Neutronic Tests in the IPR-R1 TRIGA Reactor

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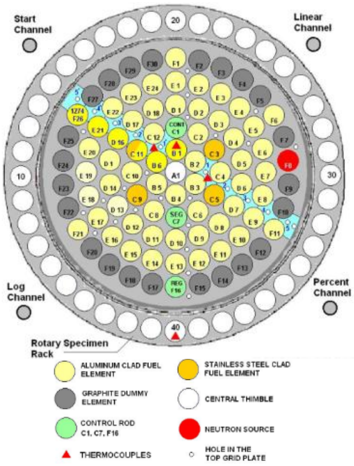
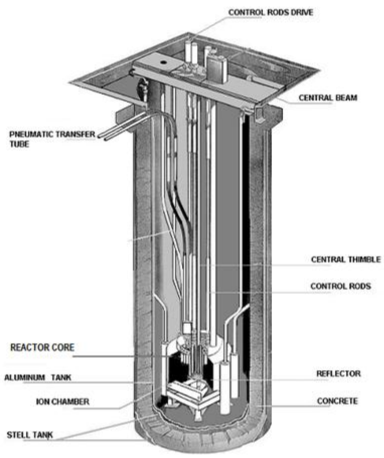
1. Introduction

The aim of this paper is to present the results of recent neutronic tests conducted in the IPR-R1 TRIGA reactor, as determined by the IPR-R1 Safety Analysis Report, which stated the need to perform them annually to ensure the safety of the reactor. The tests were performed to determine: worth of the control rods, the excess of reactivity, the shutdown margin, the power defect and the power coefficient of reactivity. It was measured the reactivity loss of the reactor core due to samples irradiation during eight hours at 100 kW. It was confirmed the necessity of new fuel elements in the core to operate the reactor at the new power (250 kW).

2. The IPR-R1 reactor

The IPR-R1 TRIGA reactor is a pool type research reactor moderated and cooled by light water. The fuel is a homogeneous mixture of U-ZrH alloy containing between 8.5% and 8% by weight of uranium enriched to 20% in ^{235}U, for SS-clad and Al-clad elements, respectively. The core has 63 fuel elements composed of 59 original Al-clad fuel elements and 4 fresh SS-clad elements. The power level of the reactor is controlled by three control rods: Regulating, Shim and Safety. The Shim and the Safety control rods are positioned at symmetrical locations of C-ring, and the Regulating rod at F-ring.



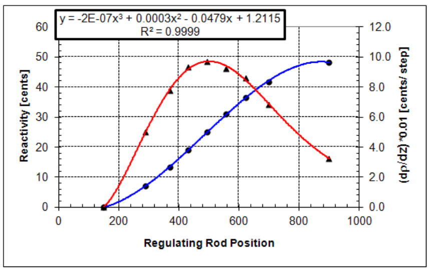


3. Description of the Tests

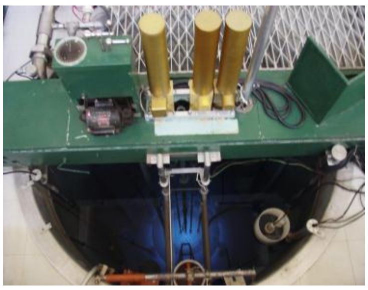
3.1. *Control Rod Reactivity Worth Determination*

The knowledge of the reactor's response to specific control rod motions is essential to the safe and efficient operation of a nuclear reactor. The rods were calibrated by the positive period method.

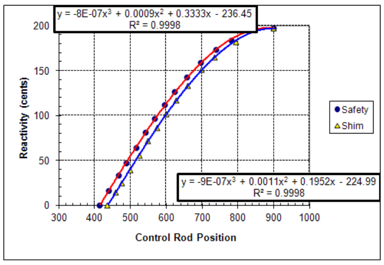
The maximum in the differential curve occurs approximately in the center, and is small near the ends because of the smaller flux density.



