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Re-evaluation of Nuclear Criticality Characteristics for Infinite and Finite Heterogeneous Lattice Systems Composed of Uranium-zirconium Hydride Fuel Rods Used in the TRIGA Annular Core Pulse Reactor NSRR

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For understandings of nuclear criticality risks of TRIGA fuel rods and review of safety measures for handling them, nuclear criticality characteristics for infinite and finite heterogeneous lattice systems composed of the NSRR fuel rods were re-evaluated with the use of a detailed computational model for the fuel rod. The MVP version 3 code was used with the JENDL libraries including the latest version, JENDL-5, for the re-evaluation. As the criticality characteristics, variations of neutron multiplication factors of the infinite and water-reflected finite systems were examined in detail with parameters of the lattice pitch and density of moderator water. From the results of the re-evaluated criticality characteristics, the minimum critical number of fuel rods for the water-reflected hexagonal shaped lattice system was obtained to be 46.8 ± 0.2 using the JENDL-5 library. Moreover, the attainability of criticality without the water as moderator and reflector was examined because the zirconium hydride moderator and graphite reflector are equipped with the TRIGA fuel rod. It was found that the criticality is possible to be attained by 115.7 ± 0.6 of the number of fuel rods, which is the smaller number of fuel rods than loaded in the NSRR standard core, even though no water exists.

Keywords: Nuclear Criticality Characteristics, Heterogeneous Lattice System, Uranium-zirconium Hydride Fuel Rod, TRIGA Annular Core Pulse Reactor, NSRR, MVP Version 3 Code, JENDL-5 Library, Water Moderator Reflector, Neutron Multiplication Factor, Critical Number of Fuel Rod

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TRIGA 環状炉心パルス炉 NSRR で使用される
ウラン水素化ジルコニウム燃料棒で構成された無限及び有限非均質格子体系の
臨界特性の再評価

日本原子力研究開発機構
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柳澤　宏司、求　惟子

（2025 年 8 月 20 日受理）

TRIGA 燃料棒の臨界リスクの把握とその取扱いの安全対策の検討のため、NSRR 燃料棒からなる無限及び有限非均質格子体系の臨界特性を、燃料棒の詳細な計算モデルを用いて再評価した。再評価には、最新バージョンの JENDL-5 を含む JENDL ライブラリと MVP バージョン 3 コードが使用された。臨界特性として、無限及び水反射有限体系の中性子増倍率の変化を、格子ピッチと減速材水の密度をパラメータとして詳細に調べた。再評価された臨界特性の結果から、JENDL-5 ライブラリを用いて、水反射の六角格子体系の最小臨界燃料棒本数は 46.8 ± 0.2 本と得られた。さらに、TRIGA 燃料棒には水素化ジルコニウム減速材と黒鉛反射材が備わっているため、減速材及び反射材としての水が存在しない場合の臨界到達可能性を検討した。その結果、水が存在しない場合でも、NSRR 標準炉心に装荷されている燃料棒の本数よりも少ない 115.7 ± 0.6 本の燃料棒で臨界に到達することが可能であることが分かった。

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1. Introduction

NSRR (Nuclear Safety Research Reactor) [1] in the Nuclear Science Research Institute of the Japan Atomic Energy Agency is a research and test reactor categorized into a TRIGA (Training, Research, Isotopes, General Atomics)[2]–ACPR (Annular Core Pulse Reactor). Fuel rods containing uranium-zirconium hydride which is the mixture of neutron moderator and fissile materials are utilized in the TRIGA reactor. Therefore, NSRR has excellent inherent safety due to prompt negative reactivity feedback resulted from rapid increase of thermal neutron temperature by the adiabatic heating of the hydrogen moderator in the fuel rod during pulse operations simulating reactivity-initiated accident conditions. In addition, graphite reflectors are installed axially inside the fuel rod for the purpose of less amount of neutron leakage along a vertical direction from the uranium-zirconium hydride and effective utilization of thermal neutrons.

In terms of nuclear criticality safety, it is reported in the former evaluation[3] that criticality is attainable without both moderator and reflector water using the NSRR fuel rods only. This is an important property of the TRIGA fuel rods. Moreover, the burnup of the fuel is quite small in NSRR due to the operation limit of small integrated thermal power. This means that changes in the critical amount from that by fresh fuel rods are small. For those features from criticality safety point of view, it is meaningful to clarify criticality characteristics of the NSRR fuel rods as the latest scientific knowledge for understandings of criticality risks of the TRIGA fuel rods and review of criticality safety measures for handling them.

In the former evaluation [3], one of the author tried to confirm the criticality characteristics for infinite and water-reflected finite lattice systems based on the simplified models of the NSRR fuel rods by using the continuous-energy Monte Carlo code, MVP version 2[4], with the Japanese evaluated nuclear data library, JENDL-4.0[5], and evaluated the minimum critical number of fuel rods. Afterwards the detailed computational models[6] of the NSRR fuel rods were created by the authors, and the uncertainties in effective neutron multiplication factor (k_{eff}) of the detailed models were also evaluated precisely.

In the present study, the authors show results of the re-evaluation of the criticality characteristics for infinite and water-reflected finite lattice systems as an application of the above-mentioned detailed models of the NSRR fuel rods. The latest version of the MVP code, MVP version 3[7], and the latest JENDL library, JENDL-5[8], are used for the re-evaluation. For comparison, a part of the calculations was conducted with the previous versions of the JENDL libraries, JENDL-4.0 and JENDL-4.0u1[9]. The results of the critical number of fuel rods re-evaluated based on those criticality characteristics were also presented in this report.

2. Calculation Method

For the re-evaluation by using the MVP version 3 code with the evaluated nuclear data libraries JENDL-5, fifty million histories (100,000 particles per batch, 700 batches in total, 200 initial batches skipped) were set for the calculations. The same histories as above are also set for the comparison calculation using the previous versions of the JENDL libraries, JENDL-4.0 and JENDL-4.0u1.

The geometry models and material data are summarized below.

2.1 Geometry model of fuel rod

Figure 2.1.1 shows the geometry model of the fuel rod, which is cited from the literature presenting the results from the earlier study on the NSRR detailed computational models[6]. The fuel meat is 19.85 wt% enriched uranium-zirconium hydride with a vertical hole in the center of the fuel meat, in which zirconium rods are inserted. Axial graphite reflectors are installed at both top and bottom of the fuel rod. A thin molybdenum disc is also installed between the uranium-zirconium hydride and the bottom axial graphite reflector. The austenitic stainless-steel type SUS304 fuel cladding and top/bottom plugs are used in the fuel rod. In the former evaluation[3] on the criticality characteristics of the NSRR fuel rods, it was assumed that the zirconium rod and the inner void inside the uranium-zirconium hydride were mixed homogeneously with the uranium-zirconium hydride as the simplified model. In addition, the molybdenum disc and the top/bottom plugs were neglected. It is considered that the neglection of those components brings the effect of positive reactivity.

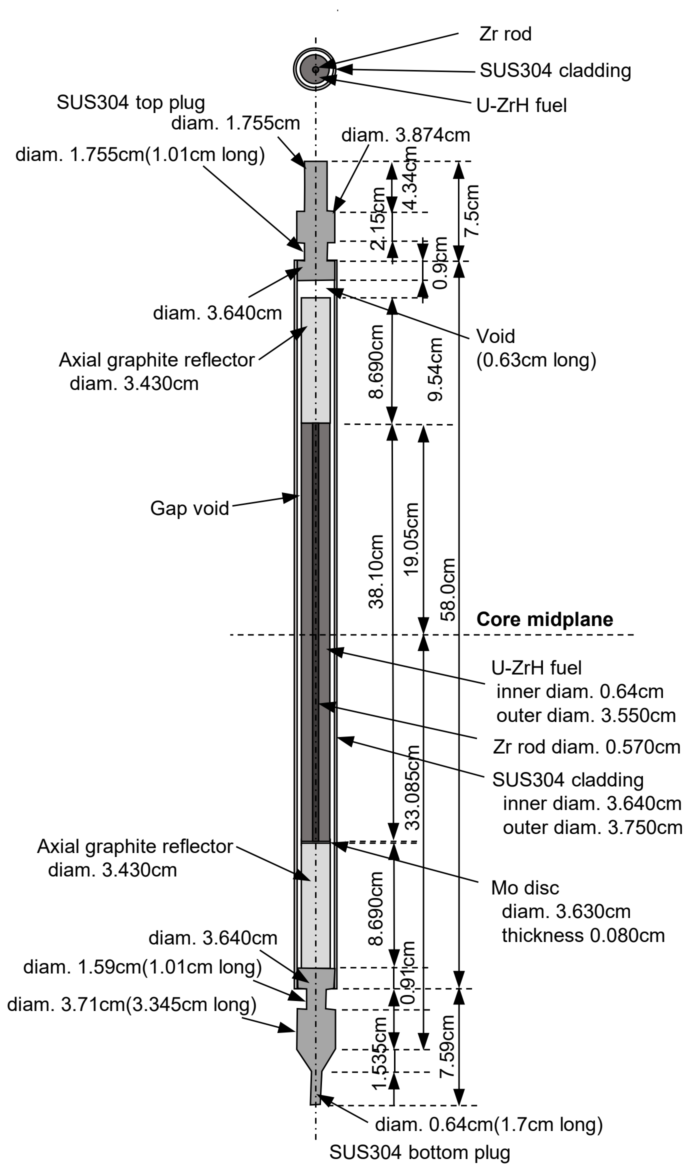

Fig.2.1.1 Geometry model of fuel rod.

2.2 Configuration of infinite lattice systems

To understand characteristics of a unit fuel cell composed of the uranium-zirconium hydride, zirconium rod, cladding and moderator water, infinite hexagonal and square lattice systems were subjected to the calculation with the same method as the former evaluation[3)]. The geometry models of configurations of the infinite lattice systems are shown in Fig.2.2.1. The fuel cell is in the range of the height of the uranium-zirconium hydride shown in Fig.2.1.1.

The mirror reflective boundary condition was adopted at all outer boundaries shown in Fig.2.2.1 are the mirror reflective conditions. The lattice pitch was set to be in the range of 3.75 to 7.00 cm. The minimum lattice pitch: 3.75 cm means the close contact of the surface of the fuel rods. The same lattice pitch as the NSRR core was also set as 4.175 cm. The characteristics were confirmed with the variation of the density of the moderator from 100 to 0%.

