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A VARIABLE REFLECTOR SIZE EXPERIMENT AT IPEN/MB-01 CRITICAL FACILITY

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ABSTRACT

Recently, the heavy reflector experiment was performed at IPEN/MB-01 in order to assess the reactivity effect due to presence of thick stainless steel plate surround reactor core and main outcome of the experiment was the reflector saving contribution to the total core reactivity[1]. Since then, experiments related to many fundamental aspects of reflector become important, specially the finding about reactivity effect and contribution to the reactor core. This paper present another reflector experiment performed in order to address the reactivity due to the size of reflector. The experiment consist of slab tank built using aluminium plates placed at one side of the reactor core, the tank is connected to two water tanks located at the IPEN/MB-01 control room, which is a part of the aluminium tank filling system. The filling system can insert and remove a specific volume of water inside of aluminium tank from empty to full, such conditions can simulate a variable reflector size. The experiment with different reflector size was properly modelled and evaluated using a MCNP Monte Code.

1. INTRODUCTION

The experiment performed at IPEN/MB-01 reactor aim to address the importance of reflector region, specially considering a variable size of reflector. During reactor design process, a reflector importance is well known and in order to fulfill and validate reflector calculations, a series of experiments was conduct to access a heavy steel reflector [1], since then others experiments addressing reflector was designed and performed.

2. IPEN/MB-01 REACTOR AND EXPERIMENT 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.

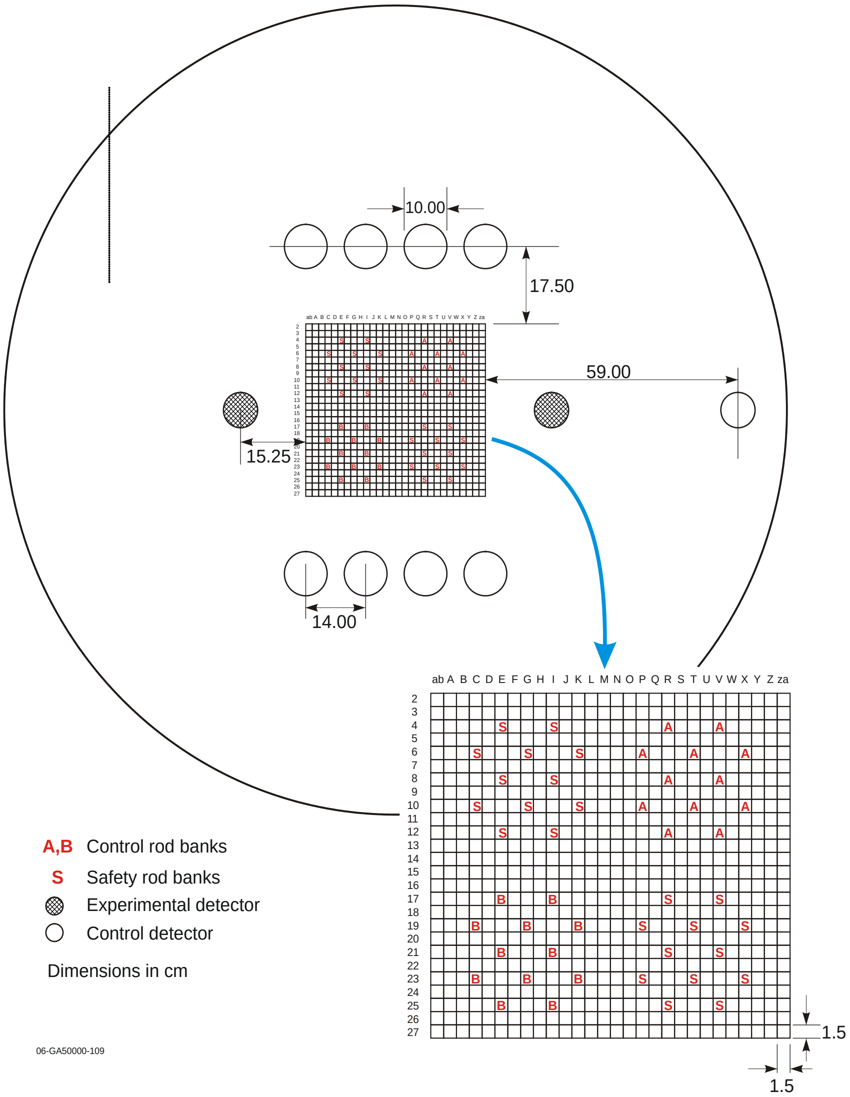

Figure 1. Schematic Diagram of the Moderator Tank (Plan View) Showing the Detector Distribution around the Core.

