***International Workshop on Advances in Applications of Burnup Credit for Spent Fuel Storage, Transport, Reprocessing, and Disposition***

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# Peak Reactivity Characterization and Isotopic Inventory Calculations for BWR Criticality Applications

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# Fuel Characterization for BWR Criticality
## 1. Introduction (1)

- For BWR criticality calculations supporting spent fuel storage racks design, the most reactive fuel assembly to be stored, at its maximum reactivity point (reactivity peak), must be considered.

- Determination of the most reactive fuel assembly needs to consider the distribution (as a function of burnup) of the fissile content, burnable absorbers and fission product inventories within the fuel assembly.

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# Fuel Characterization for BWR Criticality
# 1. Introduction (2)

- BWR fuel designs and operating conditions are highly heterogeneous:
  - ✓ Different lattice geometries in the same bundle (part-length rods)
  - ✓ Radial and axial distribution of enrichment and gadolinium inside the bundle.
  - ✓ Burnup dependent local operating conditions: void fractions and control rod insertion
- BWR fuel characterization for criticality analysis is not so straight as desirable.
- The scope of this work is to develop a simple and conservative (production) model for BWR criticality analysis.
- Production model derived from a series of sensitivity analysis to the relevant characteristics of the real model:
  - ✓ K-infinite and isotopic calculations performed with the lattice TGBLA code.
  - ✓ In-rack K-effective calculations performed with CSAS25 (SCALE5.1).

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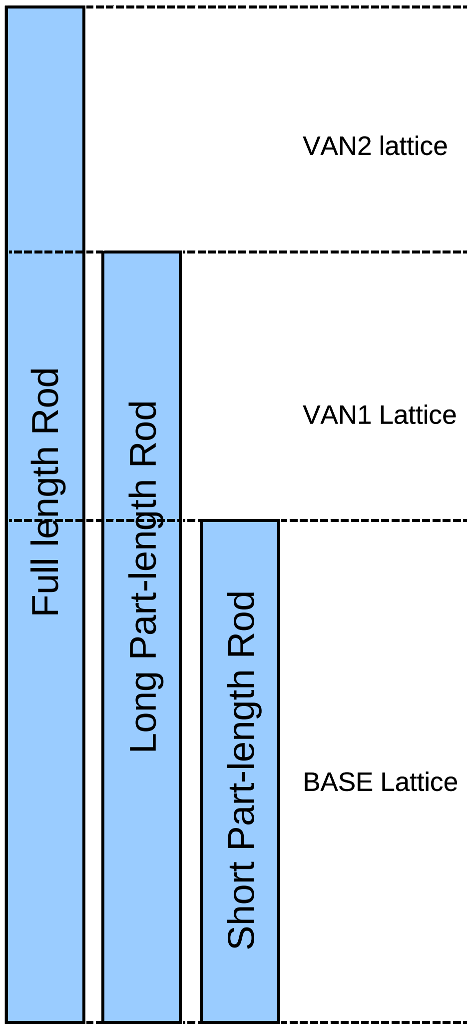
# Fuel Characterization for BWR Criticality
## 1. Introduction (3)

- The examples and results included in this presentation are for GNF fuel designs.
- Fuel lattices named as BASE, VAN1 or VAN2 depending on the existence and type of partial length rods.
- The conclusions of the study judged to be easily extrapolated to other vendors designs.

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# Fuel Characterization for BWR Criticality

## 2. Evolution of fuel reactivity with burnup and operating conditions (1)

- BWR fuel reactivity increases, due to the presence of gadolinium rods, from its fresh fuel value up to a maximum obtained at a given burnup (reactivity peak)

- For a given lattice design the reactivity peak will depend on void fraction and control rod insertion.

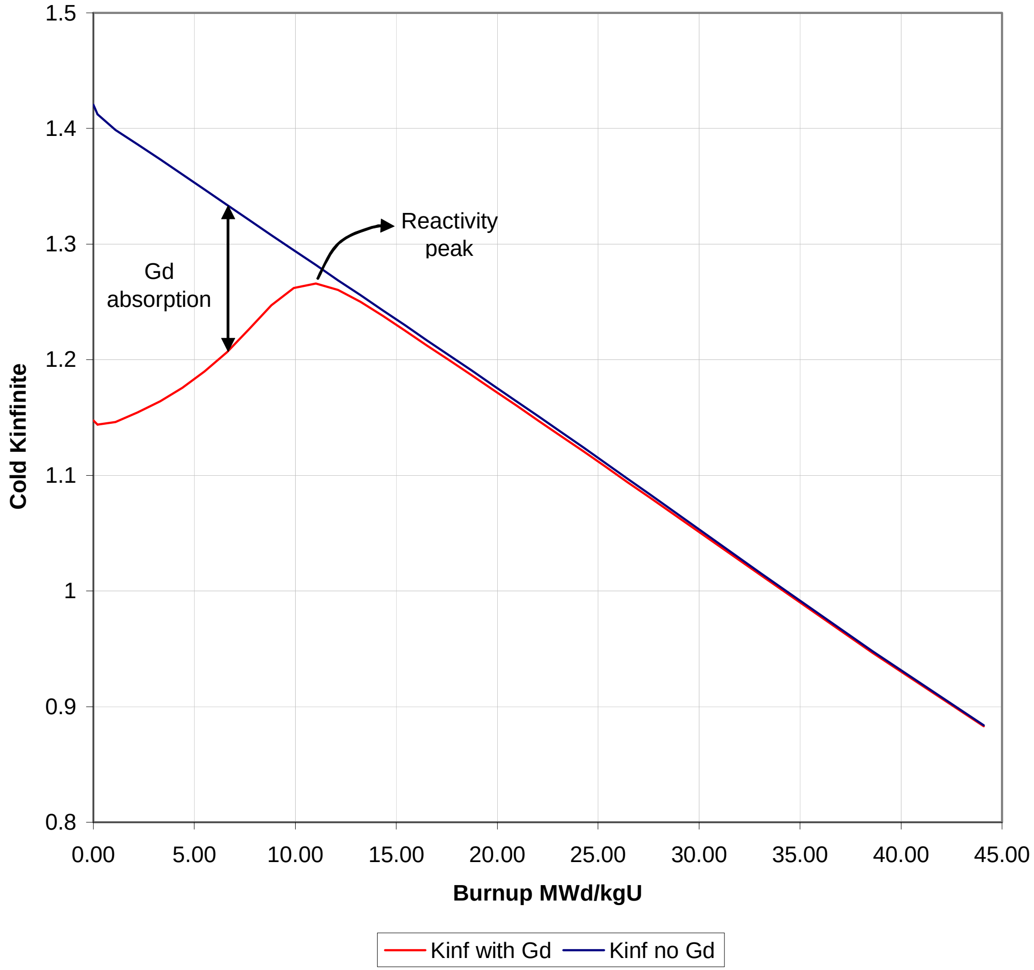


Figure: Cold K-infinite vs Burnup

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# Fuel Characterization for BWR Criticality