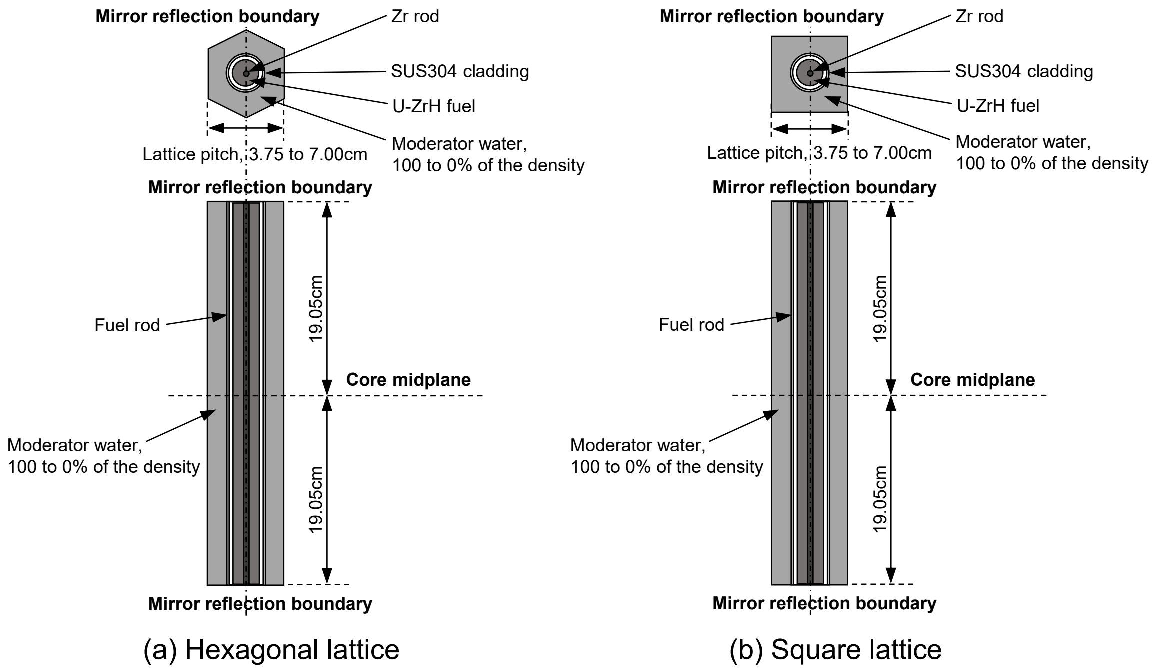

Fig.2.2.1 Geometry models of infinite lattice systems.

2.3 Configuration of finite lattice systems

The finite lattice systems were defined with similar hexagonal and square lattice systems to the former evaluation[3]. They are distinguished into two sorts of lattice systems subjected to search on either the minimum critical number of fuel rods or the criticality under no moderator water condition.

2.3.1 Configuration of finite lattice systems for search on minimum critical number of fuel rods

For the search on the minimum critical number of fuel rods, the re-evaluation of criticality characteristics was subjected to four sorts of water-reflected finite lattice systems with hexagonal and square lattice configurations, respectively. These systems are composed of 55, 49, 43 and 40 fuel rods for the hexagonal lattice configurations, and of 57, 49, 44 and 40 fuel rods for the square ones.

Figures 2.3.1.1 to 2.3.1.4 show the finite lattice systems configured with the hexagonal lattice. Figures 2.3.1.5 to 2.3.1.8 also show the finite lattice systems configured with the square lattice. The fuel rod cells were positioned horizontally to make near cylindrical arrays as much as possible. The hexagonal or square region enveloping the fuel rod lattice is surrounded by 30 cm thick reflector water, of which density is fixed to be 100 %. The same conditions on the lattice pitch and the density of the moderator water are adopted as the infinite lattice systems described in Sec. 2.2 for the purpose of direct comparisons of the lattice characteristics. Thus, the lattice pitch was set to be in the range of 3.75 to 7.00 cm, including the same lattice pitch as the NSRR core: 4.175 cm. The density of the moderator was also 100 to 0 %. The vacuum boundary condition was adopted at all outer boundaries of the reflector water shown in Figs.2.3.1.1 to 2.3.1.8.

The vertical layout of the fuel rod in all finite lattice systems is shown in Fig.2.3.1.9. The region of fuel cells is composed of the moderator water and a part of the fuel rod components in the range of the height of the uranium-zirconium hydride. The reflector water of which density is fixed to be 100 % is placed both over and under the fuel cell region. Over the top and under the bottom of the fuel rod, thickness of the reflector water is 30 cm. The top or bottom reflector region is composed of the reflector water and components of the fuel rod over or under the fuel cell region, as illustrated in Fig.2.3.1.9. Thus, the moderator water of which density varied as a calculation parameter is distinguished from the reflector water for the purpose of the comparisons of the lattice characteristics with the infinite systems. The vacuum boundary condition was adopted at the outer top and bottom boundaries of the reflector water shown in Fig.2.3.1.9.

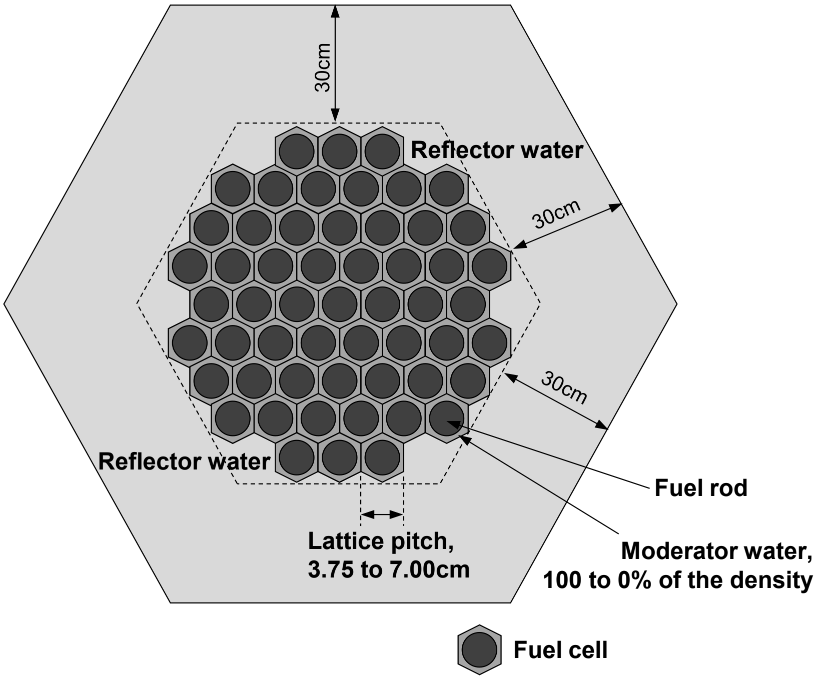

Fig.2.3.1.1 Geometry model of finite hexagonal lattice system composed of 55 fuel rods.

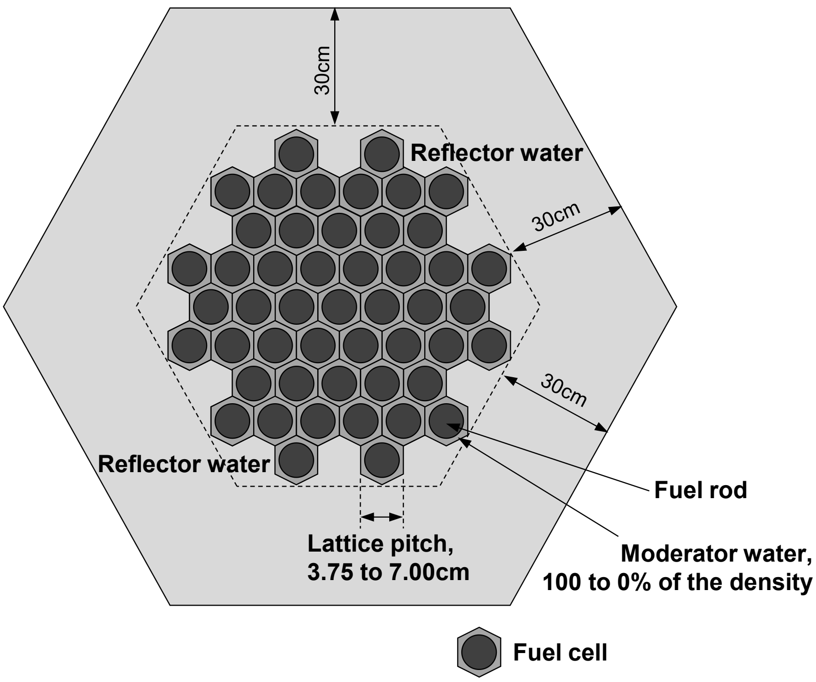

Fig.2.3.1.2 Geometry model of finite hexagonal lattice system composed of 49 fuel rods.

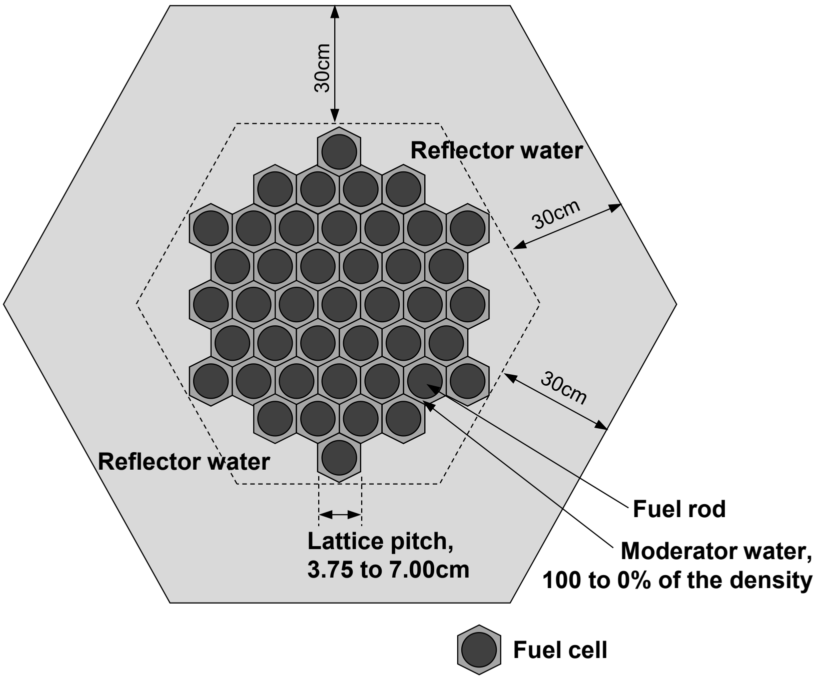

Fig.2.3.1.3 Geometry model of finite hexagonal lattice system composed of 43 fuel rods.

