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On the Starting and Operational Transients at the Core of the RMB Based on 2D Multigroup Diffusion Theory with Thermo-Hydraulic Feedback

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1. Introduction

RMB is a Brazilian multipurpose reactor designed for radioisotope production, material testing, operation of various neutron beam roles, etc. As a multipurpose facility, each activity operation can impact core criticality. In this article, we look at some of these operational transients in the core. For that, we modeled it in 2D multigroup spatial kinetic equations, with feedback, through the thermo-hydraulic equation. The expected transients would be the typical start-up of the reactor and those resulting from the introduction of samples to be irradiated, causing disturbances in the criticality of the RMB. The distribution of the neutron flux in the steady state and the transients are calculated numerically.

2. Methodology

The neutron kinetic equations are given by:

$$\frac{1}{\upsilon_g}\frac{\partial \varphi_g}{\partial t} = \nabla \cdot D_g \nabla \varphi_g - \Sigma_{Rg}\,\varphi_g + \sum_{g' \neq g}^{G} \Sigma_{sg'g}\,\varphi_{g'} + \chi_{pg}(1-\beta)\sum_{g'=1}^{G} \nu_{g'}\,\Sigma_{fg'}\,\varphi_{g'} +$$

$$+\sum_{k=1}^{I} \chi_{agk}\lambda_k C_k\,, \quad g = 1,2,\dots,G\,, \tag{1}$$

$$\frac{\partial C_k}{\partial t} = \beta_k \sum_{g'=1}^{G} \nu_{g'}\,\Sigma_{fg'}\,\varphi_{g'} - \lambda_k C_k\,,\ \ k = 1,2,\dots,I\,, \tag{2}$$

where, $\varphi_g = \varphi_g(\vec{r},t)$ now is the direct neutron flux of energy group g during transients and $C_k = C_k(\vec{r},t)$ is the delayed neutron precursor concentration of group k. At any time, the power density is given by:

$$q'''(\vec{r},t) = \sum_{g=1}^{G} \varepsilon_g \Sigma_{fg}(\vec{r},t)\varphi_g(\vec{r},t)\,. \tag{3}$$

The thermal hydraulic model, of an average channel, is given by:

$$\rho_m c_m \frac{\partial T_m}{\partial t} = rK_m \frac{\partial T_m}{\partial r} + q_m''' \ , \tag{4}$$

having in mind that m means f (fuel) or c (cladding). $P_m = P_m(r,z,t)$ can represent: ρ_m (density); c_m (specific heat); K_m (conductivity) or q_m''' (heat density). In the cladding T_c represents an average value in the volume without the heat source, $q_m''' = 0$, having in mind the Fig. 1.

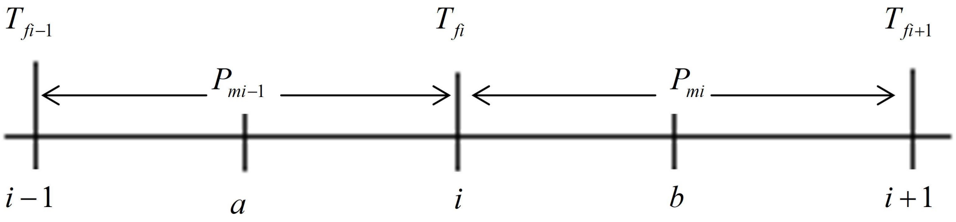

Figure 1. Temperature discretization centered at interface.

For the coolant, we have:

$$\rho_\ell c_\ell \frac{\partial T_\ell}{\partial t} = -\rho_\ell c_\ell \vec{U}.\nabla T_\ell - \nabla.\vec{q}'' \ . \tag{5}$$

3. Results

RMB core:

Table 1: Core composition.

