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VVER-1000 Burnup Credit Benchmark (CB5)

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Abstract

In the paper the specification of VVER-1000 Burnup Credit Benchmark first phase (depletion calculations), is given. The second phase – criticality calculations for the VVER-1000 fuel pin cell, will be given after the evaluation of the results, obtained at the first phase. The proposed benchmark is a continuation of the VVER benchmark activities in this field [1,2,3,4,5]

1. Objective

The aim of the first phase of this benchmark is following:

- calculation of the nuclear concentrations for the VVER-1000 spent fuel assembly model, as the spent fuel inventory is a big source of uncertainty in criticality calculations;
- comparison of the results for major and minor actinides and fission products taken into account in the Calculational Burnup Credit benchmark CB2 [2] and intercomparison of the depletion codes and libraries on this basis.

2. *Future Need*

As a next step is very important to extend such a benchmark for parameters of VVER-1000 spent fuel of a well documented irradiation history and compare the results with actual measurements (assay) for the spent fuel.

3. *Specification*

3.1 Specification of VVER-1000 Fuel Pin Cell

The data for VVER-1000 fuel assembly specification are from Ref. [6], the irradiation history data are taken from Ref. [7].

Fresh Fuel Enrichment	3 % wt. ^{235}U
Fuel Cell Pitch	1.275 cm
Fuel Radius	0.38 cm
Cladding Inner Radius	0.386 cm
Outer Radius	0.455 cm
Temperature	593 K
Material	1% wt. Nb, 98.97% wt. Zr, 0.03% wt. Hf, $\rho = 6.515$ g/cm^3
Moderator	Water Smeared with Assembly Spacer Grids (see &3.2)
Moderator Temperature	578 K
Fuel Active Length	355 cm
Fuel Temperature	1100 K

Number Densities of Nuclides in Fuel: Use the values from & 3.3

3.2 Specification of the Model of the VVER-1000 Fuel Assembly (Fig.1)

Lattice	hexagonal, pitch 23.6 cm
Gap between assemblies	0.2 cm
No shell	
Water temperature, K	578
Pressure	1583 N/cm^2
Number of fuel pins in assembly	312
Number of instrument tubes	1
Number of control rods	18

Central Instrumental Tube (Cylindrical)

Inner radius	0.480 cm
Outer radius	0.560 cm
Material	1% wt. Nb, 98.97% wt. Zr, 0.03% wt. Hf, $\rho = 6.55$ g/cm^3

Control rod

Guide tube for control rod

Inner radius, cm	0.550 cm
Outer radius, cm	0.630 cm

Material	Stainless Steel (69.88% wt. Fe, 0.12% wt. C, 18.5% wt. Cr, 10.5% wt Ni, 1% wt. Ti) $\rho = 7.85$ g/cm^3

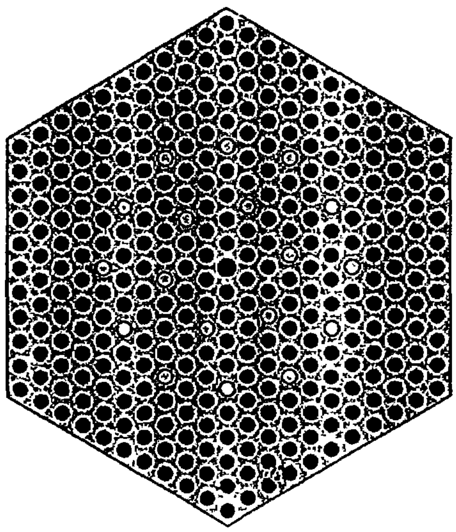
Absorber (Control Rods are withdrawn)
Water with boron (nuclear concentrations are given below in & 3.3)

Spacer grid

Material	Stain'less Steel (69.88% wt. Fe, 0.12% wt. C, 18.5% wt. Cr, 10.5% wt. Ni, 1% wt. Ti) $\rho = 7.85$ g/cm^3
Number of spacer grids	14
Masses of volume fractions of materials in one spacer grid	654 g

Steel Spacer Grids: smeared with water in the assembly volume in two cases: fuel unit cell moderator and instrumental tube cell. The initial concentrations of isotopes are given below in &3.3.

Fig.1 VVER-1000 Fuel Assembly Model (Horizontal Section)



3.3 Operating history data and fuel isotopic content

Specific power *	18.4049 MW/assembly
Number of cycles	2
Cycle duration (days)	
Uptime	302, 310

Downtime (between cycles)	139
Cooling time (year)	0, 1, 5

* the value is equal to the rated thermal power per assembly; the data for fuel cycles are based on the Operational Benchmark VVER-1000, Unit 6, Kozloduy NPP [7].

Initial isotopic composition for both fuel and water with smeared spacer grids are given as follows:

Fresh fuel

U-235	6.42156e-4
U-238	2.05016e-2
O	4.22874e-2

Water with Smeared Steel Spacer Grids in the fuel unit cell moderator

H	4.7290e-02
O	2.3676e-02
B-10	4.0865e-06
Fe	7.0491e-04
Cr	2.0045e-04
Ni	1.0077e-04
Ti	1.1767e-05
C-12	5.6289e-06

Water with boron and Smeared Steel Spacer Grids and Instrumental Tube Cladding in the Instrumental Tube Cell

H	3.88e-02
O	1.94e-02
B-10	3.35e-06
Zr	7.90e-03
Nb	7.84e-05
Hf	1.22e-06
Fe	2.12e-04
Cr	6.02e-05
Ni	3.03e-05
Ti	3.53e-06
C-12	1.70e-06

Water with Boron in the Withdrawn Control Rod Cell

H	4.7860e-02
O	2.3961e-02
B-10	4.1358e-06

4. Results

Participants are requested to calculate and report the isotopic concentrations for the major and minor actinides and fission products, defined in CB2, including U-234. These are 12 actinides (U-235, U-234, U-236, U-238, Pu-238, Pu-239, Pu-240, Pu-

241, Pu-242, Am-241, Am-243, Np-237) and 15 fission products (Mo-95, Tc-99, Ru-101, Rh-103, Ag-109, Cs-133, Nd-143, Nd-145, Sm-147, Sm-149, Sm-150, Sm-151, Sm-152, Eu-153 and Gd-155).

Some results of VVER-1000 Benchmark calculations by the SCALE4.4 [8] and NESSEL-NUKO [9] code systems have been presented at the last Symposium [10].

The form of results presentation is the same as for CB2 Benchmark, namely:

Date
Institute
Participants
Computer Code
Data library identification, origin, description. Number of energy groups or continuous energy (for cross sections, fission yields and decay data).
Notes
Please forward the results by electronic mail to INRNE (manolova@inrne.bas.bg).

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