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REACTIVITY EFFECT OF A HEAVY WATER TANK AS REFLECTOR IN THE IPEN/MB-01 REACTOR

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ABSTRACT

This experiment comprises a set of experiments performed in the IPEN/MB-01 reactor and described in the International Handbook of Evaluated Reactor Physics Benchmark Experiments, specifically the experiment aim to evaluate the reactivity due to the heavy water tank placed at reflector region of the IPEN/MB-01 reactor. An aluminum tank was designed to be filled with heavy water and positioned at the west face of the IPEN/MB-01, additionally the experiment was also designed to allow variable heavy water height inside of this tank providing different neutron leakage rate in the west face of the IPEN/MB-01, consequently providing a series of interesting combinations. The measured quantities in the experiment are reactivities and critical control bank positions for several combinations of the control banks and an excess of reactivity of the heavy water tank. The experiment will be simulated using a Monte Carlo code MCNP in order to compare the different critical control bank position.

1. INTRODUCTION

A different reflector experiment has been performed in the IPEN-MB-01[1,2] in order to evaluate the reflector performance (neutron leakage), one of this experiment was conducted using a heavy water tank in the reactor reflector region. The heavy water tank was specially designed to fit in the reflector region and flexible enough to allow different water height during the experiment. This experiment can contribute to new research reactor under design in Brazil named as RMB (Brazilian Multipurpose Reactor). The RMB research reactor intent to replace an older research reactor IEAR-1 in near future and, moreover can be utilized for radioisotope production as well material irradiation. The heavy water tank can improve the thermal neutron region in irradiation position and can act as secondary independent reactor shutdown system beside safety and control rods. Additionally, the experiment can be very useful to validate some of the design calculations, specially the required safety shutdown margin.

2. IPEN/MB-01 REACTOR AND EXPERIMENT SETUP DESCRIPTION

The IPEN/MB-01 is a zero power reactor with fuel rods containing UO_2 pellets with uranium enriched to 4.3486 wt.% ^{235}U, the fuel rods can be arranged in a very flexible configurations, which allows a diversity of critical experiments, the reactivity is controlled by means of only two banks of control rods.   The Figure 1 presents a standard schematic view of IPEN/MB-01 reactor core and Figure 2 presents details of the reflector box and the positioning relative to the active core.