A	H2O - Piscina
B	D2O
C	GUIA ALUMÍNIO
D	Be - Berilio
X	BC
F	Ir mini PL ou Alumínio Dummy
G	REGIÃO COMBUSTÍVEL - U3Si2-Al
H	Al - Placa Matriz
I	Ir MT ou Alumínio Dummy
J	H2O - Caixa de Água
L	Al - Chaminé

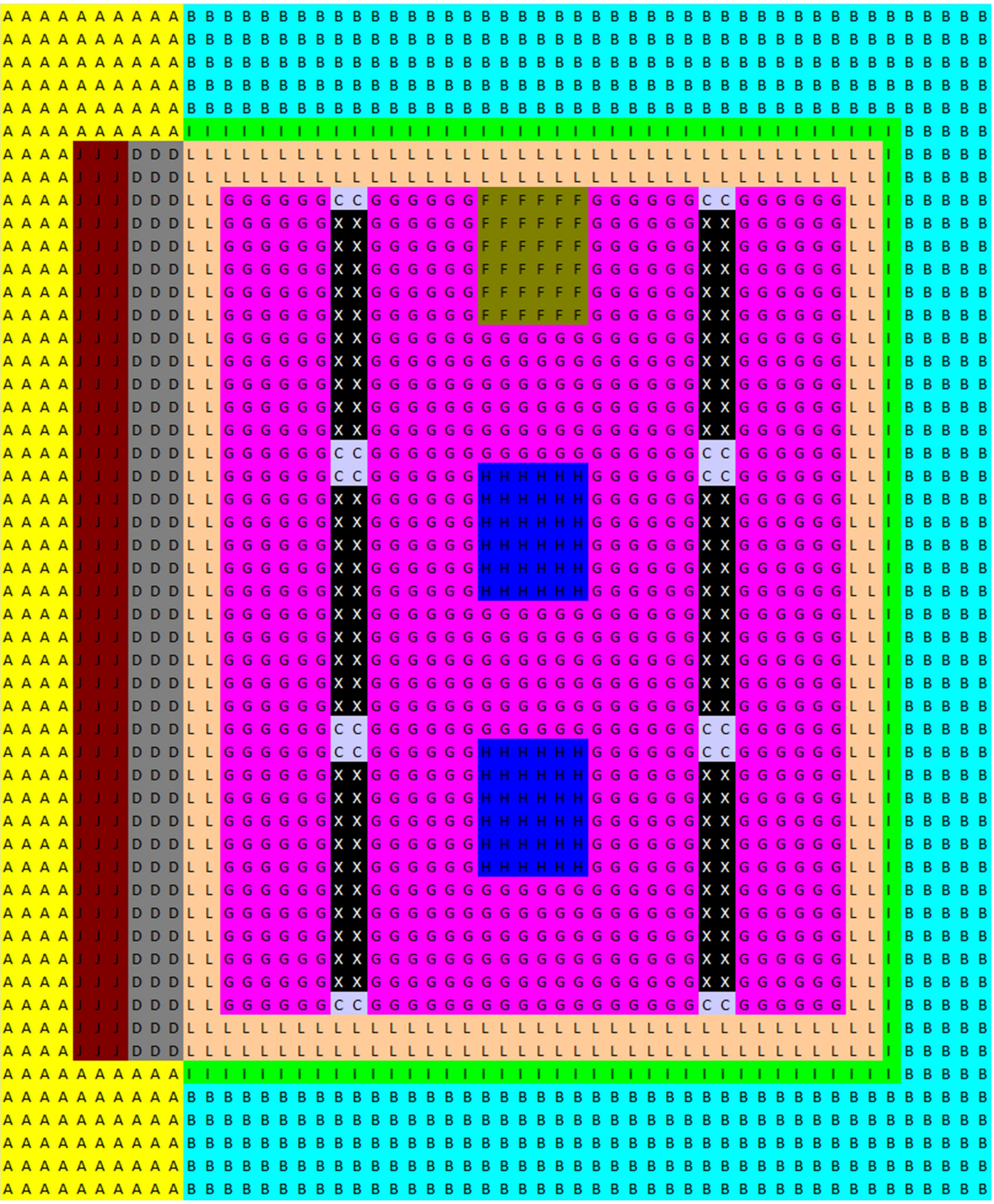

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Figure 2: Reactor core regions.