## 2. Evolution of fuel reactivity with burnup and operating conditions (2)

- First step towards simplified model consists on determining the core conditions that lead to the highest cold K-infinite value.
- Burnup calculations at several void fractions were performed for a fuel with 12 Gd rods at 5% in $Gd_2O_3$.
- Control blade insertion was also analyzed for the BASE lattice.
- For all lattices, the highest cold K-infinite was reached for the uncontrolled case at 0.0 voids.
- For the BASE lattice, the highest K-infinite corresponds to the uncontrolled case

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1.60 | 2.80 | 3.60 | 4.40 | 4.40 | 4.40 | 4.40 | 3.60 | 2.80 | 2.00 |
| **2** | 2.80 | 4.00 | 4.40<br>5.00 | 4.95 | 4.40<br>5.00 | 4.95 | 4.95 | 4.40<br>5.00 | 4.95 | 3.20 |
| **3** | 3.60 | 4.40<br>5.00 | 4.95 | 4.95 | 4.95 | 4.95 | 4.95 | 4.95 | 4.40<br>5.00 | 4.40 |
| **4** | 4.40 | 4.95 | 4.95 | 4.95 | 4.95 | WR | - | 4.95 | 4.95 | 4.95 |
| **5** | 4.40 | 4.40<br>5.00 | 4.95 | 4.95 | 4.95 | - | - | 4.95 | 4.95 | 4.95 |
| **6** | 4.40 | 4.95 | 4.95 | WR | - | 4.95 | 4.95 | 4.95 | 4.40<br>5.00 | 4.95 |
| **7** | 4.40 | 4.95 | 4.95 | - | - | 4.95 | 4.95 | 4.95 | 4.95 | 4.95 |
| **8** | 3.60 | 4.40<br>5.00 | 4.95 | 4.95 | 4.95 | 4.95 | 4.95 | 4.95 | 4.95<br>5.00 | 4.95 |
| **9** | 2.80 | 4.95 | 4.40<br>5.00 | 4.95 | 4.95 | 4.40<br>5.00 | 4.95 | 4.95<br>5.00 | 4.95 | 3.20 |
| **10** | 2.00 | 3.20 | 4.40 | 4.95 | 4.95 | 4.95 | 4.95 | 4.95 | 3.20 | 2.80 |

Figure: BASE lattice with 12 Gd5% rods.

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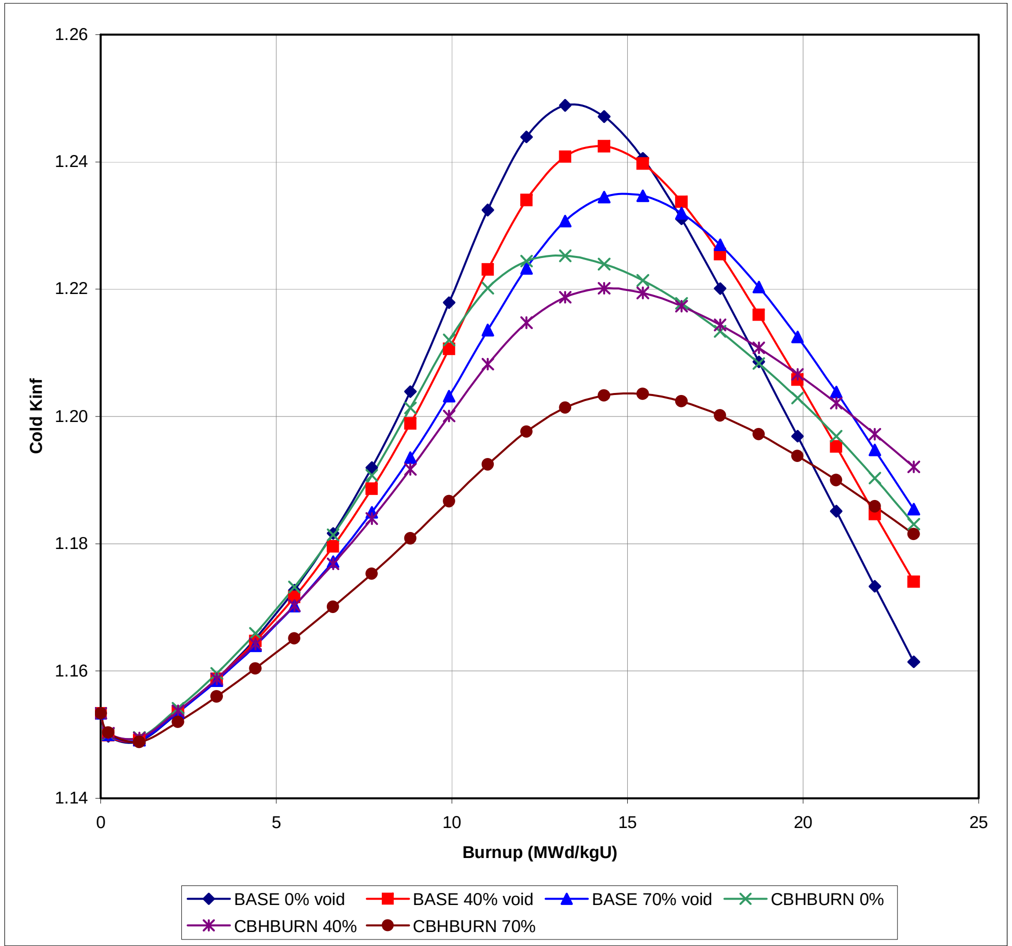
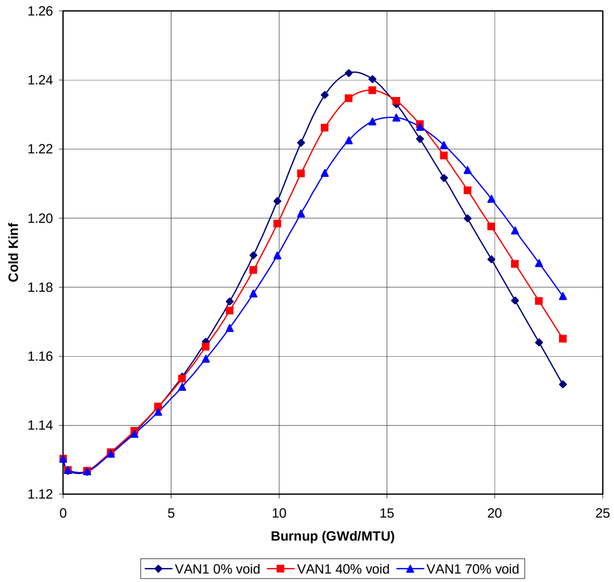
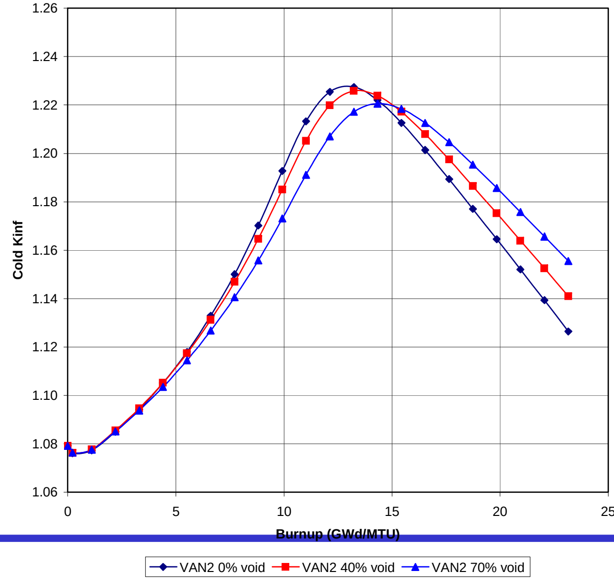
# Fuel Characterization for BWR Criticality

## 2. Evolution of BWR fuel reactivity with burnup and operating conditions (3)




K-infinite vs. void fraction and control rod insertion

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# Fuel Characterization for BWR Criticality

## 3. Evolution of fuel reactivity with axial burnup and voids shapes (1)

- Next step towards simplified model is related to the axial distribution of burnup and void fraction.
- In the figure it is represented the axial burnup shape at two different locations of a particular equilibrium cycle design.
- The average burnup of those bundles being similar to that of the reactivity peak (slide 7).