Beside flexible core where fuel rods can be arranged in different configurations, the reactor allows insertions inside and vicinity of the core, there are specific positions in the grid plates for sample insertion, and room in the reflector region. Considering that, one experiment was specially conceived to verify the reflector region importance. The experiment comprise a specific system which reflector size can be variable, the system is composed of the following items: an aluminum box located at the west face of the IPEN/MB-01 core as shown in Figure 2; two tanks (one for water storage and a second one for fine adjustment); a series of line communications made with special hoses, and a control panel.

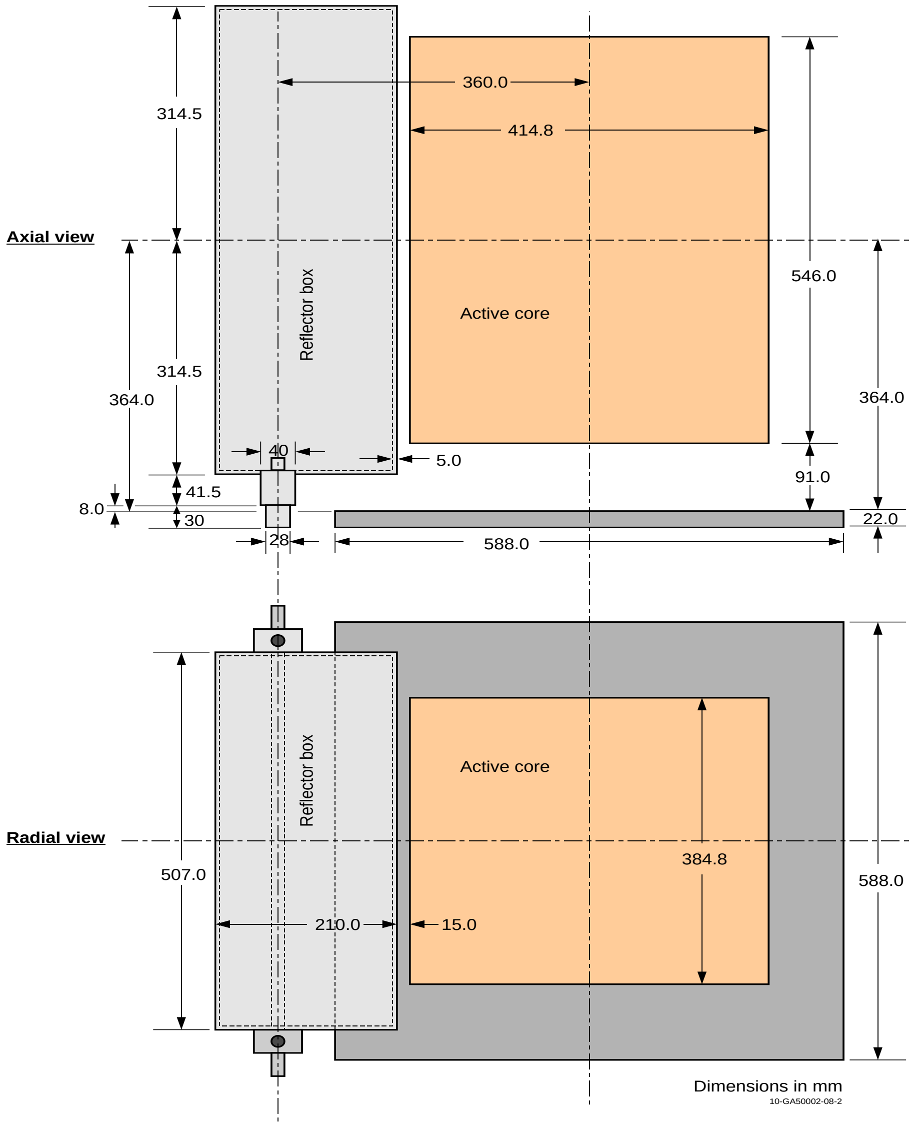

Figure 2. Details of the aluminum box and its positioning relative to the active core.

The experiment was designed to allow changes in the water height inside of the reflector box making a column of water and a column of air. In this way, the neutron leakage in the west face of the IPEN/MB-01 can be altered, thus providing variable reflector size. The reflector box was centered radially as well as axially relatively 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=384.8mm.