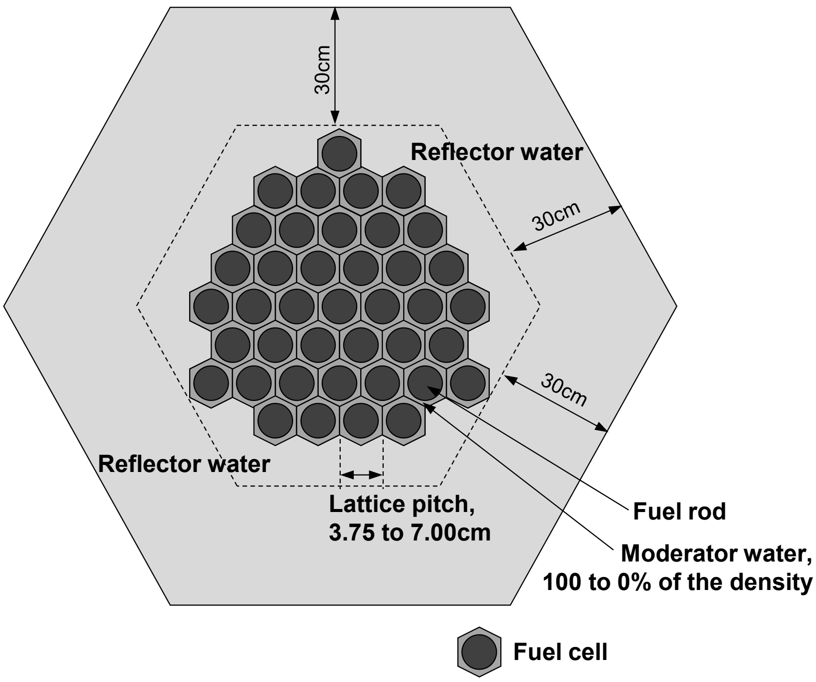

Fig.2.3.1.4 Geometry model of finite hexagonal lattice system composed of 40 fuel rods.

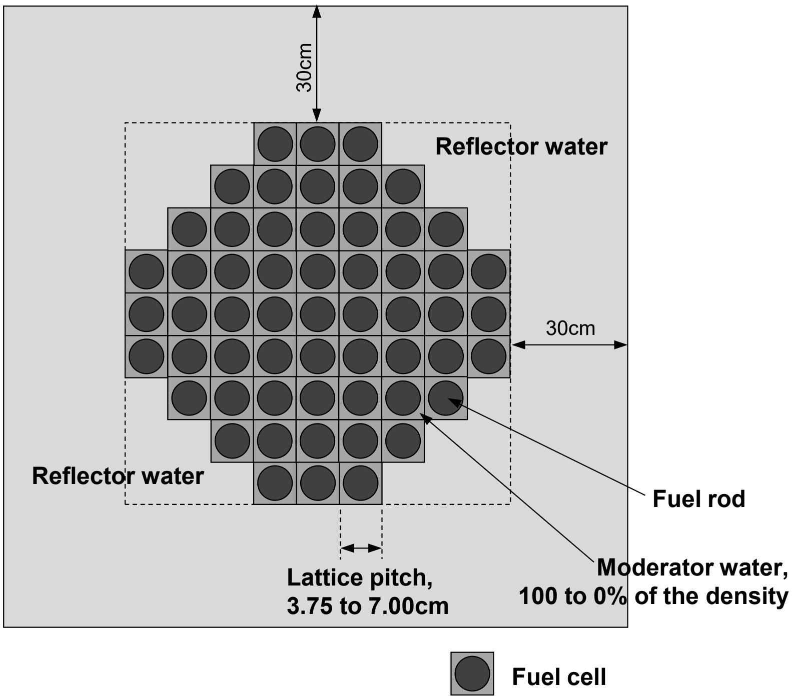

Fig.2.3.1.5 Geometry model of finite square lattice system composed of 57 fuel rods.

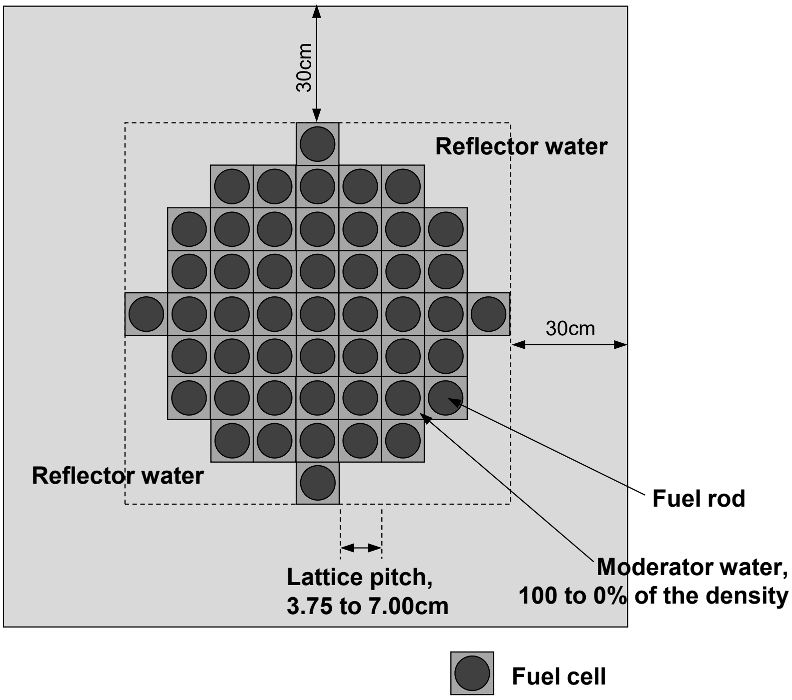

Fig.2.3.1.6 Geometry model of finite square lattice system composed of 49 fuel rods.

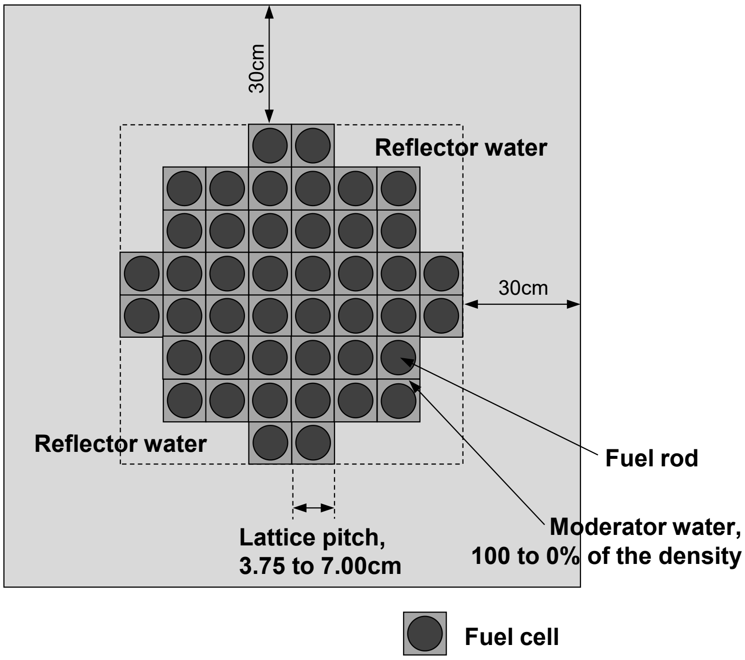

Fig.2.3.1.7 Geometry model of finite square lattice system composed of 44 fuel rods.

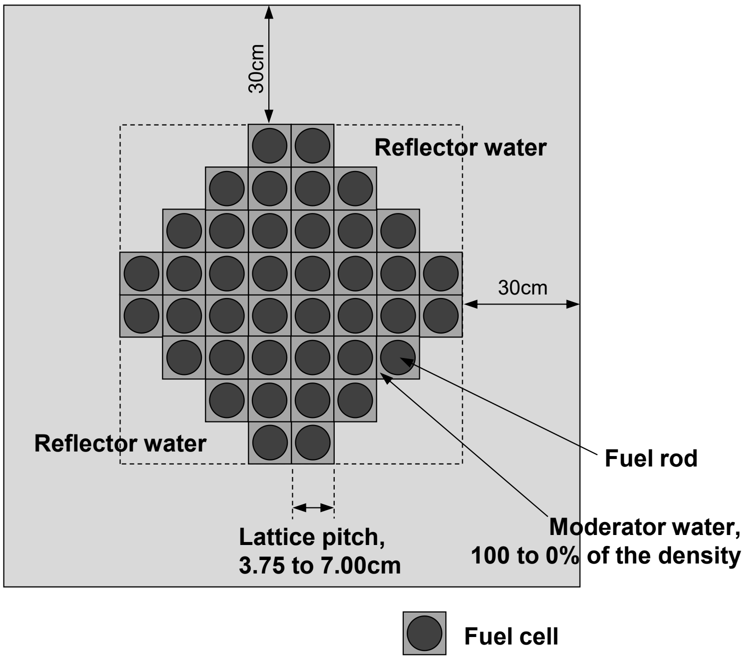

Fig.2.3.1.8 Geometry model of finite square lattice system composed of 40 fuel rods.

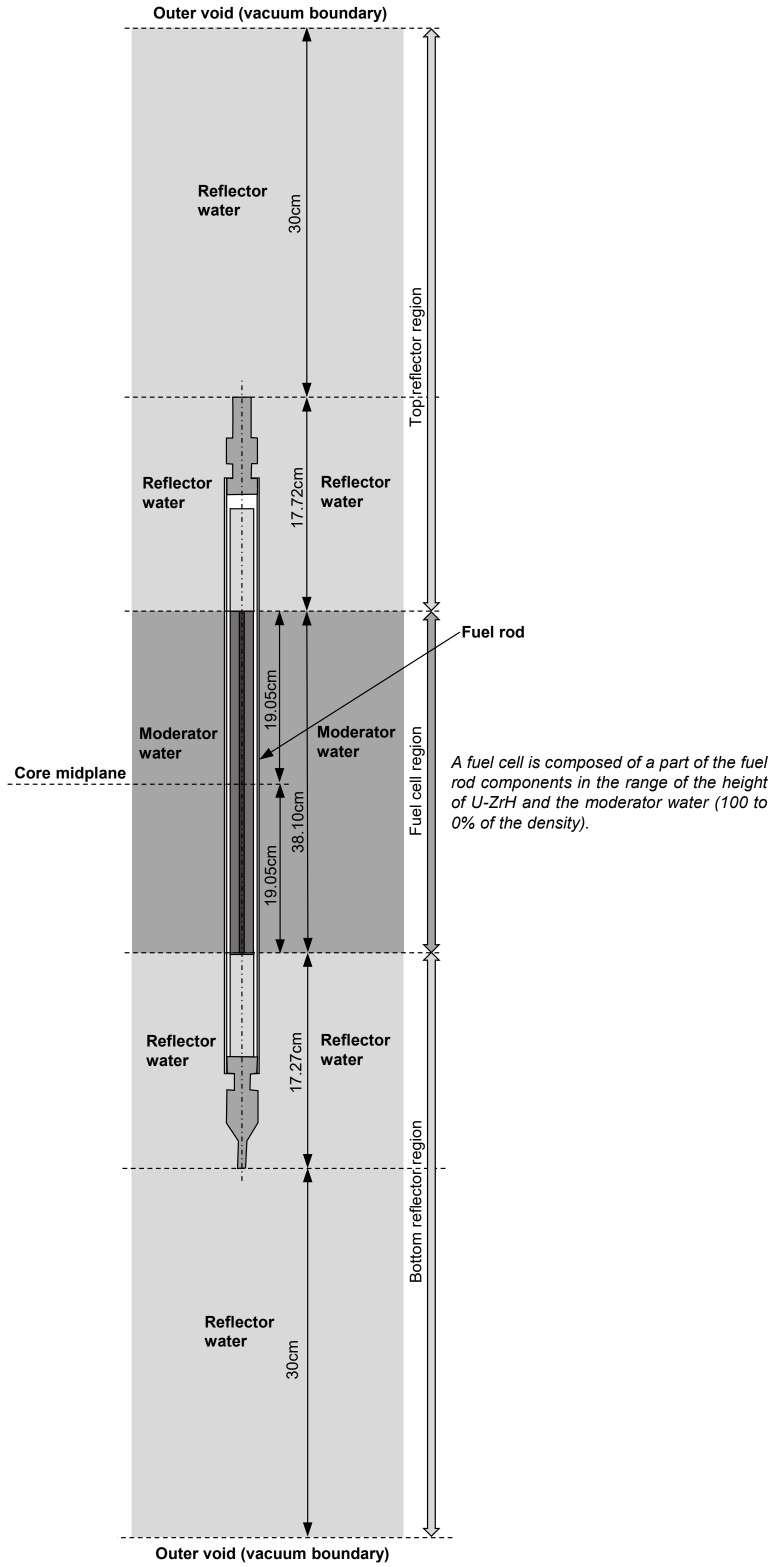

Fig.2.3.1.9 Vertical layout of fuel rod in finite hexagonal and square lattice systems.