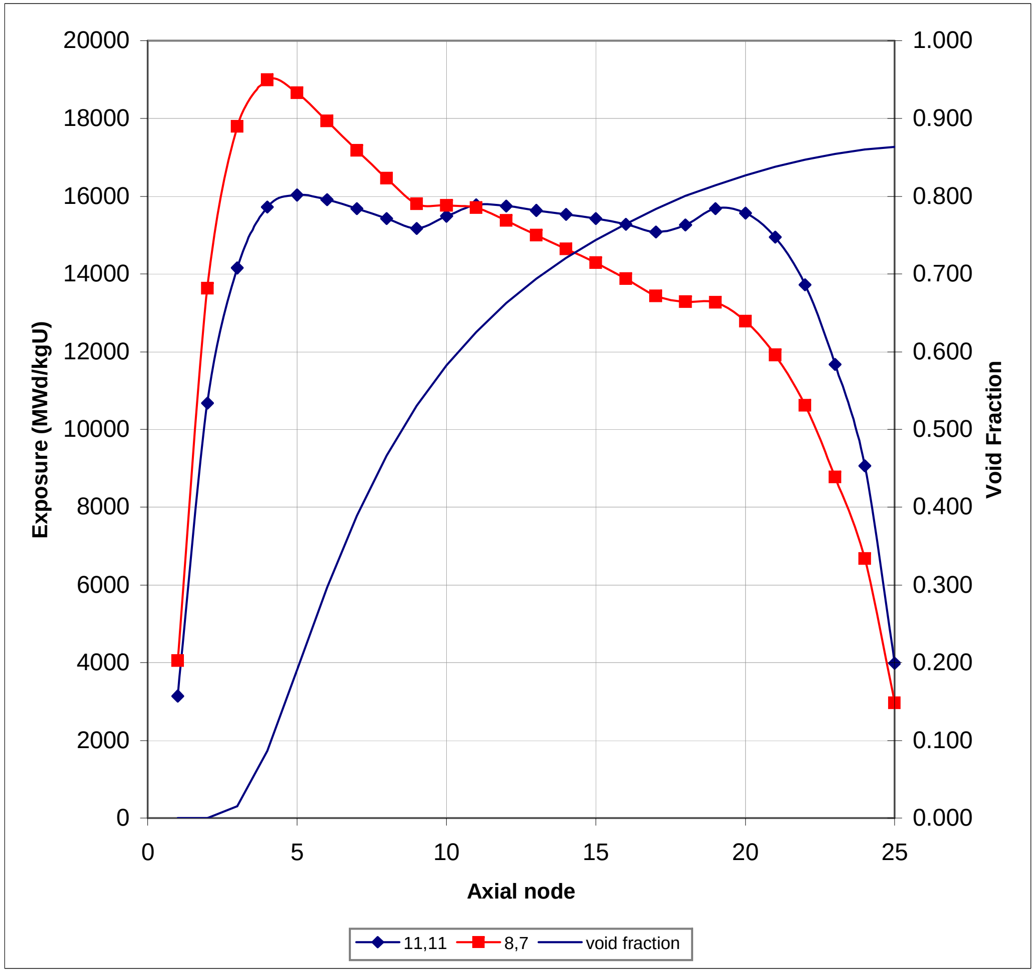


Figure: Burnup and void fraction vs. axial height

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# Fuel Characterization for BWR Criticality

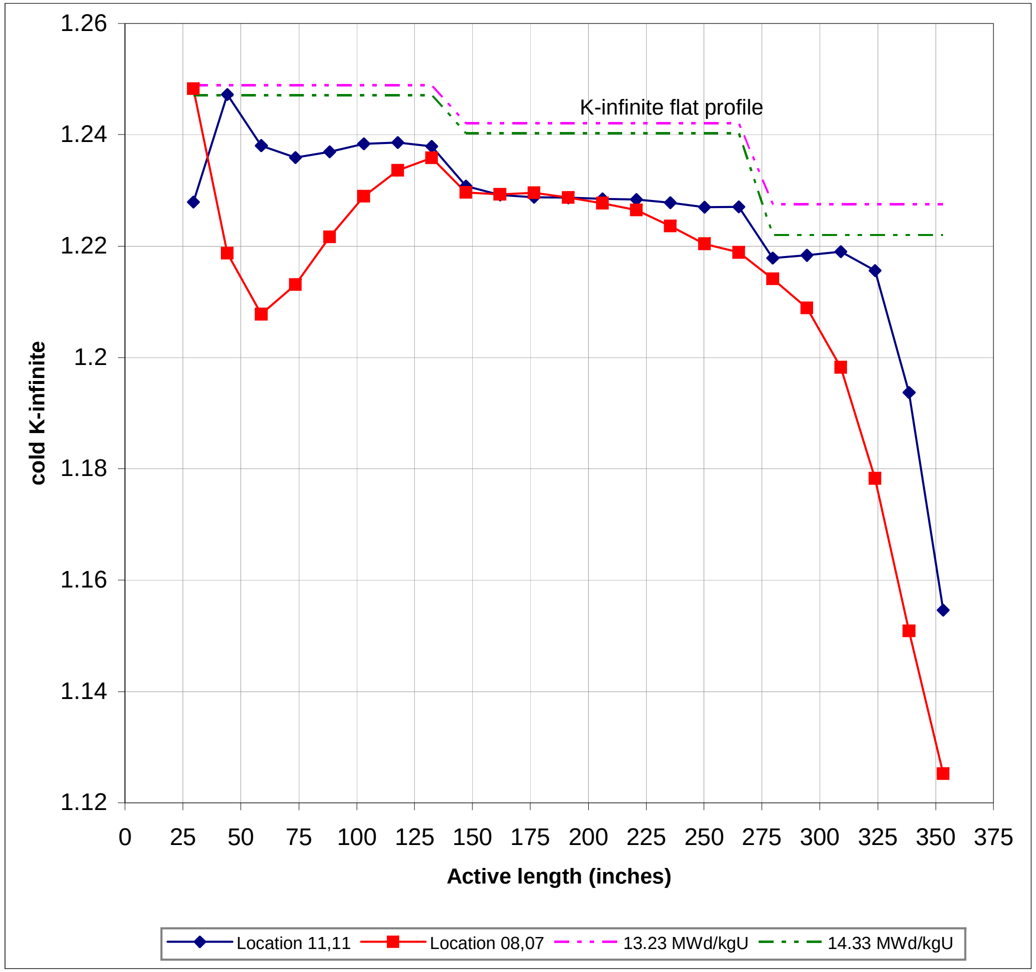
## 3. Evolution of fuel reactivity with axial burnup and voids shapes (2)

- Node by node cold K-infinite values, calculated from local node burnup and void fraction values, for the two bundles.

