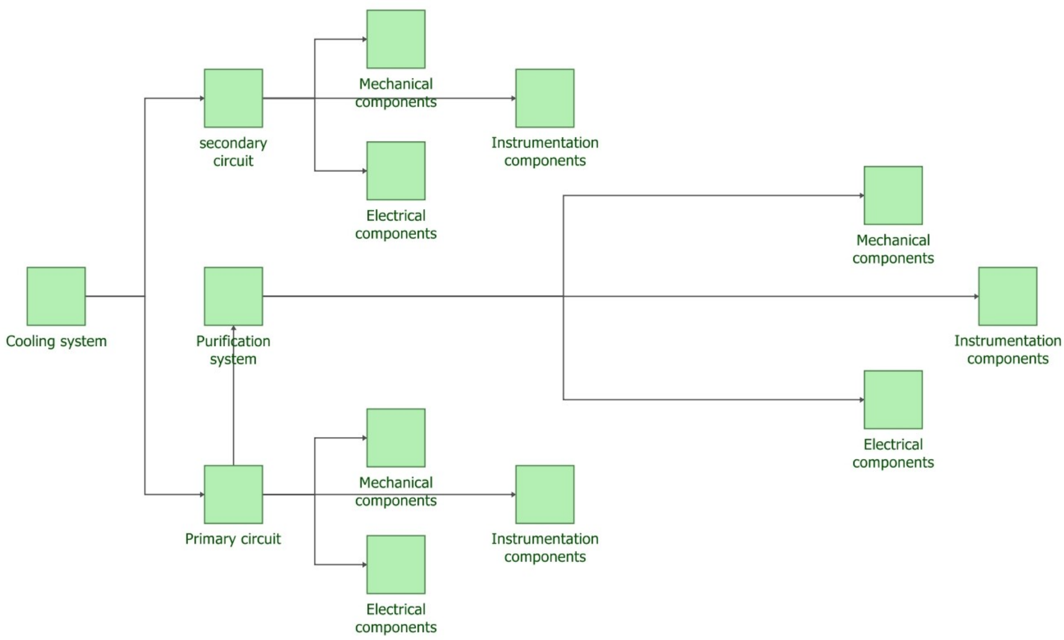

Figure 1: Block diagram of cooling system operation.

3. Results and Discussion

The approach described above has been applied to components and systems from the TRIGA IPR-R1 reactor cooling system. Tab. I displays the obtained results. It reveals that external leak is the most repetitive ageing failure mode for mechanical components, possibly occurring in the pumps, manual valves, stainless steel pipe, filters, heat exchange, cooling tower, and mixed bed resin tank. Some ageing mechanisms were identified as mechanical failures causes, such as erosion, corrosion, fretting, vibration, wear, and microbial influenced corrosion (MIC).

Table I: Primary circuit (**PC**), purification system (**PS**), and secondary circuit (**SC**) results.

Mechanical Items	**Ageing failure modes**	**Ageing mechanisms**	**System**
pump	external leak, fail to start, inadequate flow, fail to operate	wear, fretting, binding	PC, PS, SC
manual valve	external leak, low operation, internal leak, fail to operate	corrosion, erosion, wear	PC, PS, SC
stainless steel pipe	external leak, rupture, no flow cracking, wall thinning	corrosion, erosion, vibration	PC, PS, SC
diffuser	rupture, cracking, diffuser wall thinning	corrosion, erosion, radiation damage	PC
heat exchanger	external leak, inadequate flow, no flow, inadequate heat exchange, inrternal leak	corrosion, erosion, microbial influenced corrosion (MIC)	PC
cooling tower	fail to start, inadequate flow, fail to operate	wear, foreign material intrusion	SC
pipe filters and surface filters	external leak, inadequate flow, fail to operate, plugged	wear, foreign material intrusion	PS
mixed bed resin tank	external leak, fail to operate,	corrosion, erosion, chemical attack	PS
Electrical Items	**Ageing failure modes**	**Ageing mechanisms**	**System**
pump motor and cooling tower motor	fail to start, high vibration, short circuit, fail to operate	wear, thermal ageing, fatigue	PC, SC, PS
cables and conectors	open circuit, short circuit short to ground	thermal ageing, insulation ageing	PC, SC, PS,
circuit breaker	fail to close, fail to operate, open spuriously, spurious operation	oxidation, fatigue, thinning of contacts, wear	PC, SC, PS
instrumentation items power supply	no power supply, fail to operate, open spuriously, spurious operation	oxidation, fatigue, thinning of contacts, wear	PC, SC, PS
Instrumentation Items	**Ageing failure modes**	**Ageing mechanisms**	**System**
flow meter	erratic measurement, high measurement, low measurement, no measurement	corrosion, wear	PC, SC, PS
differential pressure transmitter	measuring set failure, electronic module failure, measuring set communication failure	corrosion, wear	PC
pressure indicators	erratic indication, high indication, low indication, no indication	wear	PC, SC, PS
PT-100 thermocouple	erratic output, no output	corrosion, wear	PC, SC, PS

For electrical components, which involves pumps motors, cables and connectors, circuit breakers, and instrumentation power supply, the potential failure modes achieved might be related to thinning of contacts, thermal and insulation ageing, fatigue, and oxidation. Taking into account the instrumentation components, the possible failure modes are associated with erratic or no output. Indicators, sensors, and differential pressure transmitters can present inaccurate values or improper operation, which could lead to false information and be responsible for wrong decisions or false signals to scram the reactor.

4. Conclusions

The TRIGA IPR-R1 research reactor has been in operation for several years and therefore might present advanced stages of SSCs ageing. The initial results indicate a reliable path for future researches since the identification of ageing failure modes can be used in association with other techniques for the selection of components sensitive to ageing that need to be repaired or replaced. The next effort of the present study will be concentrated on performing an ageing failure mode and effect analysis (AFMEA) to summarize priorities for a proper modernization to meet the current safety and performance requirements of the facility, including prevention and mitigation of events that could be harmful to the safety. This information will be considered in the ageing management and periodic safety review of the reactor.

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