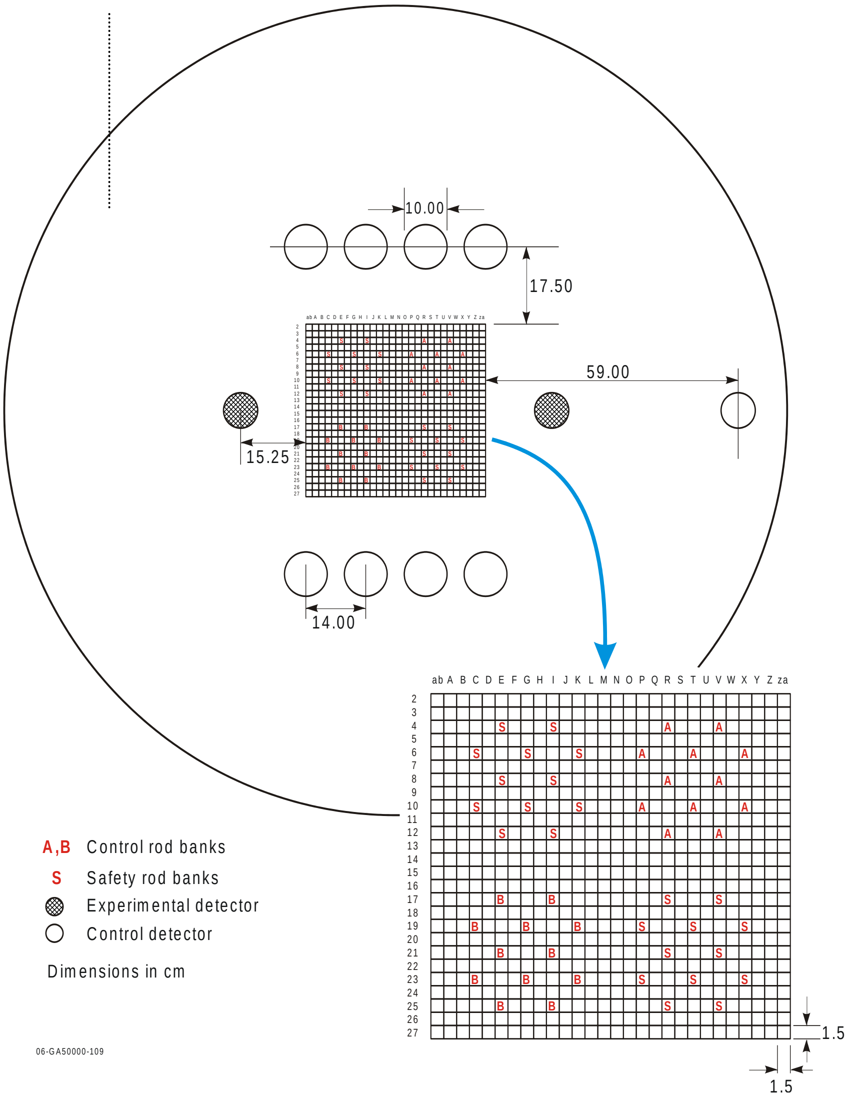

Figure 1: Schematic diagram of the Moderator Tank (Plan View) showing the detector distribution around the core.

A flexible core where fuel rods can be arranged in different geometric configurations, the reactor allows insertions inside and vicinity of the core, there are specific positions in the grid plates for sample insertion, and enough room in the reflector region. Considering that, one experiment was specially conceived to verify the reflector region importance using a heavy water tank.

