OECD/NEA Source Convergence Benchmark 2: Pincell array with irradiated fuel

Authors

Yoshitaka NAITO, Penghong LIEM, Jinan YANG
NAIS Co. Inc.
416 Tokai mura, Naka gun, Ibaraki ken, 319-1112, JAPAN
ynaito@nais.ne.jp, liemph@nais.ne.jp, yangja@nais.ne.jp

Co-ordinator

Dr. Yoshitaka NAITO
President
NAIS co. inc.
416 Muramatsu, Tokai-mura
Naka-gun,
Ibaraki-ken 319-1112

JAPAN

Tel: +81 29 270 5000
Fax: +81 29 270 5001
E-mail: ynaito@nais.ne.jp

Overview

These benchmark problems are modified versions of the OECD/NEA burnup credit criticality benchmark (Phase IIA effect of axial burnup profile) which are published in JAERI-Research 96-003 (NEA/NSC/DOC(96)01). The aim is to study source convergence problems associated with the axila burnup profile (end effect).

Specifications

Geometry data

These benchmarks are composed of an infinite fuel pin array in water. Figure 1 depicts the horizontal geometry of the unit cell and Figure 2 depicts the vertical geometry, respectively. (Figures 1 and 2 are extracted from the burnup credit benchmark report). The fuel rod is divided into 9 regions as shown in Fig.2. The reflecting boundary condition is used to the boundary of the square cell of water.

Material data

The material compositions are given in the following tables.

Table 1 Atom densities (atoms/barn-cm) for fresh fuel

Fuel-type	EU45
Fresh fuel U(4.5wt.%)O2 enriched	
U-234	8.4100E-06
U-235	1.0526E-03
U-236	6.4752E-06
U-238	2.2042E-02
O	4.6219E-02
Fuel-type	EU40
Fresh fuel U(4.0wt.%)O2 enriched	
U-234	7.5481E-06
U-235	9.3949E-04
U-238	2.2256E-02
O	4.6405E-02
Fuel-type	NU
U (natural)O2	
U-234	1.2757E-06
U-235	1.6700E-04
U-238	2.3026E-02
O	4.6388E-02
Cladding and end plug	
Zircalloy-4	
Cr	7.5891E-05
Fe	1.4838E-04
Zr	4.2982E-02
Light Water	
25deg.C	
H	6.6658E-02
O	3.3329E-02

