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Technical note

Stability in boiling water reactor using fuel assemblies containing inert matrix as a fuel reload option

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ABSTRACT

The dynamic behavior of three different proposals for reload as an option for Laguna Verde Nuclear Power Plant Unit 1 in Mexico is analyzed. These reload employ a fuel assembly design containing a fuel rods mixture of UO_2 and PuO_2 of weapon-grade in an inert matrix of CeO_2. The assembly has an arrangement geometric 10×10, containing 42 fuel rods PuO_2–CeO_2, 34 fuel rods UO_2 and 16 fuel rods UO_2–Gd_2O_3. This fuel assembly is compatible with used in Laguna Verde UO_2 fuel assemblies which does not initially contain plutonium. The stability analysis of the three proposals reloads using inert matrix fuels which were compared with UO_2 reload was performed. A merge reload 36 inert matrix fuels and 80 UO_2 fuels assemblies has a very similar behavior with based reload observed that it is a viable option for reducing plutonium inventories, especially weapon-grade.

1. Introduction

In the world there are a large number of light water reactors and dominate the scenario for generation of electricity through nuclear power, so it is very important take a count the potential has this type of reactors to reduce the inventories of plutonium coming from nuclear reactors and the dismantling of nuclear weapon.

Mexico, has the Laguna Verde Nuclear Power Plant (LVNPP), with two Boiling Water Reactor (BWR), for which the National Institute for Nuclear Research has proposed designs of fuel assemblies that include the possibility of using oxide of plutonium in an inert matrix (Hernández, 2012). These designs of fuel assemblies shown a decrease in geometric dimensions of some fuel rods. As a result, an increase in the reason for moderation is reached. The new designs consider the possibility of using plutonium weapon-grade as fuel material.

Highly moderated reactors, burnup more plutonium, while producing fewer of actinides. Given that two major actinides, plutonium and americium, have significant resonance in the thermal energy range, the moderation rate becomes an important parameter for the core design with 100% MOX fuel PWR (Prunier et al., 1995; Barbrault, 1996). By increasing in moderation rate more neutrons have the opportunity to reach thermal energy and increase the probability to escape from the region of resonances of actinides. Some kinetic parameters are also a favorable performance in high moderation reactors.

An inert matrix fuel (IMF) design will be used to generate new patterns of fuel reloads. First analyzes the neutronic behavior of proposed design of fuel assembly, which contains a combination fuel rods of plutonium oxide in an inert matrix (PuO_2–CeO_2), rods of uranium oxide (UO_2) and rods of UO_2 with oxide of gadolinium (Gd_2O_3). Subsequently, three different schemes of fuel reload including the new assembly are analyzed.

In order to evaluate the dynamic behavior of the three reload proposals considering fuel assemblies with inert matrices, a comparison with a reload of UO_2 fuel assemblies, which satisfies the requirements of energy and security, was performed during the simulation of an event oscillation power and determine the core stability. To make this comparison the CASMO4 (Knott and Forssen, 2005), SIMULATE3 (Dean, 2005) and SIMULATE-3K (Grandi, 2005) Studsvik codes were used.

Stability estimation in a BWR, traditionally used the parameter of Decay Ratio (DR), which is defined as ratio between two consecutive peaks of a second order dynamic system response to a perturbation. This parameter is normally applied to the time series of reactor power.

Reactors fed with new fuel designs should be stable in operation region flow-power approved. Each new fuel design must be analyzed to demonstrate the core stability is equal or better to an existing reference fuel design. The core stability is evaluated in this work to high power reactor operating conditions and low

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Table 1
Fuel rod isotopic composition of inert matrix fuel assembly.

Pin type	# of pins	^{235}U [w/0]	^{238}U [w/0]	^{239}Pu [w/0]	Gd_2O_3 [w/0]	CeO_2 [w/0]
1	3	2.00	98.00	–	–	–
2	1	2.40	97.60	–	–	–
3	2	2.80	97.20	–	–	–
4	4	3.20	96.80	–	–	–
5	6	3.60	96.40	–	–	–
6	18	3.95	96.05	–	–	–
IMF	42	–	–	32.60	–	67.40
G	16	3.95	96.05	–	4.00	–

coolant flow to different burnup steps, in order to determine how varied the stability with respect to the reference case.