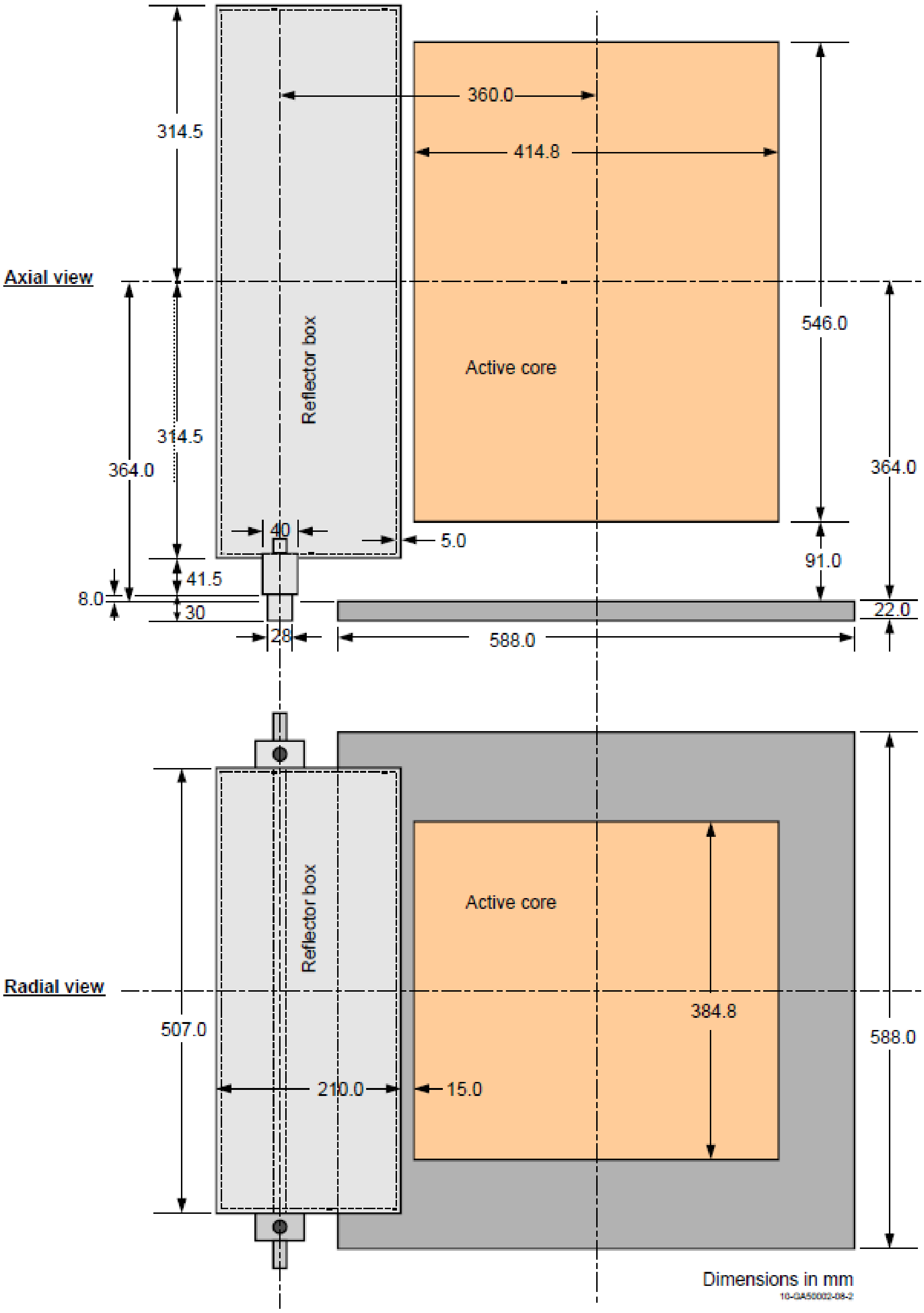

Figure 2: Details of the heavy water tank and relative position to the active reactor core.

The reflector box is made of Aluminum type 5052 (Aluminum with manganese) with 5mm thick, the as built dimension is given below:
Height: 629.00 ± 0.1 mm
Width: 507.00 ± 0.1 mm
Depth: 210.00 ± 0.1 mm

The box was positioned radially centered as well as axially relative to the center of the active core. The distance between the reflector box and the last row of fuel rods is 15.0±1.0 mm.

Therefore, the sides of the active core as shown in Figure 2 are 27*15.0 (pitch) + 9.8 (outer fuel rod diameter) = 414.8 mm and 25*15.0+9.8=384.8 mm. Figure 2 shows the details of the reflector box relative to the IPEN/MB-01 core.

The as-built dimensions of the box provide an inner volume of 61.521 liters. This volume was measured experimentally by calibrating in mass a volume of 1,000 ml using ordinary water. The accuracy of the measurements was 0.05%. After box volume measurements, the first step of the experiment was conduct in order to verify the amount of reactivity due to aluminum box filled with ordinary water comparing the standard control rod critical position (without any aluminum box). The amount of reactivity due to presence of aluminum box was about 1.5 pcm, which is quite small enough to neglect.

The IPEN/MB-01 reactor characteristics such as fuel rod composition, control rods composition as well all dimensions are in LEU-COMP-THERM-077 enclosed to International Handbook of Evaluated Criticality Safety Benchmark Experiments [3].

Specifically for this experiment, the aluminum box composition is given in the Table 1 and heavy water composition was measured at ENSI (Argentina). The measured purity of the heavy water is 99.49 ± 0.02% molar. The heavy water density at 20.5°C used in the calculation of atomic density is 1.10494 g/cc.

Table 1: Measured Composition of the Reflector Box.

Nuclide	Concentration (mass%)
B	$2.90\ 10^{-6}$
Cu	$1.90\ 10^{-2}$
Cr	$1.50\ 10^{-1}$
Fe	$3.68\ 10^{-1}$
Ga	$1.50\ 10^{-4}$
Mg	2.28
Mn	$6.50\ 10^{-2}$
Si	$1.41\ 10^{-1}$
Ti	$1.14\ 10^{-4}$
V	$4.50\ 10^{-3}$
Zn	$2.00\ 10^{-3}$
Al	96.97

3. THE EXPERIMENT MEASUREMENT

The intention of this experiment is to address the reactivity due to the presence of heavy water tank in the reflector region. The measured quantities in this experiment are reactivities and critical control bank positions for several combinations of the control banks BC#1 and BC#2, and presented in a graphical form in Figures 3 and 4, respectively for the reflector box filled with heavy water and with light water.