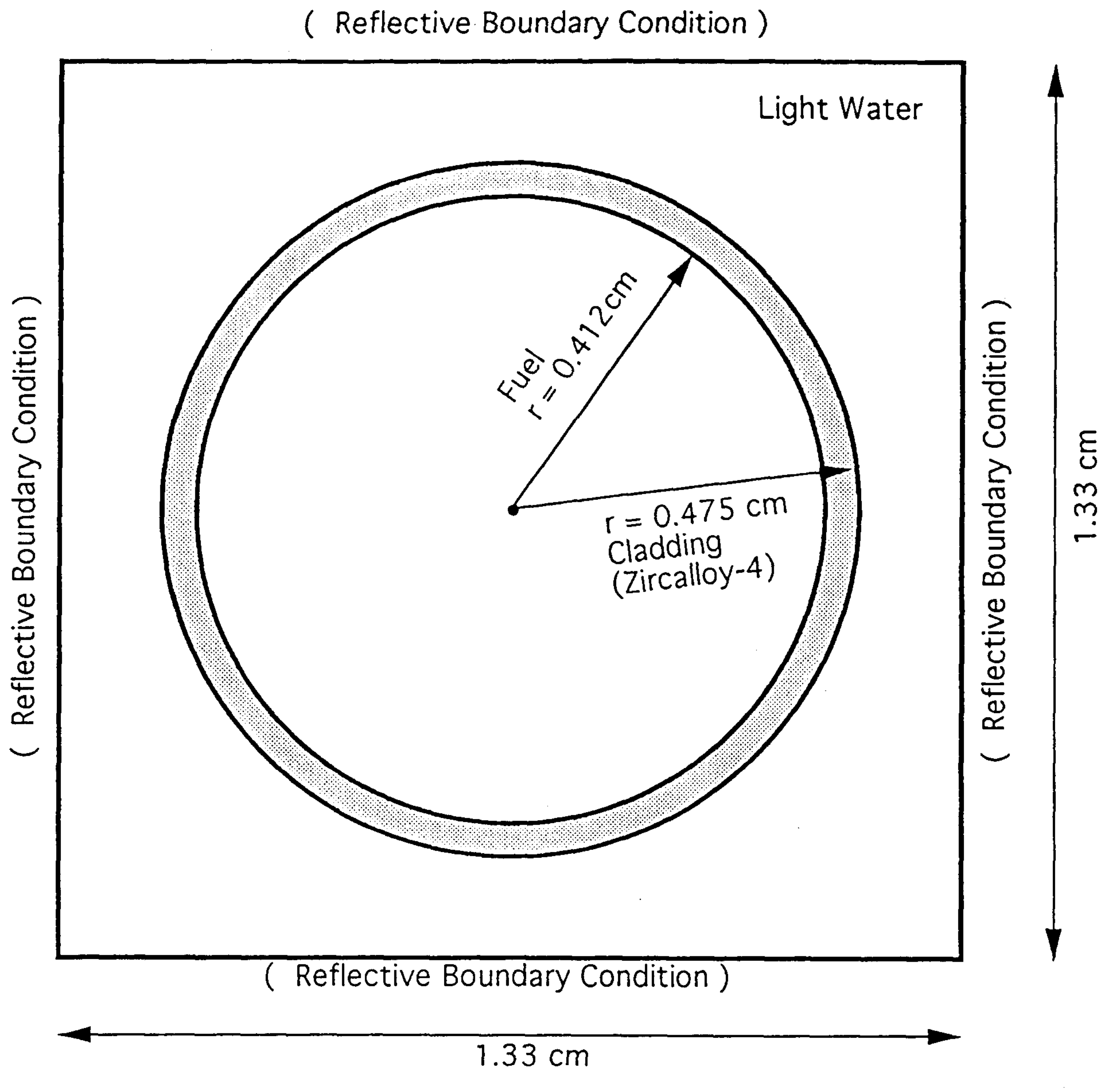

Fig. 1　Radial Dimensions

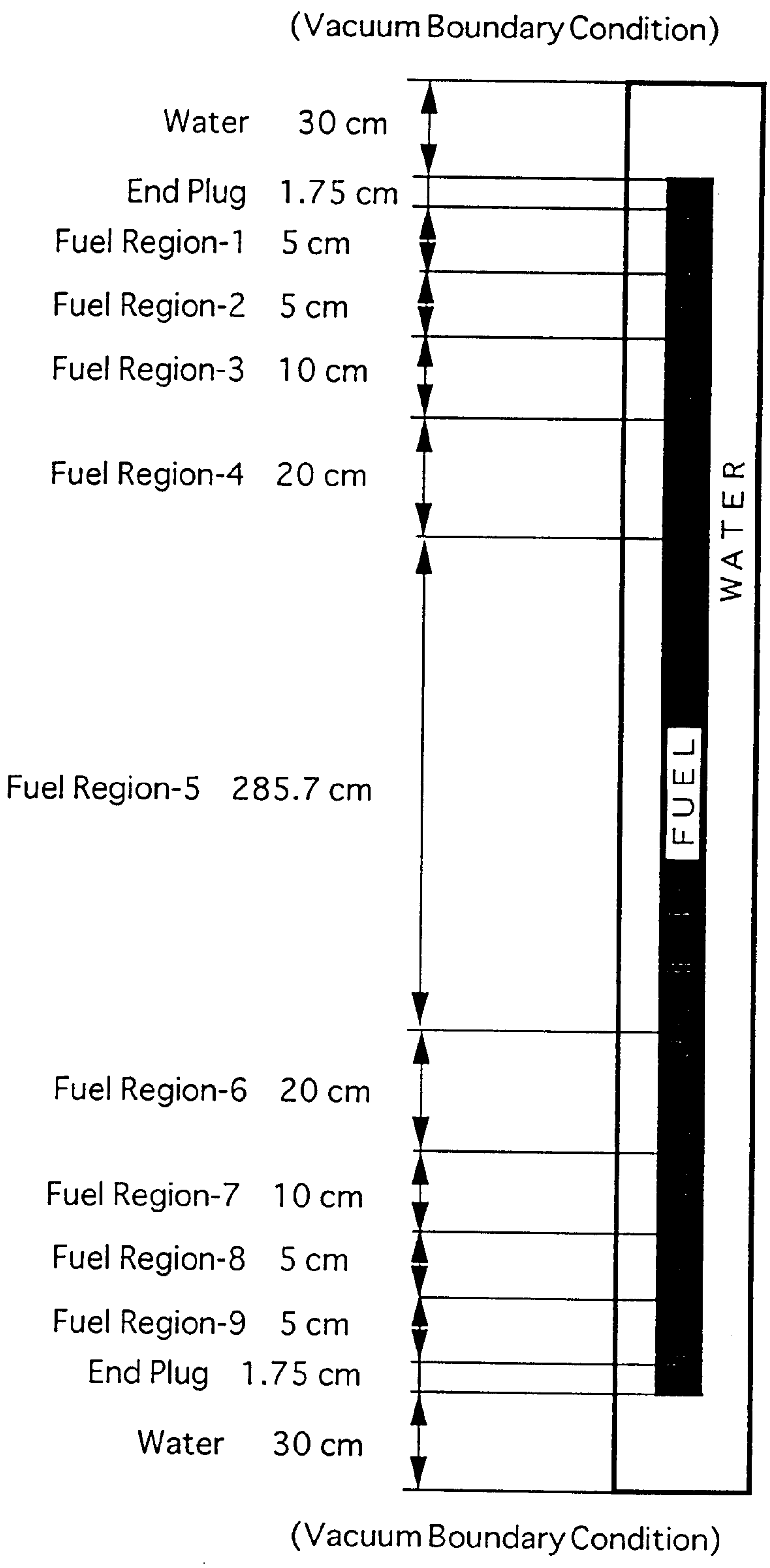

Fig. 2 Axial Dimensions

Table 2 Atom densities of irradiated fuels

Fuel-Type	B21G	B24G	B30G	B40G	B55G
	4.5wt%U235 21.57GWD/MTU	4.5wt%U235 24.023GWD/MTU	4.5wt%U235 30.580GWD/MTU	4.5wt%U235 40.424GWD/MTU	4.5wt%U235 54.605GWD/MTU
U-234	6.4862E-06	6.2881E-06	5.7868E-06	5.1152E-06	4.3280E-06
U-235	5.6757E-04	5.2562E-04	4.2455E-04	3.0002E-04	1.7108E-04
U-236	9.4556E-05	1.0155E-04	1.1763E-04	1.3534E-04	1.4897E-04
U-238	2.1732E-02	2.1693E-02	2.1585E-02	2.1413E-02	2.1142E-02
Pu-238	1.1322E-06	1.4876E-06	2.7262E-06	5.3656E-06	1.0471E-05
Pu-239	1.2591E-04	1.3161E-04	1.4249E-04	1.5064E-04	1.5300E-04
Pu-240	2.6395E-05	2.9965E-05	3.9140E-05	5.1484E-05	6.5540E-05
Pu-241	1.3614E-05	1.5953E-05	2.1863E-05	2.9175E-05	3.6032E-05
Pu-242	2.2623E-06	3.0335E-06	5.6472E-06	1.0893E-05	2.0303E-05
Am-241	4.0266E-06	4.7603E-06	6.6579E-06	9.0866E-06	1.1405E-05
Am-243	2.6222E-07	3.9809E-07	9.7353E-07	2.5108E-06	6.1550E-06