2.3.2 Configuration of finite lattice systems for search on criticality under no moderator water condition

For the search on possible criticality under no moderator water conditions, the re-evaluation of criticality characteristics was subjected to five sorts of the finite hexagonal lattice systems composed of 217, 169, 127, 91 and 61 fuel rods, as shown in Figs.2.3.2.1 to 2.3.2.5. The vertical layout of the fuel rod was the same as illustrated in Fig.2.3.1.9.

It was already confirmed in the former evaluation[3)] that the value of k_{eff} is enlarged as the lattice pitch decreases under the condition of 0 % of the density of the moderator water. Thus, the lattice pitch was fixed to be 3.75 cm minimum similar to the former evaluation. The density of the moderator water was set to be 0 % as no moderator water condition. Both the water-reflected and no-water-reflected conditions were considered for the re-evaluation same as the former evaluation. In the case of the no-water-reflected condition, the density of the reflector water was set to be 0 %, whilst the density for the water-reflected condition was 100 %.

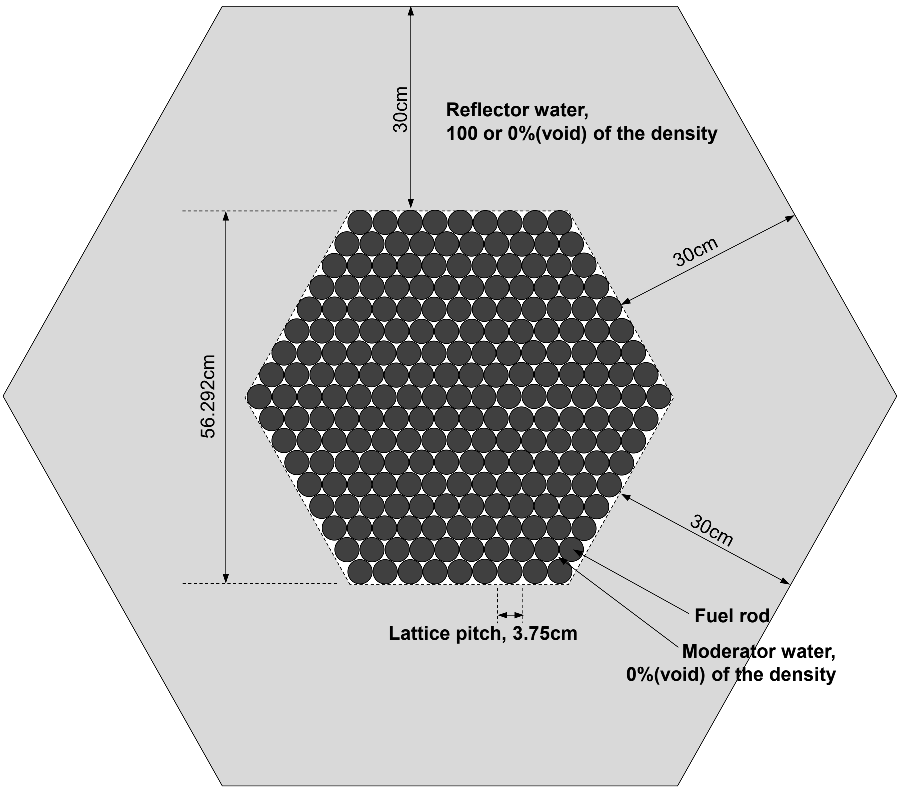

Fig.2.3.2.1 Geometry model of finite hexagonal lattice system composed of 217 fuel rods under no moderator water condition.

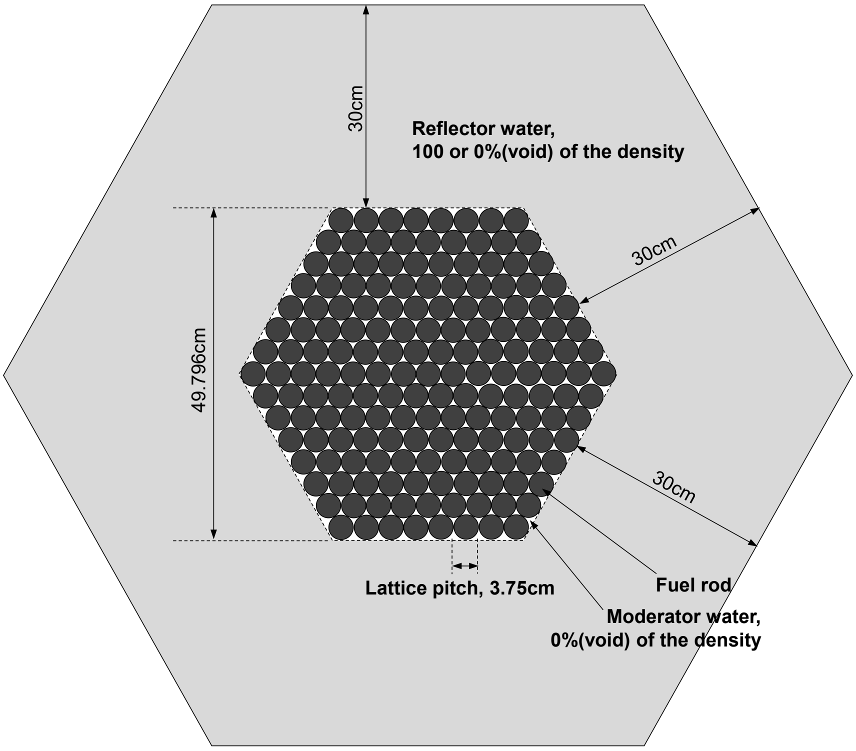

Fig.2.3.2.2 Geometry model of finite hexagonal lattice system composed of 169 fuel rods under no moderator water condition.

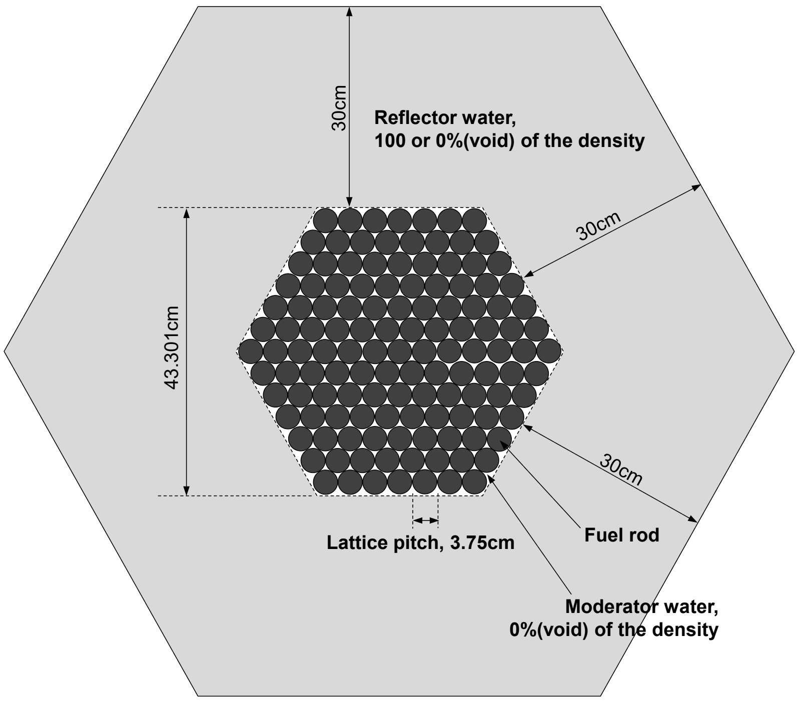

Fig.2.3.2.3 Geometry model of finite hexagonal lattice system composed of 127 fuel rods under no moderator water condition.

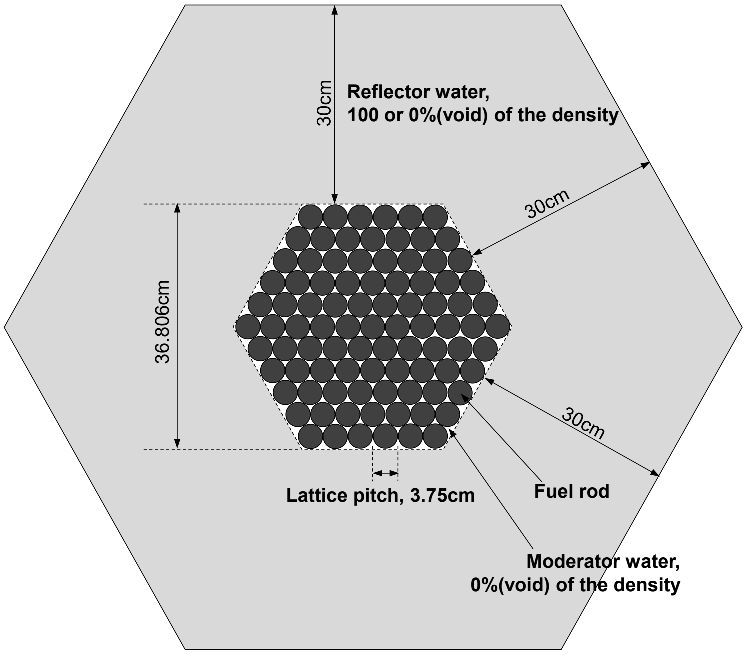

Fig.2.3.2.4 Geometry model of finite hexagonal lattice system composed of 91 fuel rods under no moderator water condition.