- Cold K-infinite calculated for each lattice at two burnups around the peak reactivity burnup point.

- Lattice cold K-infinite values calculated at the peak reactivity 1%-2% higher than local (node wise) values.

- The shown excess in reactivity is due to differences in the isotopic evolution of the fuel, which, in turn, produce differences in the in-rack K-effective of the fuel




K-infinite vs. axial height

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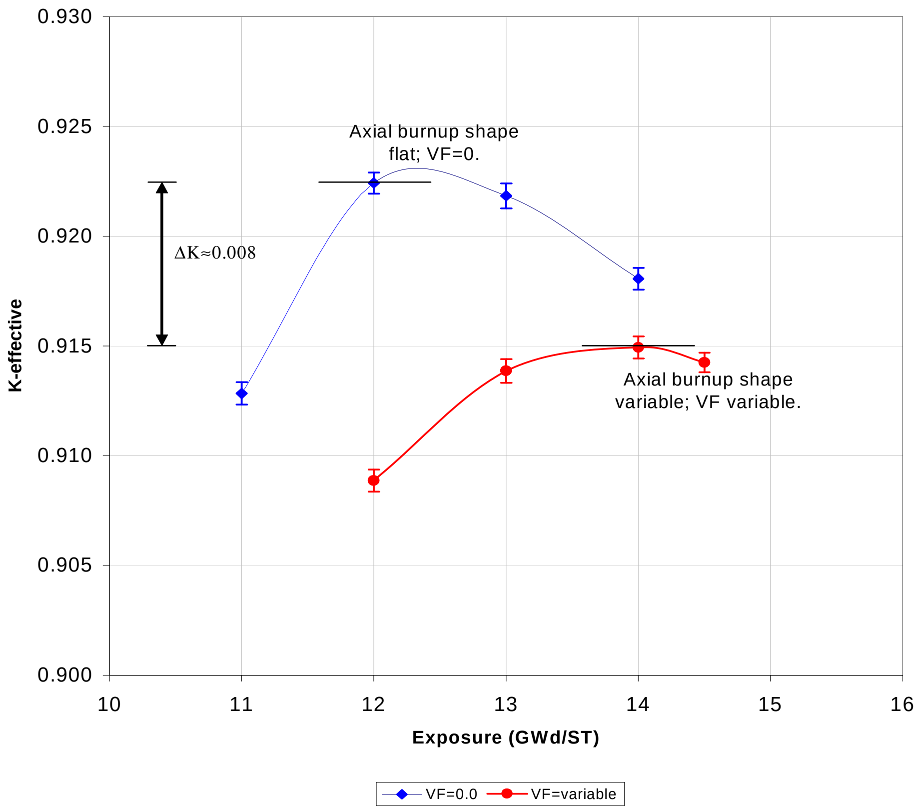
# Fuel Characterization for BWR Criticality

## 3. Evolution of fuel reactivity with axial burnup and voids shapes (3)

- Comparisons have been made with CSAS25 (SCALE5.1) between homogeneous and heterogeneous axial shapes.
- As for the K-infinite, homogeneous case produces conservative results also for the in-rack K-effective.

| | Burnup(norm.) | void fraction | burnup | void fraction |
|---|---|---|---|---|
| 14.72 | | | | |
| 29.44 | 0.725 | 0.000 | 0.725 | 0 |
| 44.16 | 0.961 | 0.016 | 0.961 | 0 |
| 58.88 | 1.068 | 0.087 | | |
| 73.6 | 1.089 | 0.191 | 1.079 | 0.191 |
| 88.32 | 1.081 | 0.297 | | |
| 103.04 | 1.065 | 0.389 | | |
| 117.76 | 1.048 | 0.466 | | |
| 132.48 | 1.030 | 0.530 | | |
| 147.2 | 1.052 | 0.582 | | |
| 161.92 | 1.071 | 0.625 | 1.057 | 0.564 |
| 176.64 | 1.069 | 0.663 | | |
| 191.36 | 1.062 | 0.694 | | |
| 206.08 | 1.055 | 0.721 | | |
| 220.8 | 1.048 | 0.744 | | |
| 235.52 | 1.038 | 0.764 | | |
| 250.24 | 1.024 | 0.784 | 1.046 | 0.779 |
| 264.96 | 1.036 | 0.801 | | |
| 279.68 | 1.065 | 0.815 | | |
| 294.4 | 1.057 | 0.827 | | |
| 309.12 | 1.015 | 0.838 | 1.015 | |
| 323.84 | 0.932 | 0.847 | 0.932 | 0.850 |
| 338.56 | 0.793 | 0.855 | 0.793 | |
| 353.28 | 0.616 | 0.860 | 0.616 | |
| 368 | | | | |




K-effective vs axial shape model

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# Fuel Characterization for BWR Criticality

## 4. Evolution of fuel reactivity with gadolinium rods configuration (1)

Configuration "a"

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 2 | 3.60 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60<br>4.00 | 3.60 |
| 3 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 4 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | WR | - | 3.60 | 3.60 | 3.60 |
| 5 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | - | - | 3.60 | 3.60 | 3.60 |
| 6 | 3.60 | 3.60 | 3.60 | WR | - | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 7 | 3.60 | 3.60 | 3.60 | - | - | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 8 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60<br>4.00 | 3.60 |
| 9 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60 |
| 10 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |

Configuration "b"

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 2 | 3.60 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 3 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 4 | 3.60 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60 | WR | - | 3.60 | 3.60 | 3.60 |
| 5 | 3.60 | 3.60<br>4.00 | 3.60 | 3.60 | 3.60 | - | - | 3.60 | 3.60 | 3.60 |
| 6 | 3.60 | 3.60 | 3.60 | WR | - | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 7 | 3.60 | 3.60 | 3.60 | - | - | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 8 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 9 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |
| 10 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 | 3.60 |