Differential and integral curves of the Regulating control rod



The Shim and Safety rods were intercalibrated. One control rod is measured in presence of the other rod, which is used for compensating the reactivity introduced by step withdrawal of the measured rod.



Integral curve of the Shim and Safety control rods

3.2. *Excess of Reactivity and Shutdown Margin Measurements*

The value of excess reactivity, ρ_{exc}, must be such as to compensate the effects of negative feedback reactivity due to the temperature coefficient, xenon poisoning, fuel burn up (long term) and introduction of samples for irradiation.

To measure ρ_{exc} , the reactor was left critical at low power with various control rod configurations. The reactivity inserted in the core by each control rod was obtained considering the respective calibration curve. The average value of the core excess reactivity was (2.00 ± 0.02) $. The corresponding experimental value of k_{eff} is 1.01605.

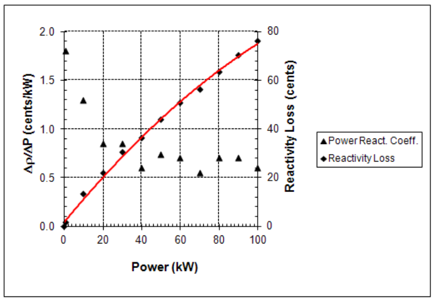
The shutdown margin is defined as negative reactivity by which the reactor is subcritical if all control rods were fully inserted in the core except the most reactive rod. The shutdown margin is equal the excess reactivity minus the sum of all control rod worth except the most reactive one. The table shows the values of the control rods worth, the ρ_{exc}, and the shutdown margin for the current IPR-R1 reactor core.

Results of reactivity (β_{eff} = 0.0079 for the IPR-R1 reactor).

	ρ ($)	ρ (pcm)
Regulating Worth	0.48	379
Shim Worth	3.21	2536
Safety Worth	2.84	2244
Reactivity Excess	2.00	1580
Reactivity of the control system	6.53	5159
Shutdown Margin (Shim rod out)	1.32	1043

3.3. *Power Defect Measurement*

The experiment was performed by increasing the reactor power, and, consequently, the fuel temperature by withdrawing the Shim rod in a number of steps. Initially, the reactor was critical at 20 W. The reactivity was determined from the calibrated curves, considering each critical rod position. The figure below shows two curves: ($\Delta\rho/\Delta P$) and the reactivity loss to achieve a given power level versus the reactor power. A significant amount of reactivity is needed to overcome temperature and allow the reactor to operate at high power levels. The reactivity needed to operate the IPR-R1 reactor at 100 kW, or the power defect, was 0.76 $. The curve of the reactivity loss is almost linear, and gives a power coefficient of reactivity about -0.66 ¢/kW (-5.2 pcm/kW).



Reactivity loss and power coefficient of reactivity versus reactor power

4. Conclusions and Acknowledgements

- This paper presents the results of neutronic tests which are performed annually, as determined by the RAS of the IPR-R1 TRIGA reactor.
  - The control rods were calibrated by the positive period method:
    - Regulating worth = 0.48 $,
    - Shim worth = 3.21 $,
    - Safety worth = 2.84 $;
  - Excess reactivity = 2.00 cents; k_{eff} = 1.0161;
  - Shutdown margin = 1.32 $;
  - Power defect = 0.76 $;
  - Power coefficient of reactivity = 0.66 ¢/kW.
- Reactivity losses of the reactor core:
  - Samples irradiated for 8 hours at 100 kW in the rotary specimen rack positions: 16.2 cents,
  - Xenon poisoning, after 8 hours of operation at 100 kW: 20 cents,
  - Void in the central thimble of the reactor: 22 cents

- To operate the reactor at the new power (250 kW), the excess reactivity of the core should be increased with the addition of new fuel elements.
- Thanks are due to the the operation staff of the IPR-R1 TRIGA reactor. This research project is supported by CDTN/CNEN, FAPEMIG and CNPq.

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