Originally, the experiment was designed to have two reflector boxes placed in the west and east faces of the IPEN/MB-01 core, but this experiment was conducted using only one reflector box. The associated system which control the water flow inside the aluminum box is quite straightforward, basic principle to transfer water from one reservoir tank to aluminum box is by pressure difference make available by the air supply in the communication lines.

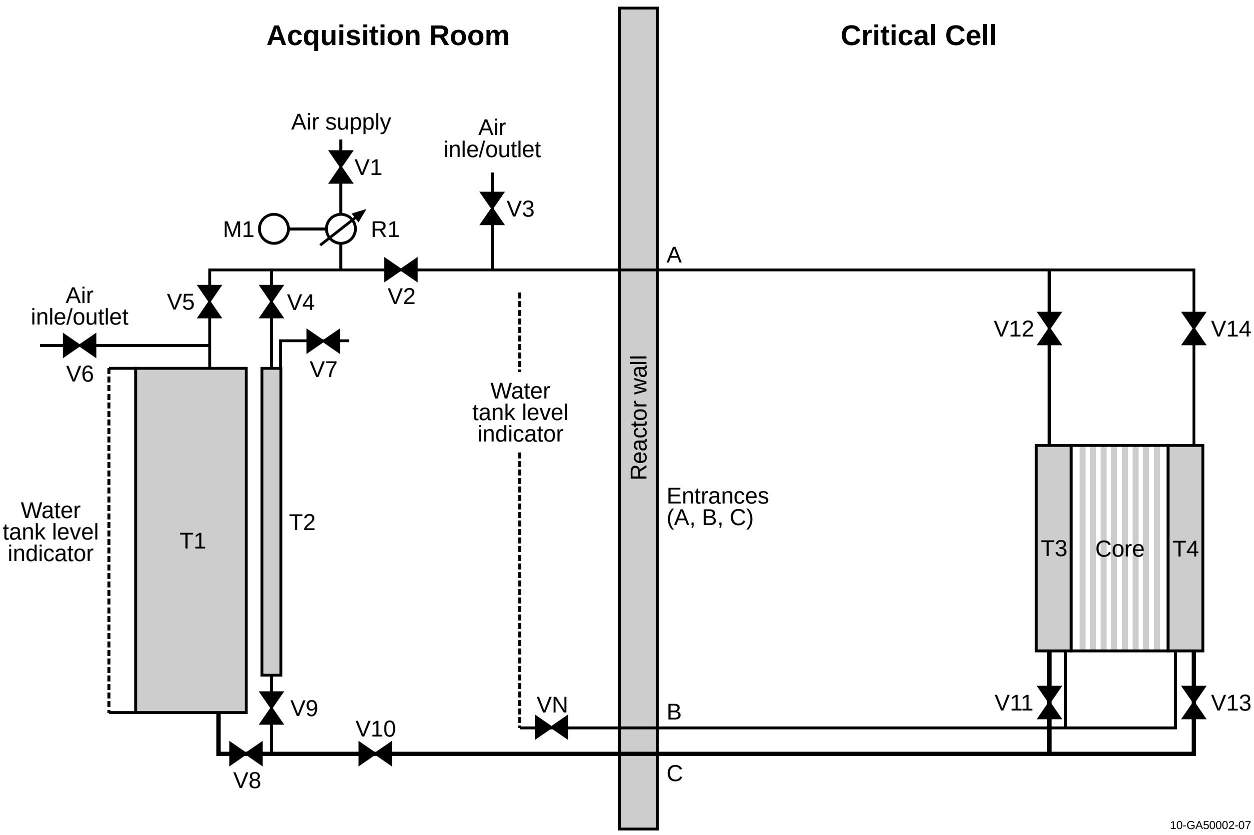

Figure 3. Water transfer system to aluminum box

The quantity of water sent to or removed from the reflector box is measured by volume variation. A special device was set up to measure this volume variation. Also, the measuring system can control the total water content in the reflector box and from that the water height inside of the box can be inferred. The reflector boxes are connected to two tanks located at the IPEN/MB-01 acquisition room as shown in Figure 3.