| | |
|---|---|
| 3.60 | UO2 rod |
| 3.60<br>4.00 | UO2+Gd rod |

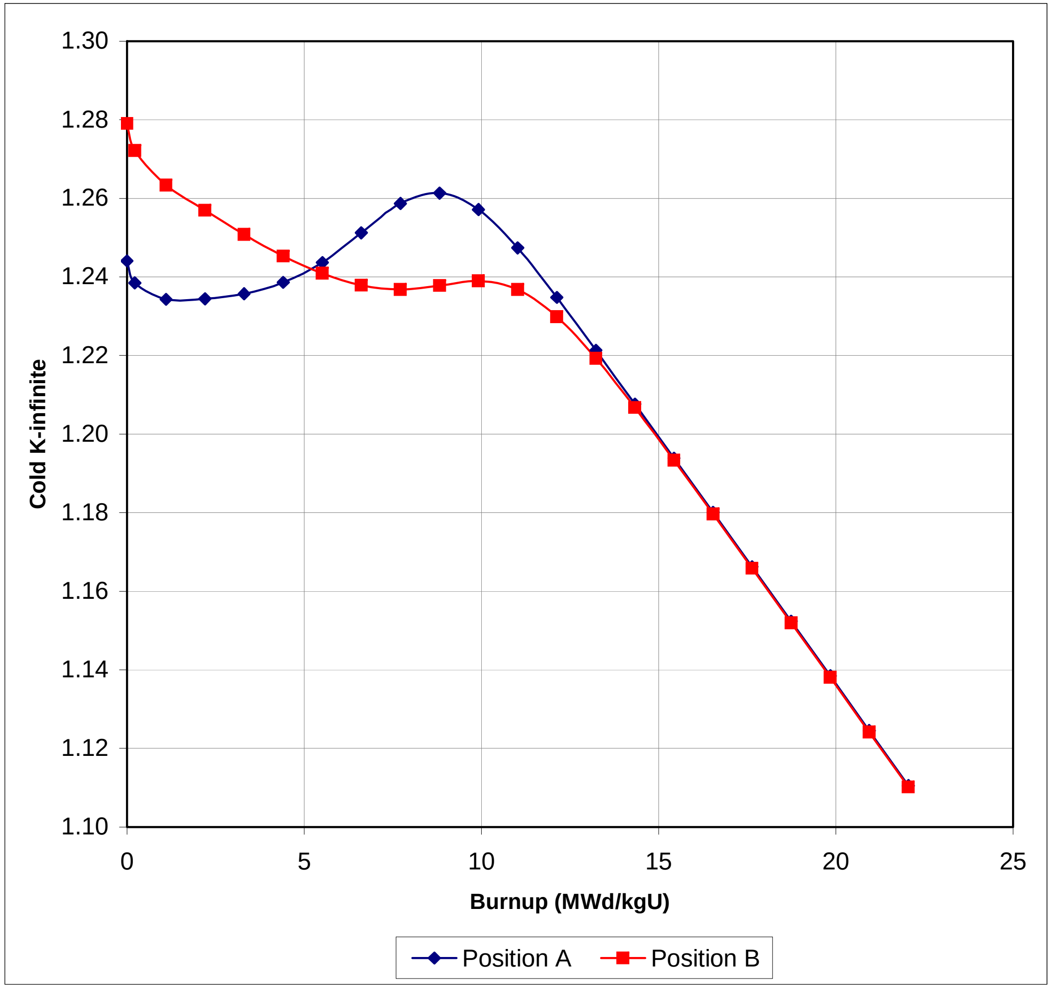


Figure: Gad rods configurations analyzed for 6Gd4% lattice

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# Fuel Characterization for BWR Criticality

## 4. Evolution of fuel reactivity with gadolinium rods configuration (2)

Configuration "a"

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| 2 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 |
| 3 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 |
| 4 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | WR | - | 3.98 | 3.98 | 3.98 |
| 5 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98 | - | - | 3.98 | 3.98 | 3.98 |
| 6 | 3.98 | 3.98 | 3.98 | WR | - | 3.98 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 |
| 7 | 3.98 | 3.98 | 3.98 | - | - | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| 8 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 |
| 9 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 |
| 10 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |

Configuration "b"

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| 2 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| 3 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | WR | - | 3.98 | 3.98 | 3.98 |
| 5 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98 | - | - | 3.98 | 3.98 | 3.98 |
| 6 | 3.98 | 3.98 | 3.98 | WR | - | 3.98 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 |
| 7 | 3.98 | 3.98 | 3.98 | - | - | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 |
| 8 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 |
| 9 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 |
| 10 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |

Configuration "c"

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| 2 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| 3 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | WR | - | 3.98 | 3.98<br>4.00 | 3.98 |
| 5 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 | 3.98 | - | - | 3.98 | 3.98 | 3.98 |
| 6 | 3.98 | 3.98 | 3.98 | WR | - | 3.98 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 |
| 7 | 3.98 | 3.98 | 3.98 | - | - | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| 8 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 |
| 9 | 3.98 | 3.98 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98<br>4.00 | 3.98 | 3.98 |
| 10 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |

| | |
|---|---|
| 3.98 | UO2 rod |
| 3.98<br>4.00 | UO2+Gd rod |

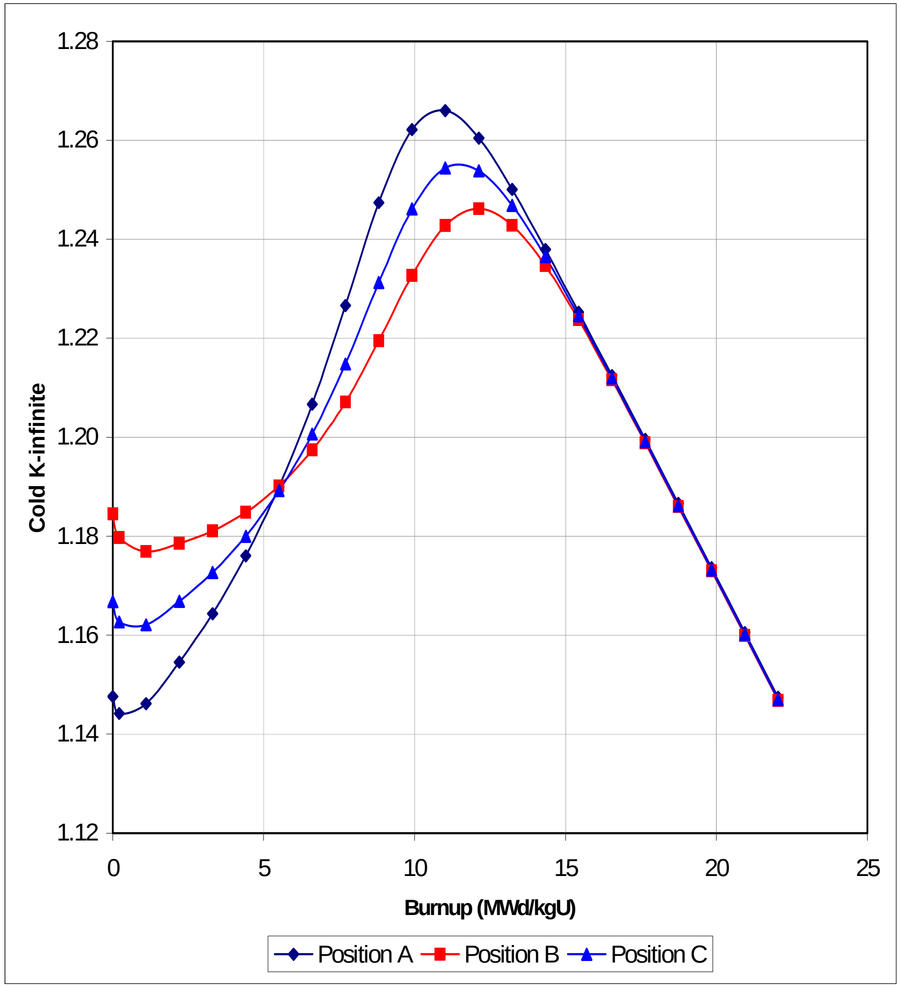


Figure: Gad rods configurations analyzed for 12Gd4% lattice

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## 4. Evolution of fuel reactivity with gadolinium rods configuration (3)