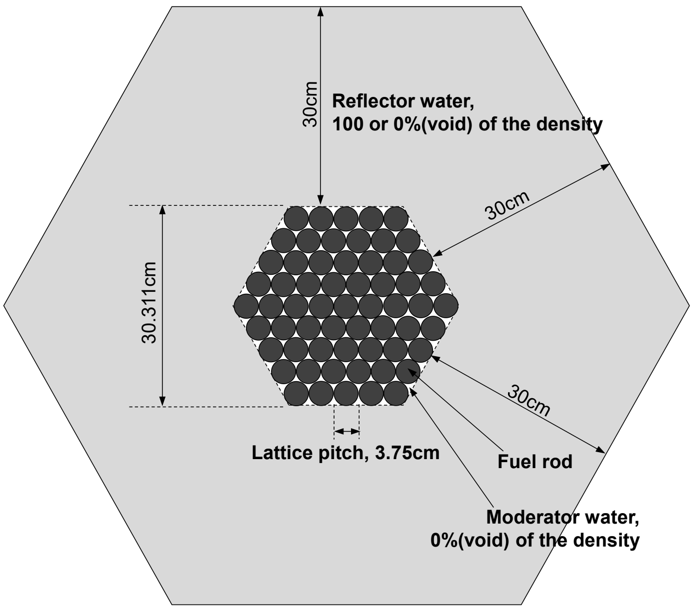

Fig.2.3.2.5 Geometry model of finite hexagonal lattice system composed of 61 fuel rods under no moderator water condition.

2.4 Material data

The atomic number densities of the materials used in the calculations are cited from the literature presenting the results from the earlier study on the NSRR detailed computational models [6)]. As presented in that literature, nuclear constants, i.e., Avogadro's Number, atomic weight, and isotopic abundance, were based on the International Criticality Safety Benchmark Evaluation Project (ICSBEP) handbook[10)]. The temperature of all materials was set to be 25 ^{o}C same as the former evaluation[3)].

The atomic number densities of nuclides for the components in the fuel rod are listed in Tables 2.4.1 to 2.4.6. In the former evaluation [3)] on the criticality characteristics of the NSRR fuel rods, any impurities in the uranium-zirconium hydride, the zirconium rod and the molybdenum disc were not considered. It was confirmed in the earlier study [6)] that the neglection of the impurities in the uranium-zirconium hydride brings the effect of positive reactivity that cannot be ignored.

For the JENDL-4.0u1 library [9)], several nuclide data used in the present calculations are modified from the JENDL-4.0 library, i.e., modifications for the elastic scattering cross sections of boron-10, and covariance data of chromium-52, chromium-53, uranium-235 and uranium-238. It is considered that those modifications may not largely affect k_{eff}.

Table 2.4.1 Atomic number densities of nuclides in uranium-zirconium hydride.

Nuclide	Atomic Number Density (1/barn cm)
H-1*1	5.5586×10^{-2}
Zr-90*1	1.7678×10^{-2}
Zr-91*1	3.8552×10^{-3}
Zr-92*1	5.8928×10^{-3}
Zr-94*1	5.9718×10^{-3}
Zr-96*1	9.6209×10^{-4}
U-235	3.6389×10^{-4}
U-238	1.4505×10^{-3}
C-12*2	3.6133×10^{-5}
C-13*2	4.0189×10^{-7}
N-14*2	4.9050×10^{-6}
N-15*2	1.8216×10^{-8}
O-16*2	1.5673×10^{-4}

*1 The thermal neutron scattering law (TSL) data were used as zirconium hydride.
*2 Impurities.

Table 2.4.1(contd.) Atomic number densities of nuclides in uranium-zirconium hydride.

Nuclide	Atomic Number Density (1/barn cm)
Mg-24*2	5.7755×10^{-6}
Mg-25*2	7.3116×10^{-7}
Mg-26*2	8.0501×10^{-7}
Al-27*2	5.7067×10^{-6}
Si-28*2	2.4758×10^{-6}
Si-29*2	1.2536×10^{-7}
Si-30*2	8.3215×10^{-8}
Cl-35*2	6.6990×10^{-6}
Cl-37*2	2.1422×10^{-6}
Cr-50*2	1.3069×10^{-7}
Cr-52*2	2.5202×10^{-6}
Cr-53*2	2.8574×10^{-7}
Cr-54*2	7.1134×10^{-8}
Fe-54*2	1.1152×10^{-6}
Fe-56*2	1.7337×10^{-5}
Fe-57*2	3.9695×10^{-7}
Fe-58*2	5.2926×10^{-8}
Ni-58*2	2.5893×10^{-7}
Ni-60*2	9.8989×10^{-8}
Ni-61*2	4.2858×10^{-9}
Ni-62*2	1.3616×10^{-8}
Ni-64*2	3.4514×10^{-9}
Hf-174*2	7.9659×10^{-10}
Hf-176*2	2.5599×10^{-8}
Hf-177*2	9.1490×10^{-8}
Hf-178*2	1.3422×10^{-7}
Hf-179*2	6.7017×10^{-8}
Hf-180*2	1.7259×10^{-7}

*2 Impurities.

Table 2.4.2 Atomic number densities of nuclides in zirconium rod.

Nuclide	Atomic Number Density (1/barn cm)
Zr-90	2.2145×10^{-2}
Zr-91	4.8293×10^{-3}
Zr-92	7.3816×10^{-3}
Zr-94	7.4806×10^{-3}
Zr-96	1.2052×10^{-3}
B-10*1	1.4455×10^{-8}
B-11*1	5.8182×10^{-8}
C-12*1	3.7180×10^{-5}
C-13*1	4.1353×10^{-7}

*1 Impurities.

Table 2.4.2(contd.) Atomic number densities of nuclides in zirconium rod.

Nuclide	Atomic Number Density (1/barn cm)
N-14*1	1.1171×10^{-5}
N-15*1	4.1488×10^{-8}
Cr-50*1	2.3460×10^{-7}
Cr-52*1	4.5240×10^{-6}
Cr-53*1	5.1293×10^{-7}
Cr-54*1	1.2769×10^{-7}
Fe-54*1	2.3251×10^{-6}
Fe-56*1	3.6146×10^{-5}
Fe-57*1	8.2759×10^{-7}
Fe-58*1	1.1035×10^{-7}
Cu-63*1	5.1287×10^{-7}
Cu-65*1	2.2859×10^{-7}
Hf-174*1	1.1582×10^{-9}
Hf-176*1	3.7220×10^{-8}
Hf-177*1	1.3302×10^{-7}
Hf-178*1	1.9516×10^{-7}
Hf-179*1	9.7440×10^{-8}
Hf-180*1	2.5095×10^{-7}

*1 Impurities.

Table 2.4.3 Atomic number densities of nuclides in SUS304 cladding.

Nuclide	Atomic Number Density (1/barn cm)
B-10	1.4944×10^{-6}
B-11	6.0150×10^{-6}
C-12	2.0959×10^{-4}
C-13	2.3311×10^{-6}
Si-28	8.4167×10^{-4}
Si-29	4.2617×10^{-5}
Si-30	2.8290×10^{-5}
P-31	3.2378×10^{-5}
S-32	1.9388×10^{-5}
S-33	1.5303×10^{-7}
S-34	8.5901×10^{-7}
S-36	4.0808×10^{-9}
Cr-50	7.3760×10^{-4}
Cr-52	1.4224×10^{-2}
Cr-53	1.6127×10^{-3}
Cr-54	4.0148×10^{-4}
Mn-55	1.1880×10^{-3}

Table 2.4.3(contd.) Atomic number densities of nuclides in SUS304 cladding.

Nuclide	Atomic Number Density (1/barn cm)
Fe-54	3.5498×10^{-3}
Fe-56	5.5184×10^{-2}
Fe-57	1.2635×10^{-3}
Fe-58	1.6847×10^{-4}
Ni-58	5.0923×10^{-3}
Ni-60	1.9468×10^{-3}
Ni-61	8.4288×10^{-5}
Ni-62	2.6778×10^{-4}
Ni-64	6.7878×10^{-5}

Table 2.4.4 Atomic number densities of nuclides in SUS304 top/bottom plugs.

Nuclide	Atomic Number Density (1/barn cm)
C-12	1.0617×10^{-4}
C-13	1.1809×10^{-6}
Si-28	8.6253×10^{-4}
Si-29	4.3674×10^{-5}
Si-30	2.8991×10^{-5}
P-31	2.4669×10^{-5}
S-32	2.8304×10^{-5}
S-33	2.2340×10^{-7}
S-34	1.2540×10^{-6}
S-36	5.9574×10^{-9}
Cr-50	7.4225×10^{-4}
Cr-52	1.4314×10^{-2}
Cr-53	1.6229×10^{-3}
Cr-54	4.0401×10^{-4}
Mn-55	1.1126×10^{-3}
Fe-54	3.5599×10^{-3}
Fe-56	5.5341×10^{-2}
Fe-57	1.2671×10^{-3}
Fe-58	1.6894×10^{-4}
Ni-58	4.9719×10^{-3}
Ni-60	1.9008×10^{-3}
Ni-61	8.2295×10^{-5}
Ni-62	2.6145×10^{-4}
Ni-64	6.6273×10^{-5}

Table 2.4.5 Atomic number densities of nuclides in molybdenum disc.

Nuclide	Atomic Number Density (1/barn cm)
Mo-92	9.5767×10^{-3}
Mo-94	5.9693×10^{-3}
Mo-95	1.0274×10^{-2}
Mo-96	1.0764×10^{-2}
Mo-97	6.1629×10^{-3}
Mo-98	1.5572×10^{-2}
Mo-100	6.2145×10^{-3}
H-1[*1]	1.2284×10^{-5}
N-14[*1]	2.2017×10^{-6}
N-15[*1]	8.1766×10^{-9}
O-16[*1]	9.6734×10^{-6}
Na-23[*1]	2.1542×10^{-6}
Al-27[*1]	3.5532×10^{-6}
Si-28[*1]	5.3522×10^{-6}
Si-29[*1]	2.7100×10^{-7}
Si-30[*1]	1.7990×10^{-7}
P-31[*1]	5.9961×10^{-7}
Ca-40[1]	3.1479×10^{-8}
Ca-42[*1]	6.4050×10^{-9}
Ca-43[*1]	9.8908×10^{-8}
Ca-44[*1]	1.9379×10^{-10}
Ca-46[*1]	9.0425×10^{-9}
Ca-48[*1]	8.6656×10^{-9}
Cr-50[*1]	5.1732×10^{-8}
Cr-52[*1]	9.9761×10^{-7}
Cr-53[*1]	1.1311×10^{-7}
Cr-54[*1]	2.8158×10^{-8}
Mn-55[*1]	1.1269×10^{-6}
Fe-54[*1]	2.6162×10^{-7}
Fe-56[*1]	4.0672×10^{-6}
Fe-57[*1]	9.3121×10^{-8}
Fe-58[*1]	1.2416×10^{-8}
Ni-58[*1]	7.2015×10^{-7}
Ni-60[*1]	2.7532×10^{-7}
Ni-61[*1]	1.1920×10^{-8}
Ni-62[*1]	3.7869×10^{-8}
Ni-64[*1]	9.5992×10^{-9}
Cu-63[*1]	8.0864×10^{-7}
Cu-65[*1]	3.6042×10^{-7}
W-180[*1]	3.6367×10^{-9}
W-182[*1]	7.9703×10^{-7}
W-183[*1]	4.3276×10^{-7}
W-184[*1]	9.3038×10^{-7}
W-186[*1]	8.6674×10^{-7}

*1 Impurities.

