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Development of a Methodology for Management and Physical-Chemical Control of the Cooling Water of the IPR-R1 Triga Research Nuclear Reactor

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1. Introduction

Triga IPR-R1 research reactor, located at CDTN (Nuclear Technology Development Center) in Brazil, is one of the oldest reactors in operation worldwide. It is in operation for more than 60 years. Most of its fuel elements are in the core where corrosion can occur, which threatens the integrity of fuel coatings. The refrigerant must be treated and controlled to maintain its low electrical conductivity and pH close to neutrality, in order to minimize corrosion of the core components, particularly fuel elements. At some point in the future, like other reactors, IPR-R1 will be permanently shut down.

At the start of operations of the IPR-R1 reactor in 1960, its maximum output thermal power was 30 kW. In 1970, fuel elements were added to the core, increasing the power to 100 kW, which is the current maximum operating power. In 2002 modifications were carried out in the core and new fuel elements were added, allowing the power to reach levels of 250 kW, according to experiments carried out by Mesquita *et al.* (2002) [1].

The Brazilian Nuclear Energy Commission (Cnen) has granted a Permit for Permanent Operation (AOP) license for the CDTN IPR-R1 Triga research reactor. This authorization includes some conditions to be settled within a period of up to two years, that is, until the end of 2019, which has not yet been carried out and is currently being prepared by the CDTN. For this purpose, Project 0006.23 – Maintenance of Licensing of the IPR-R1 Triga Reactor was created in the CDTN's Multiannual Program. In this project, the professor Amir Zacarias Mesquita coordinates the Subproject: 6.23.3 – Preparation of the system to manage the aging of the IPR-R1 Triga reactor.

In the aforementioned subproject, a mandatory experiment was included in every research reactor, that is, the performance of tests to verify possible fission product leaks in the reactor's fuel elements [2]. Due to the Covid pandemic and the home-work activities, this experiment has not yet been carried out, but it is intended to be performed as soon as the Triga reactor returns to operation. All conditioning actions required by the regulatory agency are based on recommendations and standards from the International Atomic Energy Agency (IAEA) and the Brazilian Nuclear Energy Commission (Cnen).

The approach to the study of aging in nuclear reactors, in addition to paying attention to the economic factors directly involved with the extension of their operational life, also provides important data on safety issues. The most recent case involving the process of extending the life of a PWR reactor was at Angra 1 nuclear power plant in the last 20 years. For the Triga reactor, it would be very important to know if it is necessary to carry out any corrective measures for the extension of its life, after the recent granting of the Permit for Permanent Operation.

So, the main objectives of this proposal are:

- Research and proposal of good practices to be adopted for the management and physical-chemical control of reactor water (considering its electrical conductivity and pH), as IAEA recommendations (2010, 2011) [3], [4].
- Evaluate its physicochemical properties, as well as carry out a survey of the chemical elements present and radioisotopes that arise from neutron activation.
- Perform gamma spectrometry of the water from the IPR-R1 reactor well, with samples of the coolant with the reactor off and with it in operation, during the experiments to check for possible leaks of fission products in the reactor fuel elements (sipping test) [2].

2. Methodology

Practical procedures will be elaborated to be adopted for the management and physical-chemical control of water (electrical conductivity, pH and temperature) from the IPR-R1 Triga reactor, according to the recommendations of the IAEA standard (2011) [3]. In the experimental part, the analytical instruments shown in Fig. 1 [5] will be installed in the primary circuit of the IPR-R1 reactor. They are:

- Two digital meters/controllers with probes for monitoring electrical conductivity and water temperature (George Fischer-Signet, model 8850-2 GF conductivity indicator/transmitter) [6]. Each equipment has two cables (conductivity and temperature), which connect the probes to the conductivity meters (indicator and analog output).
- A pH controller meter (with sensor), brand Dosatronic PH 1000 TOP [7]. This is a high-precision, fast-response microprocessor instrument for automatic pH analysis and control over its entire range from 0 to 14.

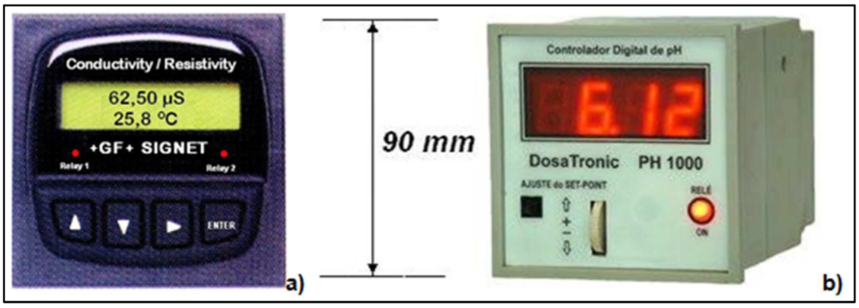

Figure 1. Conductivity/temperature transmitter and pH controller [5].

The output signals from the pH, electrical conductivity and temperature sensor monitors will be connected to the Data Acquisition System (DAS) developed in the research [8]. All parameters will be displayed on a video monitor. The characteristics of DAS are as follows:

- Data Acquisition System (DAS) with USB-6211 output, manufactured by National Instruments Co. (2007) [9]. This is a multifunctional device, offering analog inputs, digital inputs, digital outputs and two 32-bit counters.
- LabVIEW® supervisory program (academic license) developed by National Instruments Co. (2007) [9]. This is engineering software created specifically for applications that require test, measurement and control, with fast access to hardware and information obtained from the acquisition system data.