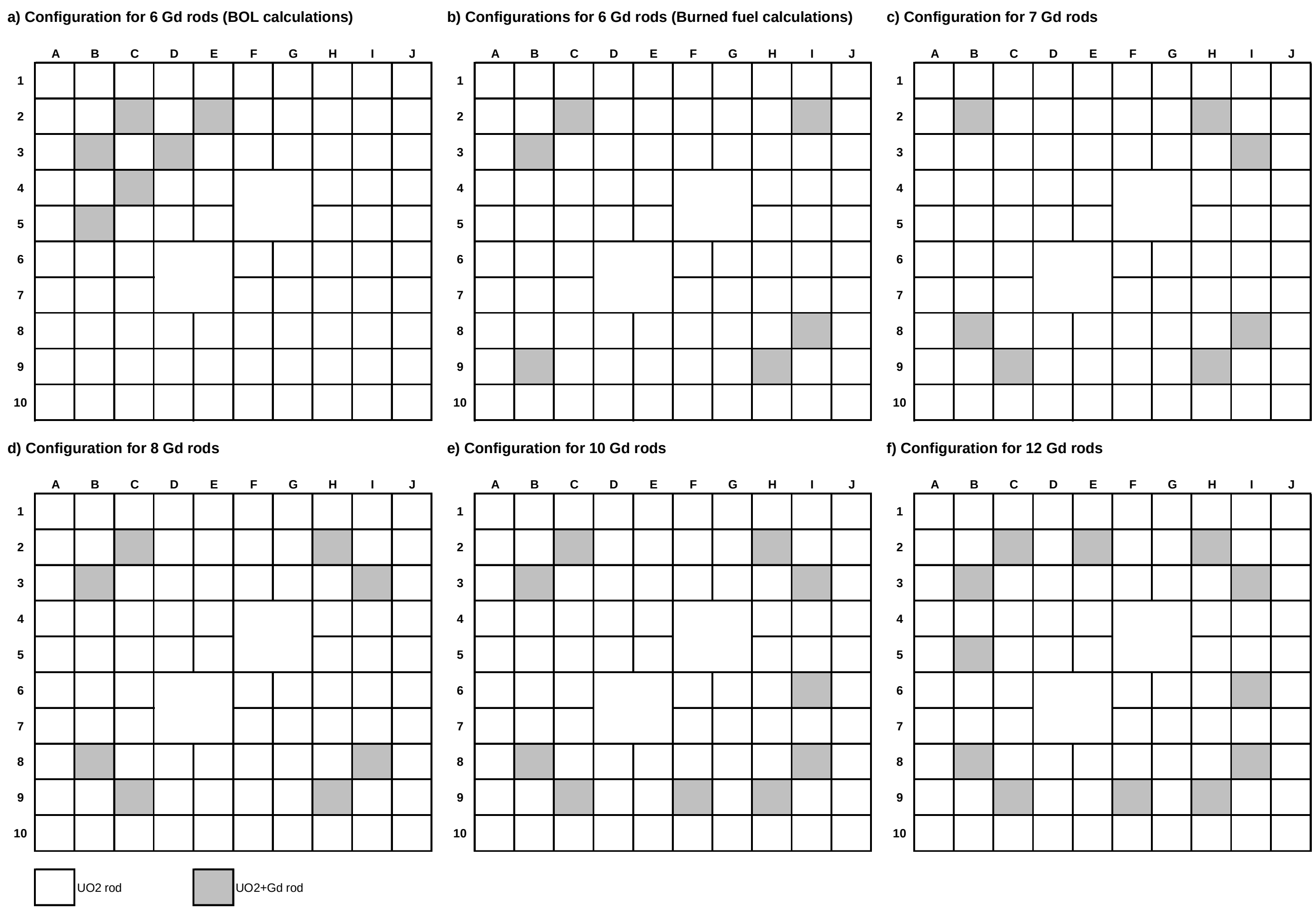


Figure: Conservative Gd rods configurations for Criticality Analysis

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## 4. Evolution of fuel reactivity with gadolinium rods configuration (4)

•In conclusion:

- ✓ Limiting gadolinium configurations can be different for fresh and burned fuel.
- ✓ For given fuel design and gadolinium needs, it is possible to establish limiting configurations of gadolinium rods, based on a reduced number of K-infinite lattice calculations.

# Fuel Characterization for BWR Criticality
## 5. Initial enrichment distribution (1)

• Fresh fuel may be limiting only for ≤5 Gd rods, with all Gd rods closely packed (see figure in slide 11).

• Heterogeneous and homogeneous cases have been analyzed for a fuel with 3.735% average enrichment and 5Gd4% rods.