2. The assembly design

Studies with core partially loaded for pressure water reactors with homogeneous fuel assemblies containing fuel rods of UO_2 and PuO_2–CeO_2 (Aike et al., 1994) have been conducted. So to analyze fuel Assembly design takes as a fuel assembly with 10 × 10 geometric arrangement, which contains 42 rods IMF (PuO_2–CeO_2) with plutonium weapon-grade, 34 rods of UO_2, and 16 rods contain fuel and consumable poison, UO_2–Gd_2O_3. The concentrations isotopic of each fuel rod type used in lattice calculations is shown in Table 1, and the pellets geometry on the fuel assembly is shown in Fig. 1.

Geometrically the inert matrix fuel rods have less than dimensions to fuel rods of UO_2, but the rod to rod separation (pitch) remains the same. Fig. 1, shows the dimensions of the fuel pellets and the casing for both fuels, the UO_2 standard rods (left) and the inert matrix (right).

The axial fuel design considered three regions; the edges of UO_2 and the central region was considered a homogeneous region which contained inert matrix fuel rods, and rods of uranium oxide with or without gadolinium. The geometric dimensions of natural uranium as homogeneous central regions are shown in Fig. 2.

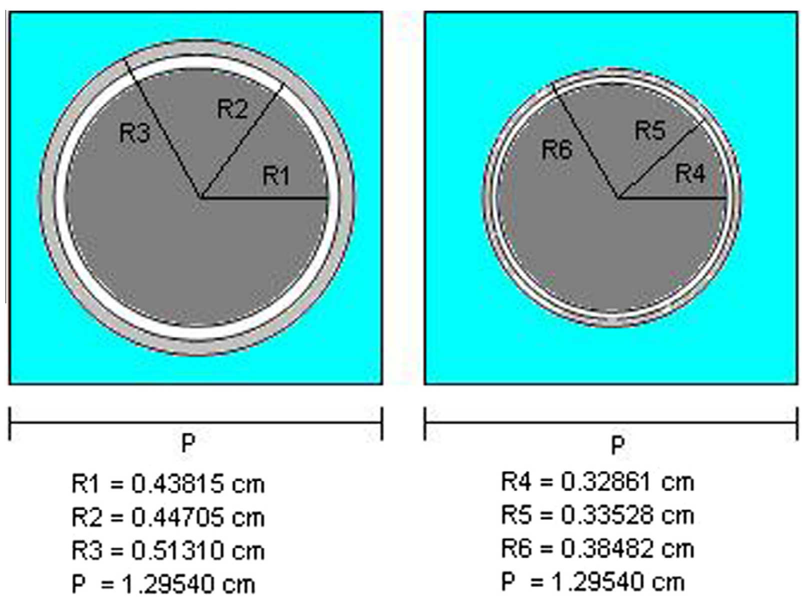

Fig. 1. Geometry of rods into fuel assembly. UO2 (left) and inert matrix (righ).

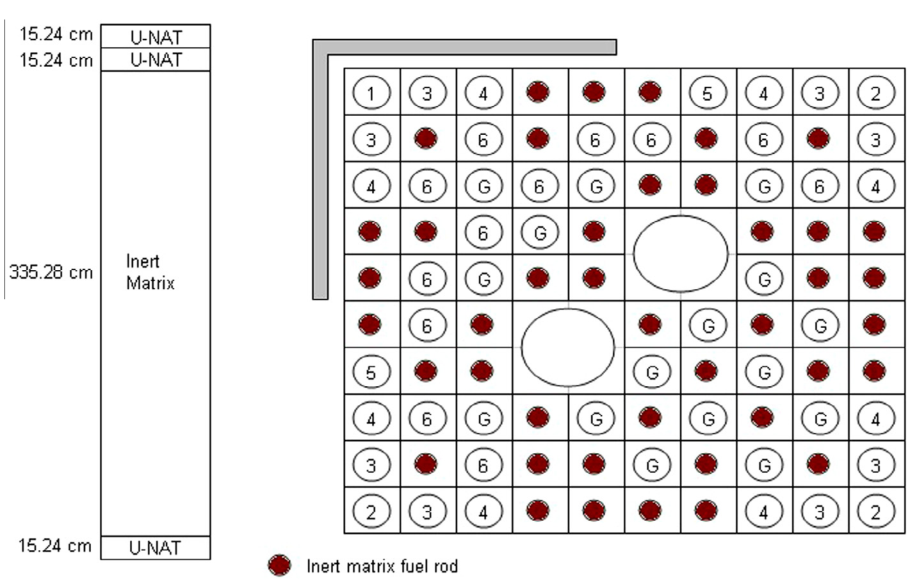

Fig. 2. Axial description of assembly and inert matrix fuel cell.