Np-237	6.8089E-06	7.9041E-06	1.0948E-05	1.5602E-05	2.1806E-05
Mo-95	3.1530E-05	3.4781E-05	4.3130E-05	5.4806E-05	6.9892E-05
Tc-99	3.0319E-05	3.3465E-05	4.1531E-05	5.2746E-05	6.6975E-05
Ru-101	2.7452E-05	3.0548E-05	3.8751E-05	5.0881E-05	6.7875E-05
Rh-103	1.7260E-05	1.9008E-05	2.3371E-05	2.9057E-05	3.5406E-05
Ag-109	1.8879E-06	2.2230E-06	3.1774E-06	4.7134E-06	6.9836E-06
Cs-133	3.3140E-05	3.6549E-05	4.5257E-05	5.7263E-05	7.2263E-05
Sm-147	6.4488E-06	6.9339E-06	8.0315E-06	9.2075E-06	1.0106E-05
Sm-149	1.9390E-07	1.9611E-07	1.9935E-07	1.9993E-07	1.9259E-07
Sm-150	7.1174E-06	8.0472E-06	1.0496E-05	1.3997E-05	1.8627E-05
Sm-151	5.7531E-07	6.0064E-07	6.6160E-07	7.3765E-07	8.1779E-07
Sm-152	3.0178E-06	3.3473E-06	4.1844E-06	5.3316E-06	6.7637E-06
Nd-143	2.5793E-05	2.8067E-05	3.3502E-05	3.9984E-05	4.5992E-05
Nd-145	1.8633E-05	2.0504E-05	2.5263E-05	3.1783E-05	3.9892E-05
Eu-153	2.0026E-06	2.3329E-06	3.2546E-06	4.6705E-06	6.5858E-06
Gd-155	1.1986E-07	1.4386E-07	2.2155E-07	3.6871E-07	6.0862E-07
O	4.6219E-02	4.6219E-02	4.6219E-02	4.6219E-02	4.6219E-02