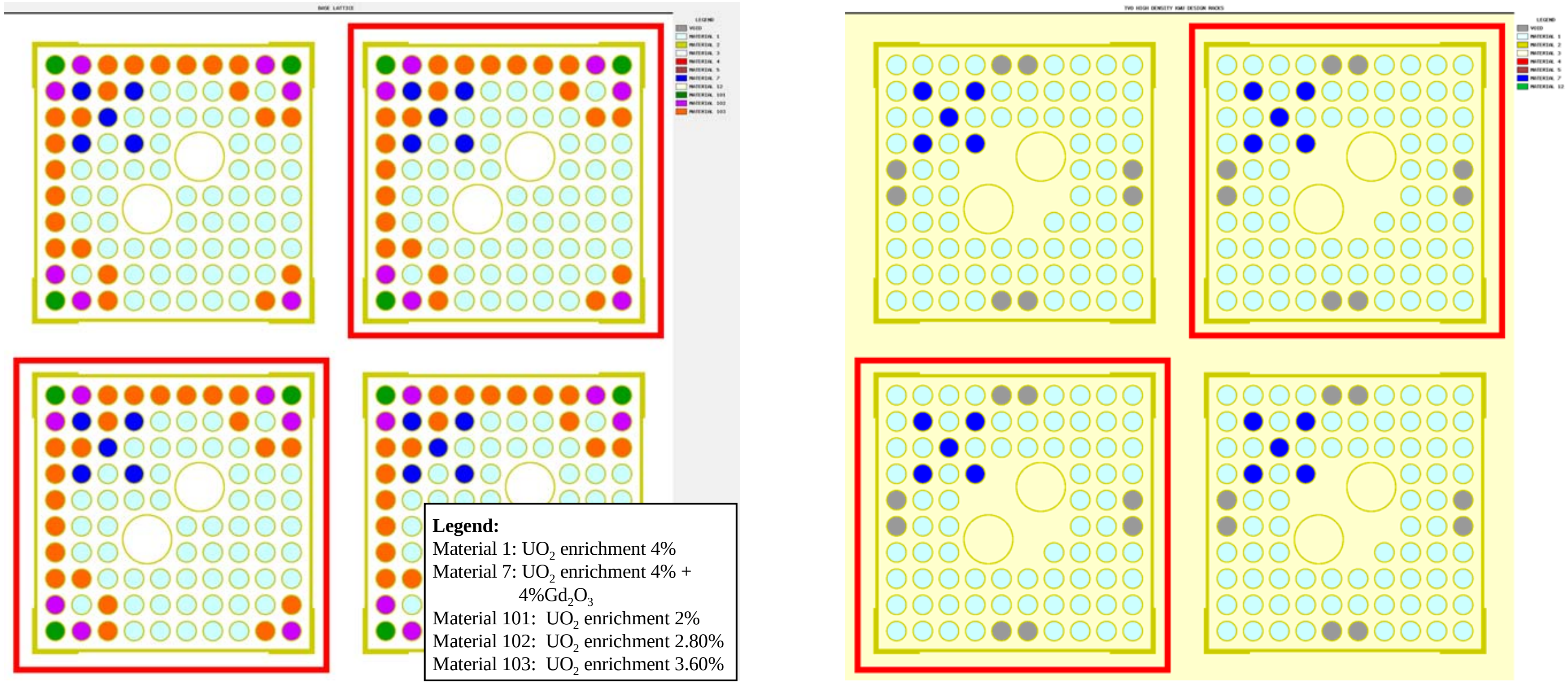


Figure: Heterogeneous and homogeneous initial enrichment distribution

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# Fuel Characterization for BWR Criticality

## 5. Initial enrichment distribution (2)

• Results for CSAS25 simulations:

| Enrichment model | K-effective | σ |
|---|---|---|
| Homogeneous | 0.92564 | 0.00048 |
| Heterogeneous | 0.91766 | 0.00051 |

• K-effective for the homogeneous radial model is almost 1% higher than that of the (real) heterogeneous model. Thus, the homogeneous (radial) enrichment model is conservative for fresh fuel criticality analysis.

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# Fuel Characterization for BWR Criticality
## 6. Radial Isotopic distribution (1)

- Now, we examine the radial rod-by-rod isotopic distribution.

- For burned fuel, the isotopic content is different in each rod, due to differences in their initial enrichment and because their power histories are also different.

RELATIVE POWER DISTRIBUTION

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.7741 | 0.9091 | 1.0043 | 1.2055 | 0.0000 | 0.0000 | 1.2105 | 1.0074 | 0.9031 | 0.8544 |
| 0.9091 | 0.9161 | 0.8663 | 0.9691 | 1.0054 | 1.0832 | 0.9869 | 0.8719 | 1.0220 | 0.9543 |
| 1.0043 | 0.8663 | 0.8539 | 0.9113 | 1.0609 | 1.0931 | 1.0127 | 0.8942 | 0.8451 | 1.0953 |
| 1.2055 | 0.9691 | 0.9113 | 1.1416 | 0.0000 | 0.0000 | 0.0000 | 1.0097 | 0.9686 | 1.2639 |
| 0.0000 | 1.0054 | 1.0609 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0926 | 1.0745 | 0.0000 |
| 0.0000 | 1.0832 | 1.0931 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0592 | 0.9902 | 0.0000 |
| 1.2105 | 0.9869 | 1.0127 | 0.0000 | 0.0000 | 0.0000 | 1.1421 | 0.9001 | 0.9347 | 1.2509 |
| 1.0074 | 0.8719 | 0.8942 | 1.0097 | 1.0926 | 1.0592 | 0.9001 | 0.8164 | 0.8125 | 1.1475 |
| 0.9031 | 1.0220 | 0.8451 | 0.9686 | 1.0745 | 0.9902 | 0.9347 | 0.8125 | 0.9618 | 0.9276 |
| 0.8544 | 0.9543 | 1.0953 | 1.2639 | 0.0000 | 0.0000 | 1.2509 | 1.1475 | 0.9276 | 0.9984 |

RELATIVE EXPOSURE DISTRIBUTION

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.7922 | 0.9795 | 1.0624 | 1.2770 | 0.0000 | 0.0000 | 1.2931 | 1.0570 | 0.9502 | 0.8711 |
| 0.9795 | 0.9654 | 0.6546 | 0.9910 | 0.7595 | 1.1307 | 1.0472 | 0.6608 | 1.0806 | 1.0077 |
| 1.0624 | 0.6546 | 0.8705 | 0.9649 | 1.0897 | 1.1483 | 1.0681 | 0.9096 | 0.6311 | 1.1443 |
| 1.2770 | 0.9910 | 0.9649 | 1.1868 | 0.0000 | 0.0000 | 0.0000 | 1.0558 | 1.0056 | 1.3147 |
| 0.0000 | 0.7595 | 1.0897 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.1306 | 1.0868 | 0.0000 |
| 0.0000 | 1.1307 | 1.1483 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0660 | 0.7100 | 0.0000 |
| 1.2931 | 1.0472 | 1.0681 | 0.0000 | 0.0000 | 0.0000 | 1.1680 | 0.9305 | 0.9207 | 1.2620 |
| 1.0570 | 0.6608 | 0.9096 | 1.0558 | 1.1306 | 1.0660 | 0.9305 | 0.8133 | 0.6083 | 1.1761 |
| 0.9502 | 1.0806 | 0.6311 | 1.0056 | 1.0868 | 0.7100 | 0.9207 | 0.6083 | 0.9816 | 0.9368 |
| 0.8711 | 1.0077 | 1.1443 | 1.3147 | 0.0000 | 0.0000 | 1.2620 | 1.1761 | 0.9368 | 1.0027 |

Figure: Relative power and burnup distribution for a 4.41% heterogeneous lattice with 12Gd5% rods at 13.23 MWd/KgU burnup step.

# Fuel Characterization for BWR Criticality
## 6. Radial Isotopic distribution (2)

- The heterogeneous (diagonal symmetric) CSAS25 model uses different fuel rods types, each one with its corresponding set of isotopic composition, for each of the axial segments being considered: BASE, VAN1 and VAN2.
- For the case being presented a total of 51+47+43= 141 different isotopic sets for the CSAS25 model were used.
- In the homogeneous model only 6 different isotopic sets were used: one for the UO2 rod and other for the UO2+Gd2O3 rod, for each of the three axial lattices.