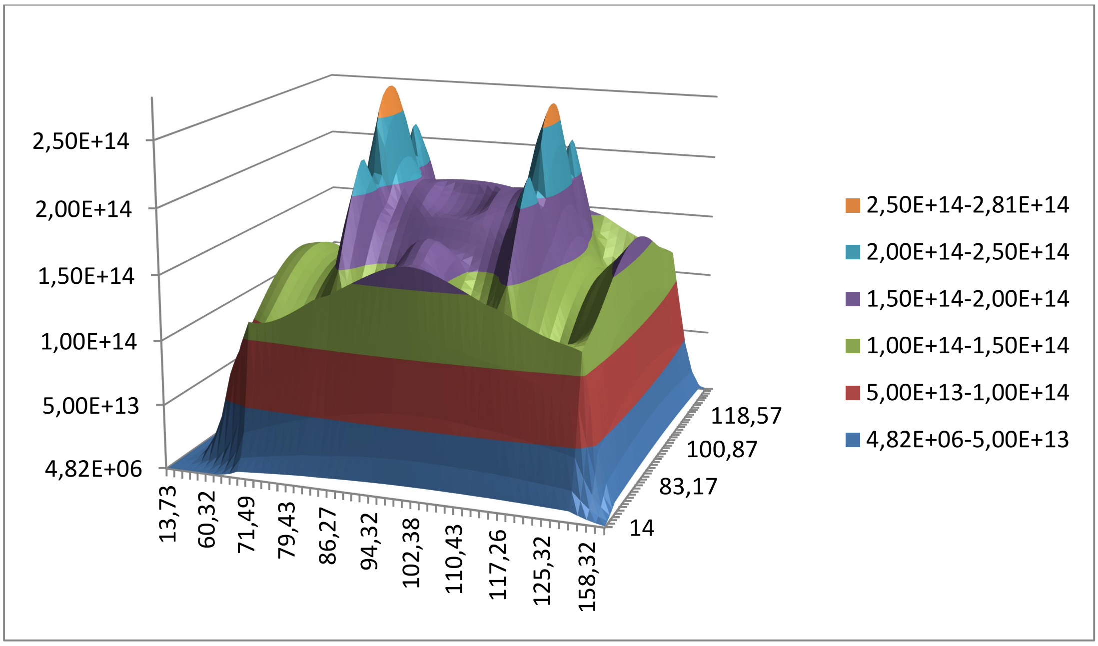

Figure 3: Thermal flux distribution in the steady state.

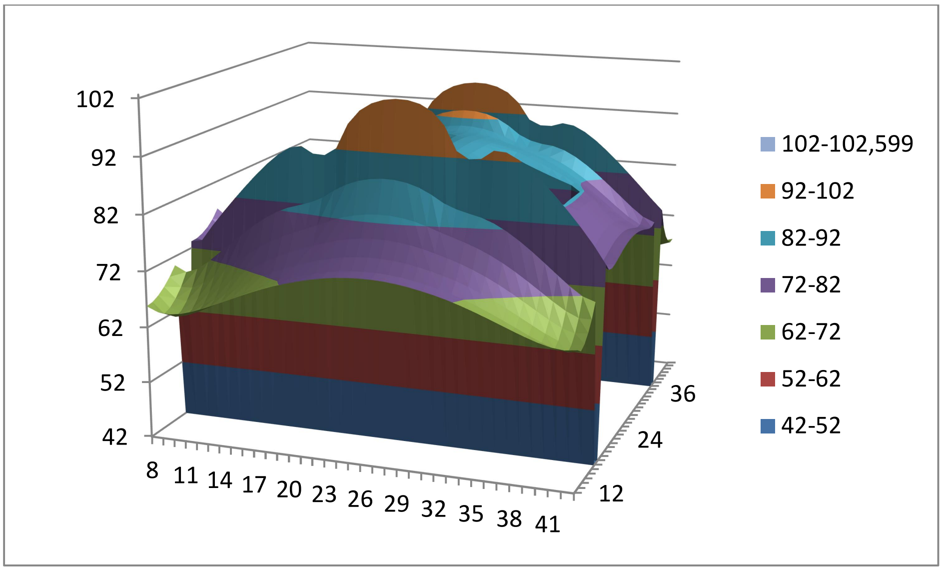

Figure 4: Fuel centerline temperature distributivo in the steady state.