Additionally, it will be performed a spectrometry based on a model 5019 coaxial HPGe (hyper-pure germanium) detector, with 50% nominal efficiency, model DSA-2000, coupled to a Canberra gamma spectrometer equipped with 8.0 channels. The system will be connected to a computer with a multichannel spectra acquisition board with the Genie 2K program, from the Nuclear Spectrometry Laboratory - LEN, from the Analysis and Environment Service - Seama/CDTN. The assembly will detect and identify fission products that may be released. The presence of isotopes Cs-137, La-140 and I-131 being verified, indicates that some of the sampled fuel elements present leaks, that is, they have a compromised coating, since these elements are known indicators of leaks in nuclear reactors.

3. Expected results

Among the expected results, depending on the experiments to be carried out described in methodology section, are the values of electrical conductivity and pH for the water from Triga reactor. To exemplify the expected results of this proposal, it will be comment on the next paragraph the values of electrical conductivity and pH from previous similar studies about CDTN Triga. The recommendation of the IAEA standard (2011) [4] is that the pH of the cooling water of research reactors is between 5.5 and 6.5. In the IPR-R1 values of 5.2 and 7.0, measured monthly between Jun/2016 May/2017, have already been reached and showed in Fig 2 [10]. Regarding electrical conductivity, the IAEA publication (2011) [3] recommends that it be below 1.0 µS.cm-1. In Triga IPR-R1 this value was never reached, the lowest value reached was 1.3 µS.cm-1, measured monthly between Jun/2016 May/2017 as can be seen in Fig.3 [10]. All these samples for the IPR-R1 were analyzed by the Analytical Chemistry Laboratory of the Analysis and Environment Service (Seama) of CDTN [10].

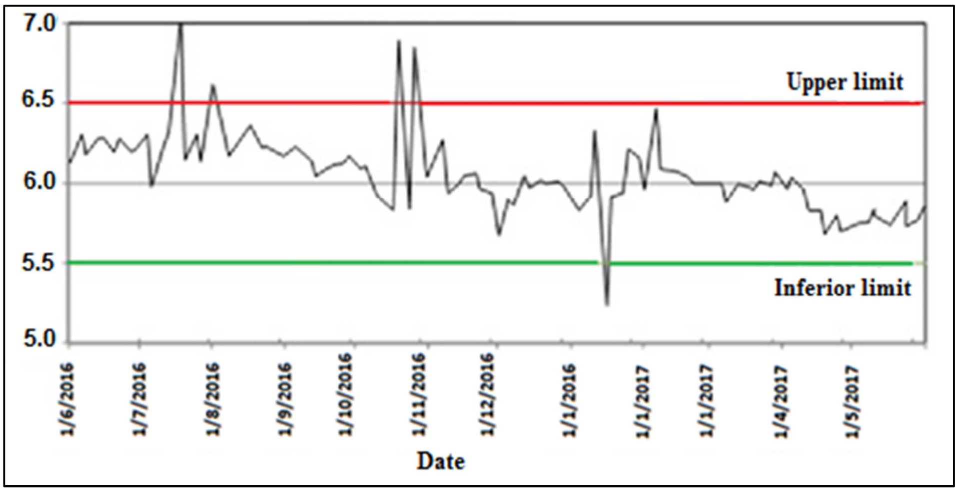

Figure 2. Primary cooling water pH values from June 2016 to May 2017 [10].

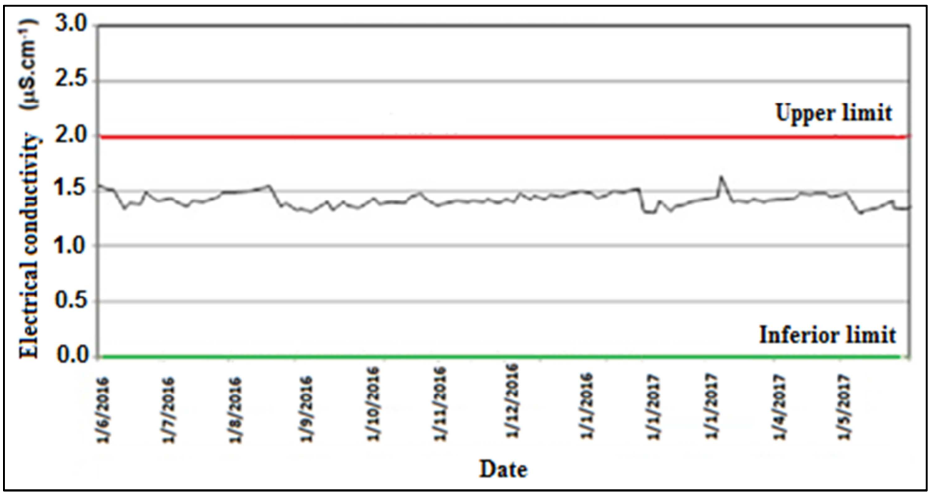

Figure 3. Primary cooling water electrical conductivity values from June 2016 to May 2017 [10].

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