Table 2.4.6 Atomic number densities of nuclides
in axial graphite reflector.

Nuclide	Atomic Number Density (1/barn cm)
C-12*1	8.5785×10^{-2}
C-13*1	9.5413×10^{-4}

*1 The thermal neutron scattering law (TSL) data were used as graphite.

The density of water was referred to the literature[11)], as 0.99704 g/cm^3. The atomic number densities of nuclides in the moderator and reflector water of 25 °C are listed in Table 2.4.7.

Table 2.4.7 Atomic number densities of nuclides
in moderator and reflector water of 25°C.

Nuclide	Atomic Number Density (1/barn cm)
H-1*1	6.6655×10^{-2}
O-16*1	3.3329×10^{-2}

*1 The thermal neutron scattering law (TSL) data were used as light water. The TSL data of O-16 were used in the JENDL-5 library only.

3. Results of Calculation

The calculated lattice characteristics were summarized with the use of the moderator water to the fuel volume ratio (VR), similar to the former evaluation[3)]. VR is an index of degree of neutron moderation by water functioning as moderator in lattice systems. By using VR, it is possible to directly compare characteristics of the hexagonal lattices with those of the square ones. VR for the NSRR fuel rod is defined by the following expressions.

VR of hexagonal lattice:

$$VR = \frac{\frac{\sqrt{3}}{2} P_L^2 - \pi \left(\frac{D_{oR}}{2}\right)^2}{\pi \left\{ \left(\frac{D_{oF}}{2}\right)^2 - \left(\frac{D_{iF}}{2}\right)^2 \right\}}, \quad \text{.......} \quad (3.1)$$

VR of square lattice:

$$VR = \frac{P_L^2 - \pi\left(\frac{D_{oR}}{2}\right)^2}{\pi\left\{\left(\frac{D_{oF}}{2}\right)^2 - \left(\frac{D_{iF}}{2}\right)^2\right\}}, \qquad \text{(3.2)}$$

where,

P_L: lattice pitch, varying from 3.75 to 7.00 cm,
D_{oR}: outer diameter of the fuel rod (3.750 cm),
D_{oF}: outer diameter of the uranium-zirconium hydride (3.550 cm), and
D_{iF}: inner diameter of the uranium-zirconium hydride (0.64 cm), respectively.

All calculated results are shown below together with errors of three times their standard deviations (3σ's) unless otherwise noted.

3.1 Characteristics for infinite lattice systems

In addition to the calculation of infinite neutron multiplication factor (k_{inf}) for the infinite lattice systems, three sorts of ratios of reactions were also calculated as defined below for the purpose of examination on characteristics of k_{inf} varying with VR.

$$Ratio(1) = \frac{\nu F}{A_{RD}}, \qquad \text{(3.1.1)}$$

$$Ratio(2) = \frac{A_{RD}}{A_{RD} + A_{WA}}, \qquad \text{(3.1.2)}$$

$$Ratio(3) = Ratio(1) \times Ratio(2) = \frac{\nu F}{A_{RD} + A_{WA}} = k_{\mathrm{inf}}, \qquad \text{(3.1.3)}$$

where,

νF: fission reaction in the fuel rod multiplied by the number of neutrons emitted per a fission,

A_{RD}: capture reaction in the fuel rod, which is total of fission and non-fission capture, and

A_{WA}: capture reaction in the moderator water, respectively.

As an analogy from the well-known four-factor formula of k_{inf}, Ratio(2) corresponds to the thermal neutron utilization factor in the formula. So, Ratio(1) represents characteristics of the products of the resonance escape probability, neutron regeneration factor and fast fission one in the formula. In particular, it is considered that the characteristics on the resonance escape probability affect largely Ratio(1), as presented in the former evaluation[3)].

In the calculations, k_{inf} was determined from the most probable eigenvalue and its σ using the standard estimation method defaulted in the MVP code[7)]. This is based on the maximum likelihood method with the combination of the multiple estimators including the track length one. The ratios of reactions defined in Eqs.(3.1.1) to (3.1.3) were determined by using the track length estimator only.

Figures 3.1.1 to 3.1.3 show k_{inf}, Ratio(1), and Ratio(2) varying with VR calculated using the JENDL-5 library, respectively. Any graphs showing results of Ratio(3) are not presented here since Ratio(3) as defined in Eq.(3.1.3) is considered to be identical to k_{inf}. All numerical data are listed in Appendix-1, including the results of Ratio(3) as well as k_{inf}, Ratio(1), and Ratio(2). In Appendix-1, calculated results using the JENDL-4.0 and JENDL-4.0u1 libraries are also listed on condition that the densities of moderator water are 100 and 0 %. The comparisons of the results using the JENDL-5 library with those using the JENDL-4.0 and JENDL-4.0u1 ones are shown in Appendix-4.

The results from the comparison between the JENDL-5 and the previous versions of the JENDL libraries are briefly mentioned here. As presented in Appendix-4, it is clarified that the differences in k_{inf} between the JENDL-5 and JENDL-4.0 libraries under the condition of 100 % of the density of the moderator water are small and nearly constant in the range below 0.7 of VR, but the differences become larger in the range beyond 0.7 of VR as VR increases[*1]. It is

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[*1] The differences in k_{inf} between the JENDL-5 and JENDL-4.0 libraries are about -0.1 % in the range below 0.7 of VR, increases as VR in the range beyond 0.7 of VR, are expanded more than 0.8 % at 4.0 of VR.

confirmed that the differences between the JENDL-4.0 and JENDL-4.0u1 libraries are smaller than three times their σ's. It is also found that the differences in k_{inf} between the JENDL-5 and JENDL-4.0 libraries are affected mainly by the differences in Ratio(2). For the condition of 0 % of the density of the moderator water, it is clarified that the differences in k_{inf} between the JENDL-5 and JENDL-4.0 libraries are nearly constant and small in the full range of VR[*2]. It is also confirmed that the differences between the JENDL-5 and JENDL-4.0 libraries are determined by the differences in Ratio(1) since Ratio(2) is identical to unity by its definition in Eq.(3.1.2).

*2 The averaged difference in k_{inf} between the JENDL-5 and JENDL-4.0 libraries is about -0.1 %.

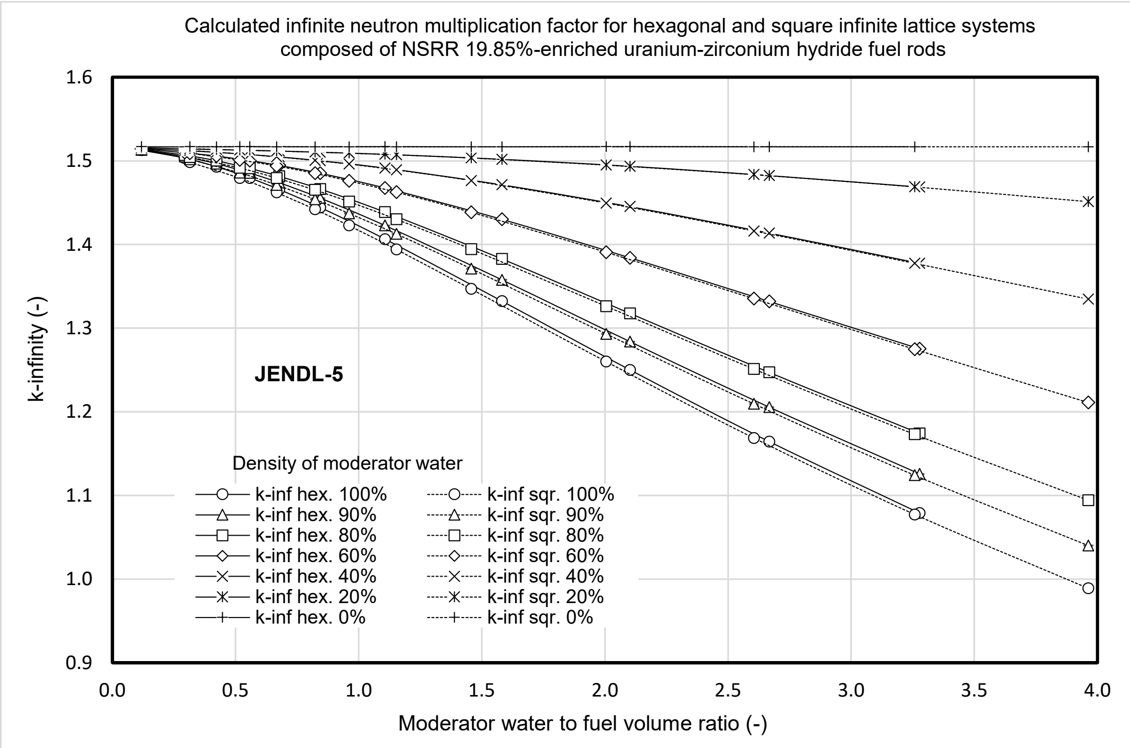


Fig.3.1.1 Infinite neutron multiplication factor for hexagonal and square infinite lattice systems as function of VR, using JENDL-5.

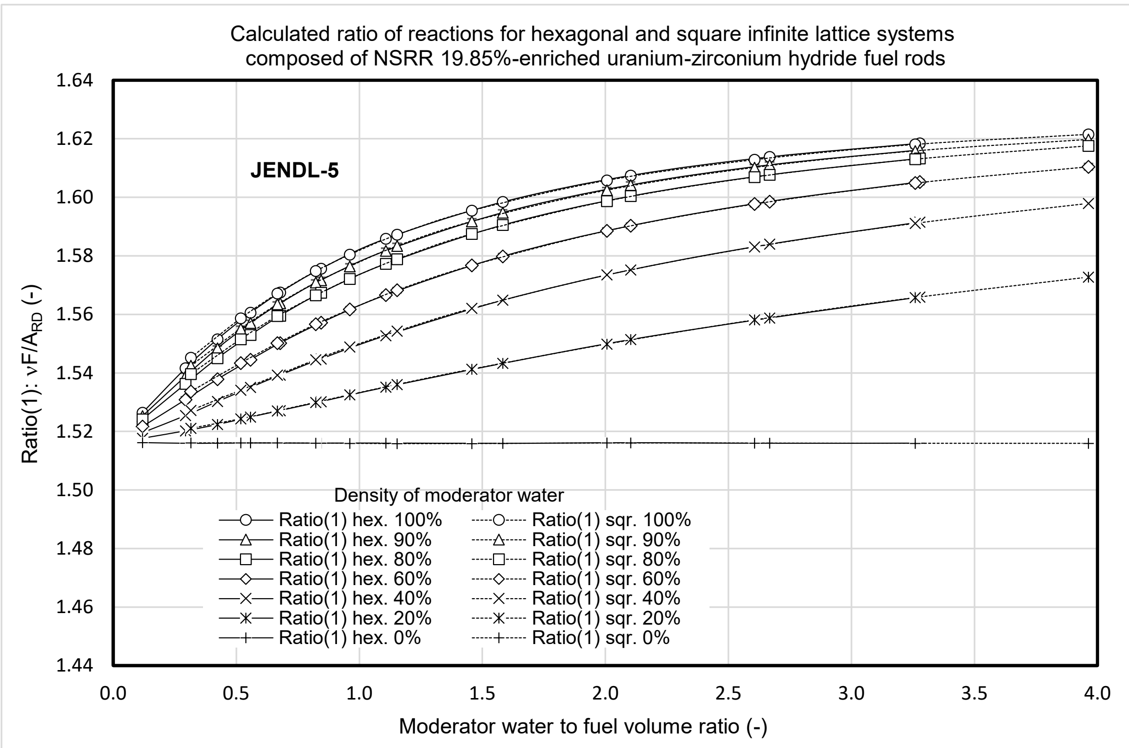


Fig.3.1.2 Ratio(1) for hexagonal and square infinite lattice systems as function of VR, using JENDL-5.