The experimental data shown in these figures were fitted in a Maxwell function. The reactivity excess could be obtained in the straightforward. The light water reactivity excess is just the worth of BC#2 when BC#1 is completely withdrawn. In this case for the heavy water case, the procedure was somewhat different. From the experimental data might be noted that when BC#1 is at zero level, BC#2 is still inserted to make the reactor critical. That means that the reactivity excess is bigger than the worth of a single bank, either BC#1 or BC#2. The procedure adopted in this evaluation was to fit the measured reactivity data of BC#2 and then to extrapolate the curve to the position totally withdrawn. The extrapolated reactivity is then the reactivity excess for the heavy water case. The final results are shown in Table 2.

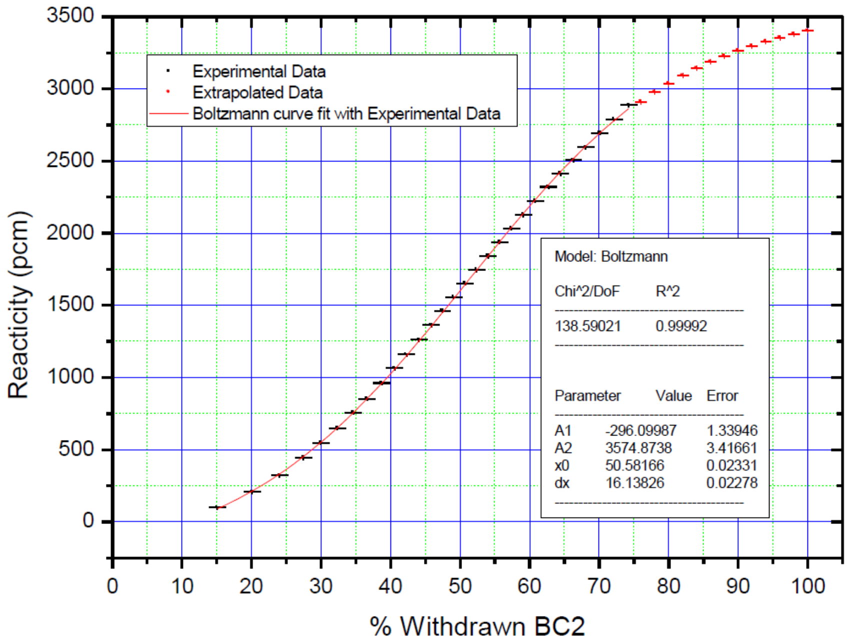

Figure 3: BC#2 Control Bank Calibration for the Heavy Water.

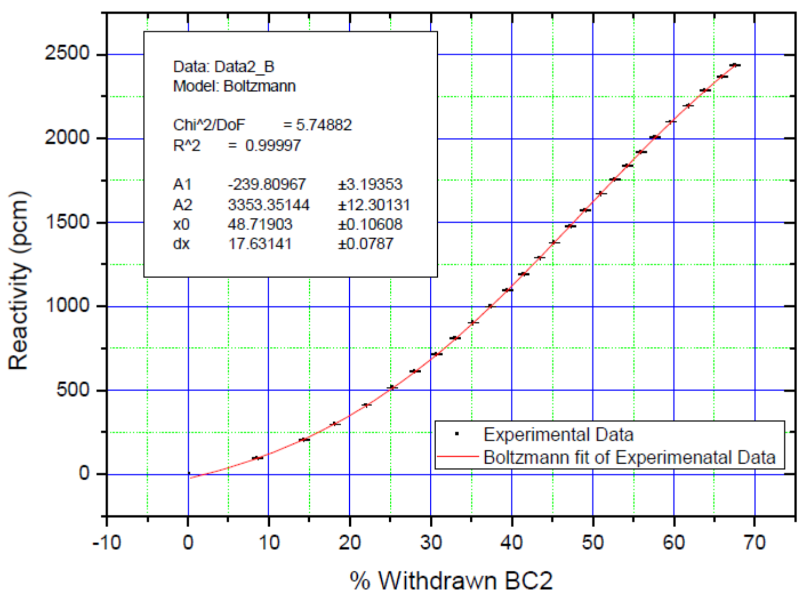

Figure 4: BC#2 Control Bank Calibration for the Light Water .

Table 2: Measured Excess of Reactivity.