The reflector box is made of Aluminum type 5052 (Aluminum with manganese). The aluminum thickness is 5mm thick. The as-built dimensions are:

Outer dimensions: height: 629.00 mm, width: 507.00 mm and depth: 210.00 mm
Inner dimensions: height: 619.00 mm, width: 497.00 mm and depth: 200.00 mm

The as-built dimensions provide an inner volume of 61.521 liters. This volume was measured experimentally by calibrating in mass a volume of 1,000ml. The respective equivalence in mass measured by a Mettler P11N balance is 994g; with an accuracy of 0.1 grams. For a volume of 10 liters, the mass measured is 9.938 grams. The reflector box was then filled with water, and the water removed and its total mass measured. The total volume from the mass calibration could then be obtained and equal to 61.550ml. A second measurement was performed, resulting in a value of 61.560ml. Therefore the measured of the inner reflector box volume was then obtained as: V = 61,555ml or 61.56 liters. The accuracy of the measurements was 0.05%. The measured composition of the reflector box performed at IPEN is given in Table 1.

Other important reactor data such as fuel composition, dimensions, etc, can be found in a series of critical benchmark experiments performed at IPEN/MB-01[2] during last years.

The procedure adopted for the experimental approach was the following: firstly, the reference condition was setup and all relevant data were assessed, specially water temperature was initially kept at around 21.0 °C. The temperature in the fuel region was monitored by the 12 thermocouples strategically located in the reactor core. After reference operation, where control rods worth and critical position were verified, the aluminum box was properly assembled and positioned at west side of reactor core.

Table 1. Measured Composition of the Aluminum Box.

Nuclide Present	**Concentration (mass %)**
B	2.90E-06
Cu	1.90E-02
Cr	1.50E-01
Fe	3.68E-01
Ga	1.50E-04
Mg	2.28E+00
Mn	6.50E-02
Si	1.41E-01
Ti	1.14E-04
V	4.50E-03
Zn	2.00E-03
Al	96.97

In order to measure the reactivity induced by the reflector box, supports, and screws, initially the IPEN/MB-01 reactor was made critical without the aluminum box and supports. The critical control bank positions were registered. The reactor configuration was the standard rectangular one (28x26). After that, the reflector box was positioned following the procedure described above and the box was completely filled with water. The IPEN/MB-01 reactor was made critical again and the critical control bank positions were recorded. Converting the difference in the control bank positions into reactivity employing a control bank calibration curve, the final result is 1.5 pcm which is small enough. These results demonstrate that the variation of reactivity due to the presence of the reflector box, supports, tabs, screws, etc, was negligible.

The experiment began with aluminum box fully of water, and step by step the water inside of aluminum box was removed using a water removal system. Each step with a specific water volume inside of aluminum box was taken following experimental activities: level of water and temperature measurements, control rods critical position and reactivity measurement.

The water level inside of aluminum box was inferred using a correlation formula taken from storage tank height, as presented below :

$$h_{Cx} = \frac{A_{Tq}}{A_{Cx}}\left(H_0 - H_{Tq}\right) + h_0 \qquad (1)$$

where:

h_{Cx} is the level of the water in the reflector box,

A_{Tq} is the transversal area of the storage tank,

A_{Cx} is the transversal area of the reflector box,

H_0 = 831.0±0.5 mm

H_{Tq} is the water level of the storage tank,

h_o = 3.0±0.5 mm is the initial level of the reflector box due to the presence of a siphon inside of the box.

3. EXPERIMENTAL RESULTS AND ANALYSIS

The experiment was performed considering eight steps (eight water level inside of aluminum box), covering a fully of water up to almost empty situation.

During each step, only control rod bank BC#2 was moved to adjust critical condition and also to infer the reactivity worth; the control rod bank BC#1 was kept at 58.06% inserted.

The Table 2. shows an experimental results obtained for a variable reflector size.

Table 2. Experimental results obtained

Water Level (mm)	Control rod bank BC#2(%)	Temperature ^{0}C	Control rod bank movement BC#2(%)	Δρ (Reactivity) pcm
619.0 ± 0.5	58.10 ± 0.01	21.05 ± 0.03	58.10→58.10	0
533.3 ± 0.5	58.61 ± 0.01	21.05 ± 0.03	58.61→58.10	26 ± 1
439.5 ± 0.5	60.45 ± 0.01	21.01 ± 0.03	60.45→58.10	117 ± 2
374.9 ± 0.5	62.68 ± 0.01	21.05 ± 0.03	62.68→58.10	217 ± 4
295.6 ± 0.5	66.68 ± 0.01	21.03 ± 0.03	66.68→58.10	381 ± 6
206.7 ± 0.5	71.89 ± 0.01	21.03 ± 0.03	71.89→58.10	562 ± 8
132.3 ± 0.5	74.53 ± 0.01	21.01 ± 0.03	74.54→58.10	660 ± 9
3.0 ± 0.5	76.57 ± 0.01	21.00 ± 0.03	76.57→58.10	745 ± 10

First important results obtained was a reactivity of aluminum box inserted at reflector region, as can be seen from the Table 2., empty aluminum box represent 745 pcm reactivity.