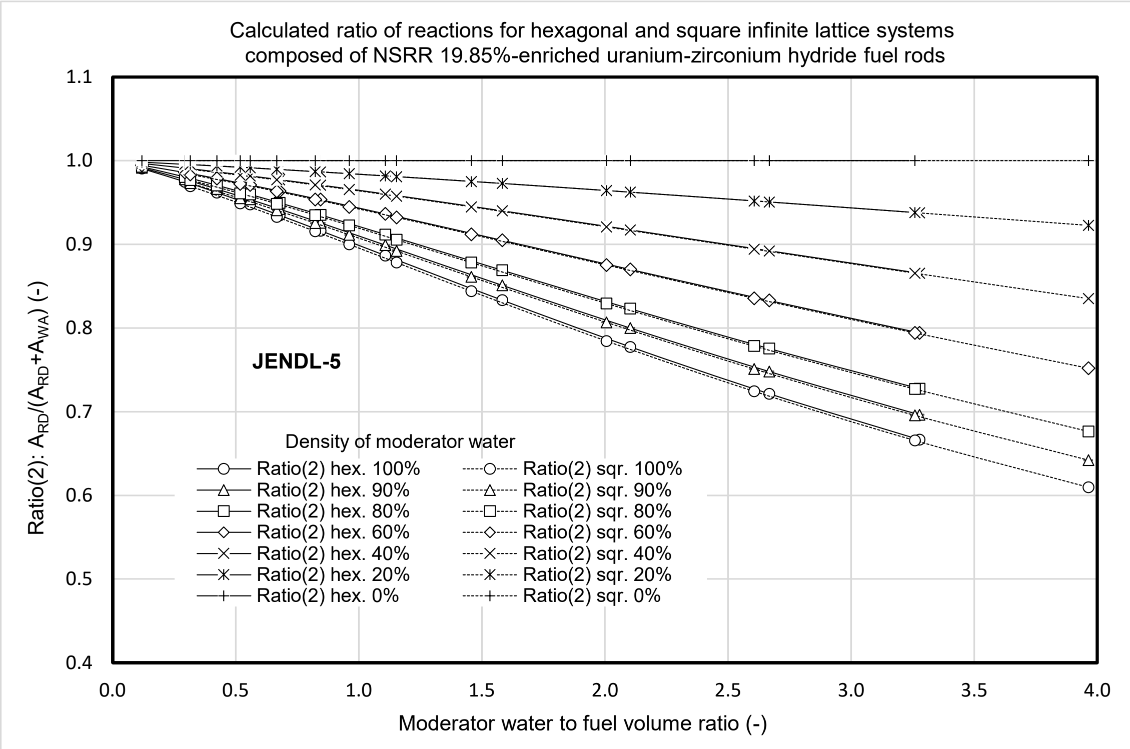


Fig.3.1.3 Ratio(2) for hexagonal and square infinite lattice systems as function of VR, using JENDL-5.

It is seen in Figs.3.1.1 to 3.1.3 that the variations of k_{inf}, Ratio(1) and Ratio(2) with VR for the hexagonal lattice systems are the same as the square ones. It is considered that the characteristics of the lattice systems are possible to be compared directly with other different shaped ones using VR, not the lattice pitch.

It is confirmed from Fig.3.1.1 that k_{inf} decreases monotonically as VR increases and the magnitude of the decrease in k_{inf} is smaller as the density of the moderator water decreases. Those tendencies can be explained by the variations of Ratio(1) and Ratio(2) with VR. As seen in Figs.3.1.2 and 3.1.3, it is confirmed that Ratio(2) decreases monotonically as VR increases like k_{inf} whilst Ratio(1) increases monotonically as VR increases. But absolute values of the variations of Ratio(2) are quite larger than those in Ratio(1). It is, therefore, concluded that Ratio(2) dominantly affects k_{inf}.

Ratio(2) is defined in Eq.(3.1.2) as the index showing the ratio of capture reactions in the fuel rod to those in the fuel cell including the moderator water. It is considered that lager VR resulting in larger volume of the moderator water make amounts of capture reactions in the moderator water enlarged. In addition, it is considered that those amounts increase similarly as the density of the moderator water increases. The tendencies of the variations of k_{inf} in Fig.3.1.1 can be explained for those reasons.

Those characteristics in k_{inf} are features in the TRIGA fuel rods in which the mixture of fissile and moderator materials. In the case of no moderator material in fuel rods, e.g., uranium dioxide ones, it had been confirmed in the former evaluation[3)] that absolute values of the variations of Ratio(2) are comparable to those in Ratio(1), thus k_{inf} is changed along a convex upward curve as VR increases.

As shown in Fig.3.1.1, it is found that another important feature on criticality, which is that the value of k_{inf} becomes maximum, larger than 1.5, in the case of 0 % of the density of the moderator water. This means that there is a possibility to reach criticality in a finite lattice system on condition of no moderator water. This feature is particular in the TRIGA fuel rods and not seen in uranium dioxide fuel rods[3)]. The possible critical amounts under no moderator water condition are re-evaluated in Sec.3.3.2.

3.2 Characteristics for finite lattice systems

In addition to the calculation of k_{eff} for the finite lattice systems, four sorts of ratios of reactions were also calculated as defined below for the purpose of examination on characteristics of k_{eff} varying with VR.

$$Ratio(4) = \frac{\nu F}{A_C}, \qquad \text{(3.2.1)}$$

$$Ratio(5) = \frac{A_C}{A_C + A_R}, \qquad \text{(3.2.2)}$$

$$Ratio(6) = Ratio(4) \times Ratio(5) = \frac{\nu F}{A_C + A_R} \approx k_{\mathrm{eff}}, \qquad \text{(3.2.3)}$$

$$Ratio(7) = \frac{\nu F}{A_C + A_R + L} = k_{\mathrm{eff}}, \qquad \text{(3.2.4)}$$

where,

νF: same as defined in Eq.(3.1.1), i.e., fission reaction in the fuel rod multiplied by the number of neutrons emitted per a fission,

A_C: capture reaction in the fuel cell region containing the fuel rod and moderator water, which is total of fission and non-fission capture,

A_R: capture reaction in the top/bottom reflector regions containing the reflector water and the part of the components in the fuel rod surrounded by the reflector water, and

L: neutron leakage from the system, respectively.

As an analogy from the well-known six-factor formula of k_{eff}, Ratio(4) corresponds to k_{inf} in the formula. Hence, Ratio(5) represents characteristics of the factor of no neutron leakage from the fuel cell region. It is considered that Ratio(6), i.e., the product of Ratio(4) and Ratio(5), is nearly equal to k_{eff} because of the presence of the 30 cm thick reflector water surrounding the fuel cell region. Exactly k_{eff} is represented by Ratio(7) in which the neutron leakage outside the reflector water is taken into account. Appendix-5 shows the effect of the neutron leakage from the finite systems.

In the calculations, k_{eff} was determined from the most probable eigenvalue and its σ using the standard estimation method defaulted in the MVP code. This is based on the maximum likelihood method with the combination of the multiple estimators including the track length one, same as the calculations of k_{inf}. The ratios of reactions defined in Eqs.(3.2.1) to (3.2.4) were determined by using the track length estimator only.

3.2.1 Finite lattice systems for search on minimum critical number of fuel rods

Figures 3.2.1.1(1) to 3.2.1.1(3) show k_{eff}, Ratio(4), and Ratio(5) for the hexagonal lattice systems composed of 55 fuel rods varying with VR calculated using the JENDL-5 library, respectively. Similarly, Figs. 3.2.1.2(1) to 3.2.1.2(3), Figs. 3.2.1.3(1) to 3.2.1.3(3) and Figs. 3.2.1.4(1) to 3.2.1.4(3) show the results using the JENDL-5 library for the hexagonal lattice systems composed of 49, 43 and 40 fuel rods, respectively. Any graphs showing results of either Ratio(6) or Ratio(7) are not presented here since they are considered to be nearly equal or identical to k_{eff}. All numerical data are listed in Appendix-2, including the results of both Ratio(6) and Ratio(7). In Appendix-2, calculated results using the JENDL-4.0 and

JENDL-4.0u1 libraries are also listed on condition that the densities of moderator water are 100 and 0 %. The comparisons of the results using the JENDL-5 library with those using the JENDL-4.0 and JENDL-4.0u1 libraries are shown in Appendix-4.

The results from the comparison between the JENDL-5 and the previous versions of the JENDL libraries are briefly mentioned here. As presented in Appendix-4, it is clarified that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries under the condition of 100 % of the density of the moderator water are changed along a convex downward curve as VR increases[*3]. but the differences between the JENDL-4.0 and JENDL-4.0u1 libraries are smaller than three times their σ's. It is also confirmed that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries are caused by those in Ratio(5) in the range of the smaller VR than about 2.0, but the differences are due to the Ratio(4) in the range of the larger VR than about 2.0. For the condition of 0 % of the density, it is clarified that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries increase slightly as VR increases, and the differences are larger than those for 100 % of the density[*4]. It is also confirmed that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries are largely affected by the differences in Ratio(5), which is quite larger than those in Ratio(4).

*3 The averaged difference in k_{eff} between the JENDL-5 and JENDL-4.0 libraries is about 0.5 to 0.6 %, which tends to increase slightly as the number of fuel rods.

*4 The averaged difference in k_{eff} between the JENDL-5 and JENDL-4.0 libraries is about 0.8 %.