Cases identification

The following Table gives identifies the cases to be calculated. The fuel types are defined in Tables 1 and 2 using the abbreviations (NU for natural uranium, EUB5 for 4.5% enriched fresh uranium…). Case1_1 through Case1_3 contain fresh fuel only. The two ends of the fuel rod are separated by central natural uranium region. Both axially symmetric (Case1_1) and slightly asymmetric (Case1_2, Case1_3) configuration of the fuel rod are proposed. This is based on the fact that a large asymmetric power distribution appears in a weakly coupled asymmetric reactor core. Case2_1 through Case2_3 are composed of burnup fuels. Similarly, both axially symmetric (Case2_1) and asymmetric (Case2_2, Case2_3) configuration of the fuel rod are proposed.

Table3 Cases identification

	Case1_1	Case1_2	Case1_3	Case2_1	Case2_2	Case2_3
Region	Fuel-type	Fuel-type	Fuel-type	Fuel-type	Fuel-type	Fuel-type
1	EU45	EU45	EU45	B21G	B21G	B21G
2	EU45	EU45	EU45	B24G	B24G	B24G
3	EU45	EU45	EU45	B30G	B30G	B30G
4	EU45	EU45	EU45	B40G	B40G	B40G
5	NU	NU	NU	B55G	B55G	B55G
6	EU45	EU40	EU45	B40G	B55G	B40G
7	EU45	EU40	EU45	B30G	B40G	B30G
8	EU45	EU40	EU40	B24G	B30G	B30G
9	EU45	EU40	EU40	B21G	B24G	B24G

Required calculations

Six cases as shown in Table 3 are to be calculated with the following parameters:

100000 neutrons per generation

200 generations skipped before tallying; it might also be interesting to show the dependency of the results as a function of the number of skipped generations

1000 active generations

Initial source distribution: flat.

Required output

The following information is required. The proposed submission format is intended to make the analysis phase easier. MS Excel spreadsheets may be used to enter the data. However, when a simple text file is used, numerical data separator should be "," without blanks and the word NODATA is to be inserted if a field is empty.
("

```
Line             Required information
=====================================================================
 1:          Date
 2:          Institution
 3:          Contact Person
 4:          e-mail address
 5:          Voice phone number
 6:          FAX Phone Number
 7:          Problem name, e.g., "Benchmark 1: Checkerboard storage"
 8:          Case name, e.g., 1
 9:          Code name
10:          Code type, e.g., Monte Carlo, SN
11:          Cross section library source, e.g., JEF-2.2
12:          Starting source
13:          nskip = number of generations skipped before beginning
             tallies or before convergence:
14:          ngen = number of generations tallied
15:          nhist = number of histories per generation
16:          ngensh = number of generations per superhistory
17:          final k-eff estimate
18:          final k-eff estimate uncertainty (one standard deviation)
19:          k-eff estimate for first supergeneration
20:          individual k-eff estimate for second supergeneration
18+ngen:     individual k-eff estimate for last supergeneration
```

Cumulative fission fractions " ff(i,g)" in fissionable region "i" in generation g, is also an important output. As all computer codes do not have the capability of printing this information for any generation, participants may choose between the following alternatives.

1) Fission fractions are given as average over all generations

2) Fission fractions are given as average over all active generations

3) Fission fractions are given at different generation sequences