The reactivity behavior due to water level variation inside of the aluminum box is very similar to the control rod banks worth (calibration curve), consequently the aluminum box can be used as alternative system to control the reactor criticality. The Figure 4. shows reactivity changes as function of water level.

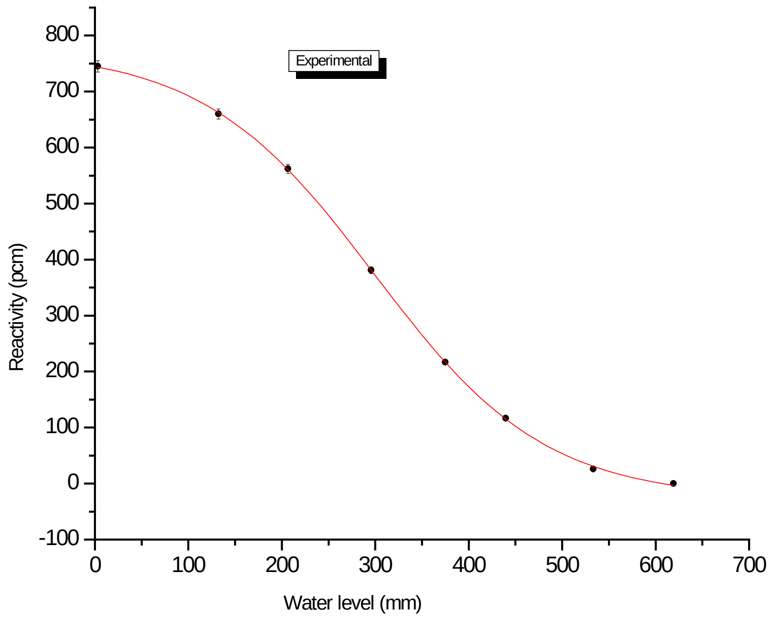

Figure 4. Reactivity as function of water level inside of aluminum box

Calculations were conducted to simulate an experimental setup using a Monte Carlo code MCNP4B[3] considering a fully detailed modeling. The reactor core model comprises all important and representative regions, including control rods banks and aluminum box. Figure 5 presents main regions considered at MCNP calculations.

All series of eight water levels inside aluminum box were simulated to obtain a representative reactivity worth, the results obtained are summarized in Table 3.