Case	Reactivity Excess (pcm)
Heavy Water	3401.86 ± 3.35
Light Water	2436.68 ± 10.56

4. THE CALCULATION MODEL AND RESULTS

The calculational model for the heavy water experiment comprises two critical configurations and two measured reactivity excesses always relative to the corresponding critical reference case. The final uncertainty was evaluated taking into account the geometrical and material uncertainties associated to the facility. Calculations were conducted to simulate an experimental setup using a Monte Carlo code MCNP[4] considering a reactor core model with all important and representative regions, including control rods banks and heavy water tank, the complete data and relevant geometry data can be found specifically in LEU-COMP-THERM-007[3]. All Monte Carlo runs was taken into account an adequate number of neutron histories, at least 50 million neutron histories were adopted. Figure 5 presents a geometrical modeling adopted to perform all calculations and Table 3 presents the calculated results.

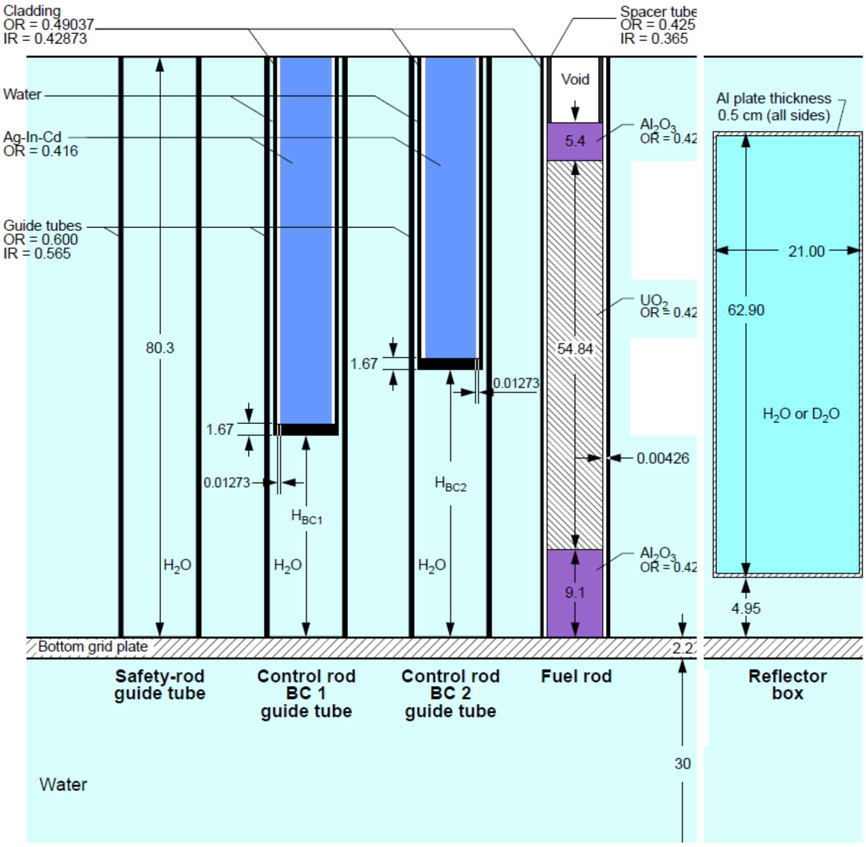

Figure 5: Representation of the fuel rod, the control rods inside their guide tubes, the safety-rod guide tube, and the Heavy Water Tank.

Table 3: Calculated and Measured Excess of Reactivity.

Case	Experimental Reactivity Excess (pcm)	Calculated Reactivity Excess (pcm)	(C-E)/E (%)
Heavy Water	3401.86 ± 3.35	3312.42 ± 4.24	-2.64
Light Water	2436.68 ± 10.56	2354.40 ± 4.24	-3.38
Net Reactivity	965.18 ± 14.99	958.02 ± 6.00	-0.74

5. CONCLUSIONS

The experiment using heavy water tank as reflector was performed at IPEN/MB-01 reactor using one aluminum box filled with heavy water, where excess of reactivity was measured by means of control rod worth. The calculation performed using Monte Carlo code MCNP shown an excellent agreement, moreover this experiment can contribute to validate current under design calculation applied to RMB research reactor.

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