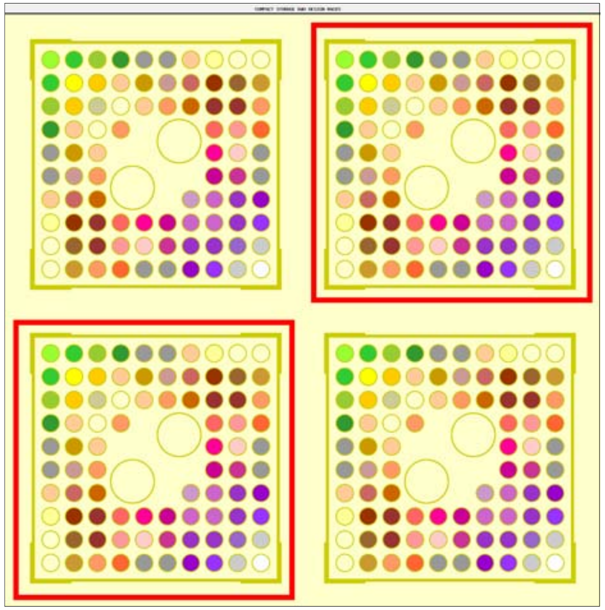
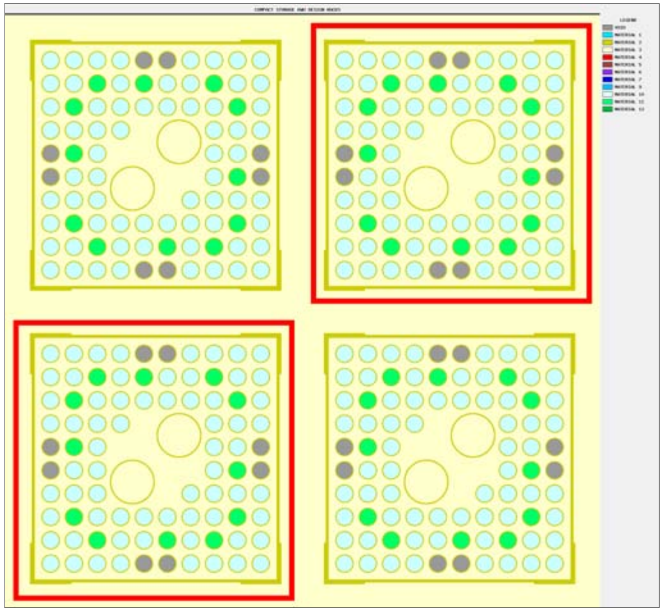

Figure: Heterogeneous and homogeneous radial model.

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## 6. Radial Isotopic distribution (3)

- Several pairs of (enrichment, gadolinium) were analyzed, for different racks geometries and fuel designs.
- In all cases the homogeneous model gave higher K-effective results than the corresponding heterogeneous case.
- Therefore, homogeneous radial isotopic model is conservative for burned fuel Criticality Analysis.

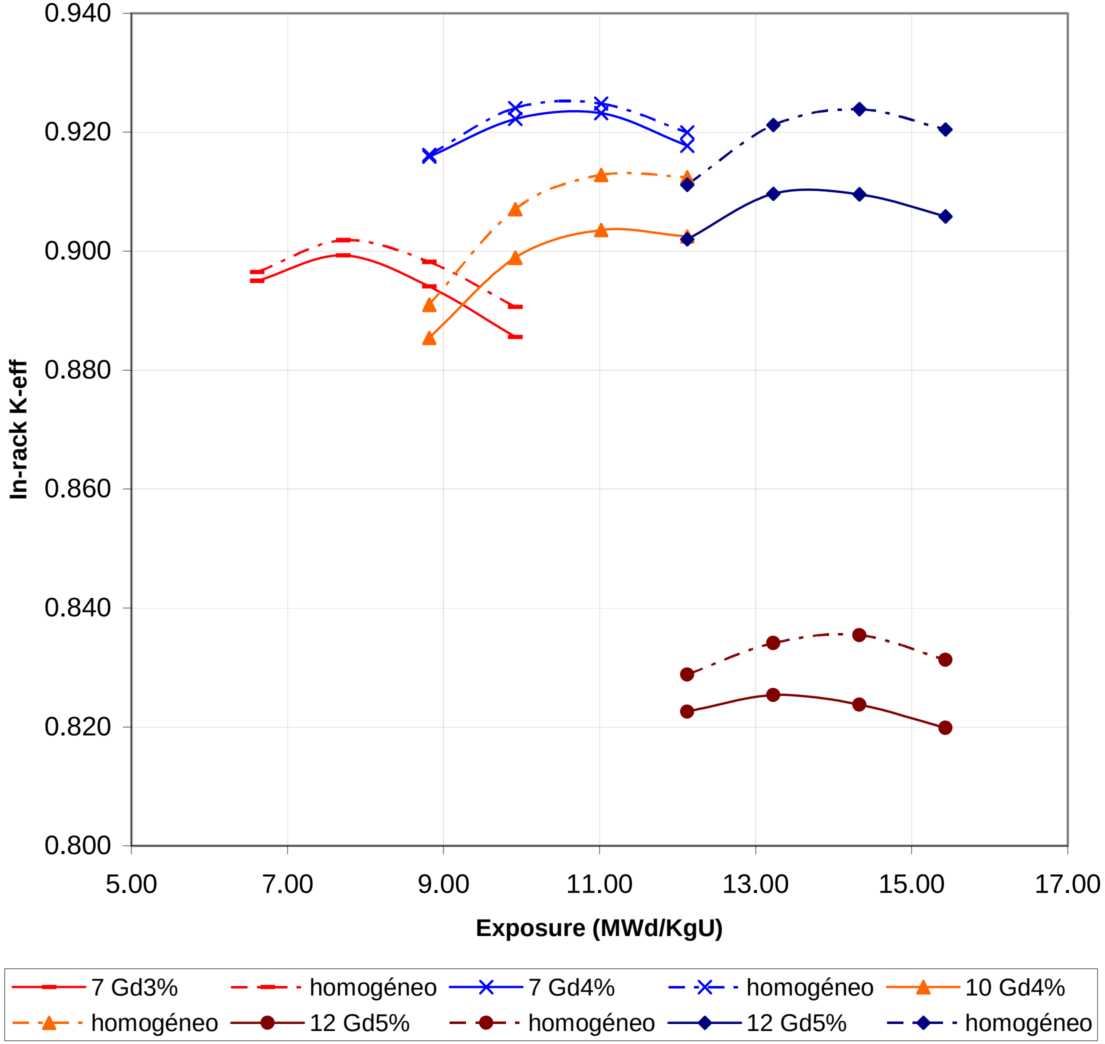


Figure: Heterogeneous vs homogeneous radial model K-eff.

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# Fuel Characterization for BWR Criticality
# 7. Summary and conclusions (1)

- BWR fuel designs and operating conditions are highly heterogeneous:
  - ✓ Different lattice geometries in the same bundle (part-length rods)
  - ✓ Radial and axial distribution of enrichment and gadolinium inside the bundle.
  - ✓ Burnup dependent local operating conditions: void fractions and control rod insertion
- A conservative 3D-model, useful for Criticality Analysis production work, has been developed.
- The production model is characterized by:
  - ✓ Different actual lattice geometries (Full length and Part-length fuel rods) are explicitly modeled.
  - ✓ Fuel isotopic content obtained from uncontrolled 0 void fraction burnup calculations, covering the peak reactivity range.
  - ✓ Flat axial burnup shape (i.e. all axial lattices at the same burnup) in the range of the peak reactivity.
  - ✓ Conservative locations of Gd rods.
  - ✓ Homogeneous initial enrichment in all rods (fresh fuel).
  - ✓ Homogeneous radial isotopic distribution for spent fuel (except for Gd isotopes) for each lattice.

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# Fuel Characterization for BWR Criticality
## 7. Summary and conclusions (2)

- This way, the BWR fuel can be characterized, for Criticality Analysis, by the Enrichment/Gadolinium content pair.
- The examples and conclusions presented here are for GNF fuel designs.
- Nevertheless, the conclusions of the study judged to be easily extrapolated to other vendors designs.