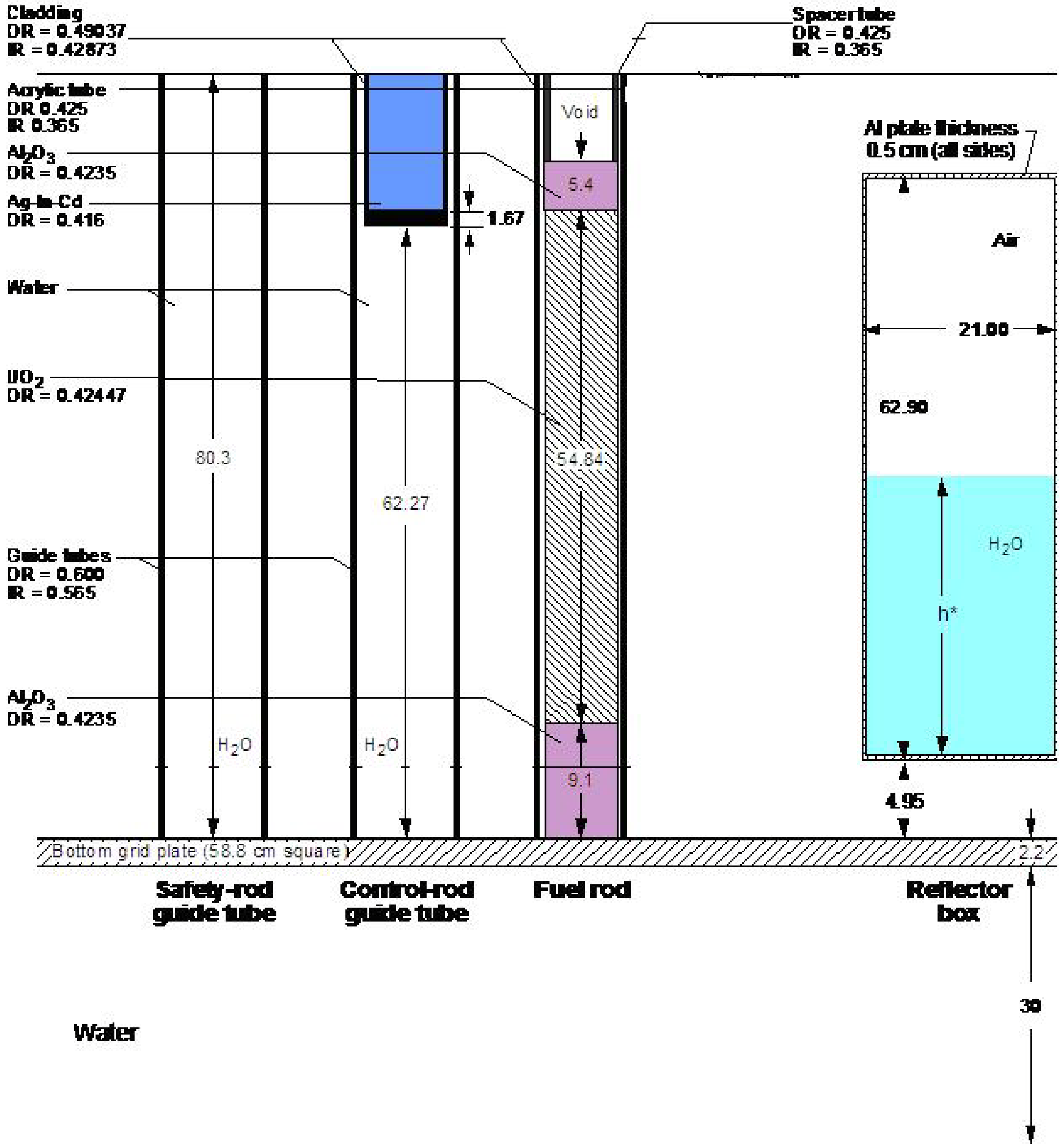

Figure 5. Representation of the Fuel Rod, the Control Rod Inside its Guide Tubes, the Safety-Rod Guide Tube and the Aluminum Reflector Box in the Benchmark Model

Table 3. Reactivity results obtained using Monte Carlo Code MCNP

Control Bank Insertion BC#1 (%)	Control Bank Insertion BC#2 (%)	Water Level (mm)	Experimental Reactivity (pcm)	Calculated Reactivity (pcm)
58.06 ± 0.01	58.10 ± 0.01	619.0 ± 0.5	0	0
58.06 ± 0.01	58.61 ± 0.01	533.3 ± 0.5	26 ±1	20.0
58.06 ± 0.01	60.45 ± 0.01	439.5 ± 0.5	117 ± 2	98.0
58.06 ± 0.01	62.68 ± 0.01	374.9 ± 0.5	217 ± 4	176.0
58.06 ± 0.01	66.68 ± 0.01	295.6 ± 0.5	381 ± 6	325.0
58.06 ± 0.01	71.89 ± 0.01	206.7 ± 0.5	562 ± 8	514.0
58.06 ± 0.01	74.53 ± 0.01	132.3 ± 0.5	660 ± 9	605.0
58.06 ± 0.01	76.57 ± 0.01	3.0 ± 0.5	745 ± 10	670.0

The results obtained with MCNP code shown generally underestimated compared to experimental results. Remarkable deviations are observed to highest water level but the reactivity worth is quite small. The lowest water level presents a better agreement compared to experimental data. For further understanding of reactivity effect due to the reflector size changes, another experiment will be performed considering aluminum box at both sides.

4. CONCLUSIONS

The variable reflector size experiment was performed at IPEN/MB-01 reactor using one aluminum box, where a special system was designed to control of water level inside of box. The designed system shown an alternative reactivity control of reactor beside control rod banks and can improve some critical experiment without presence of control rod banks perturbation. The calculation performed using Monte Carlo code MCNP shown a systematic underestimation, which will be investigated in future experiment considering aluminum boxes at both sides of reflector region.

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