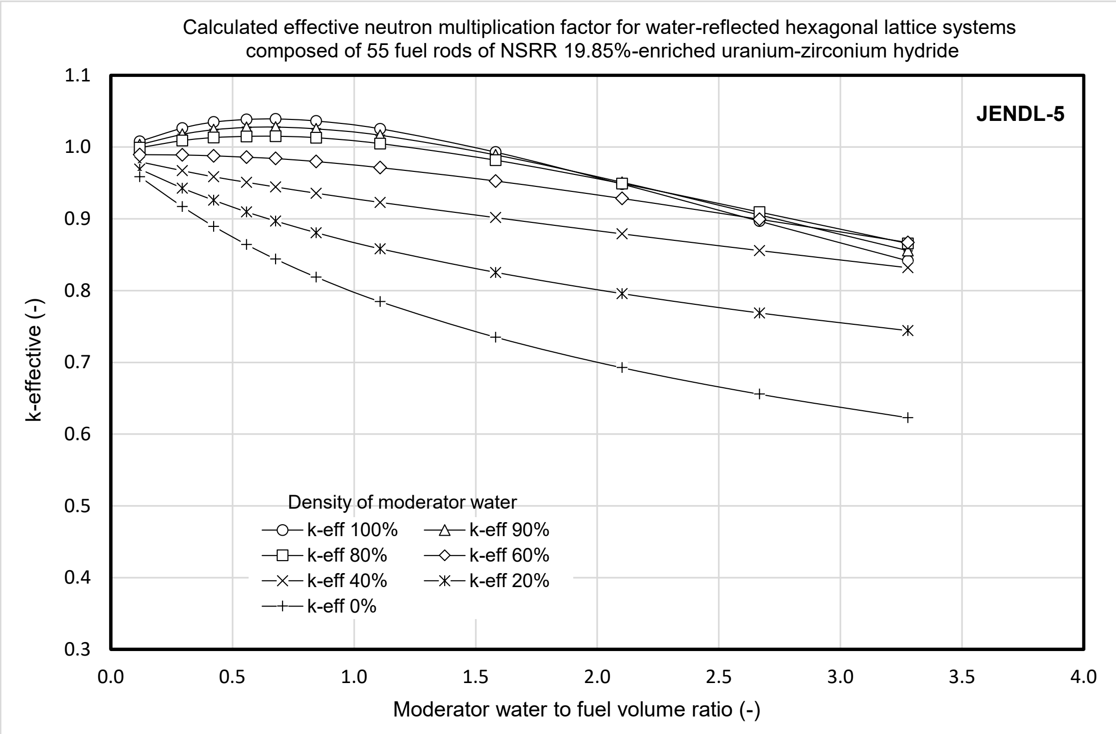


Fig.3.2.1.1(1) Effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 55 fuel rods as function of VR, using JENDL-5.

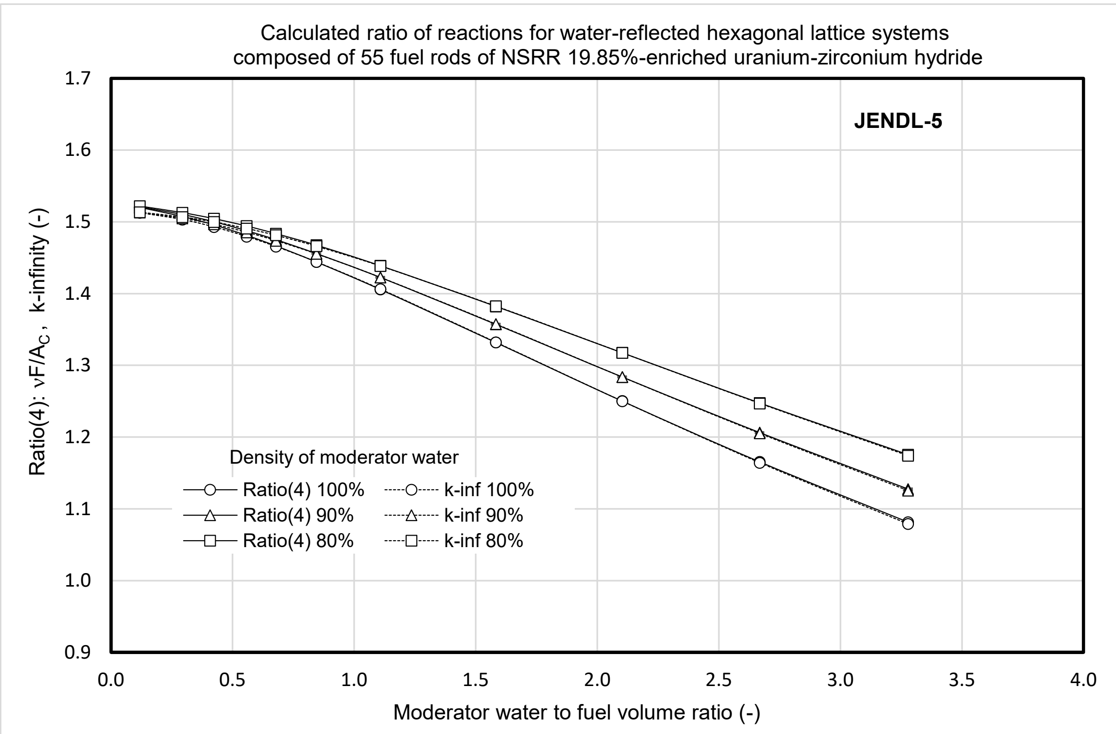


Fig.3.2.1.1(2) Ratio(4) for water-reflected hexagonal lattice systems composed of 55 fuel rods as function of VR, using JENDL-5.

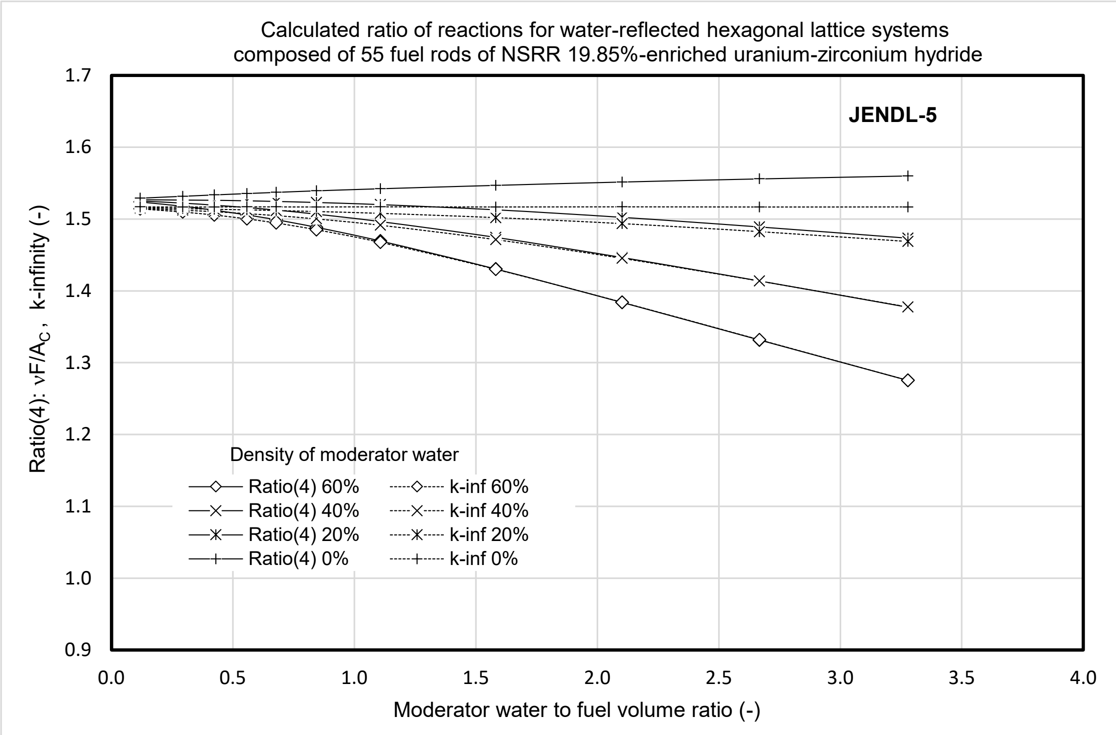


Fig.3.2.1.1(2)(contd.) Ratio(4) for water-reflected hexagonal lattice systems composed of 55 fuel rods as function of VR, using JENDL-5.

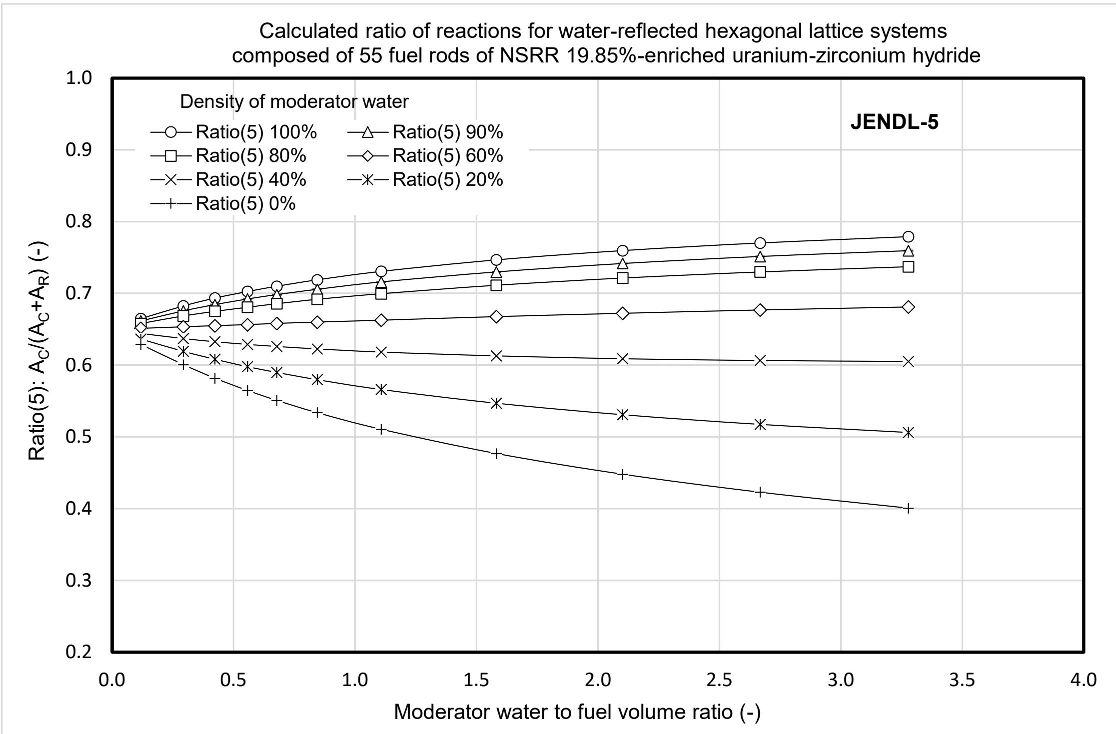


Fig.3.2.1.1(3) Ratio(5) for water-reflected hexagonal lattice systems composed of 55 fuel rods as function of VR, using JENDL-5.

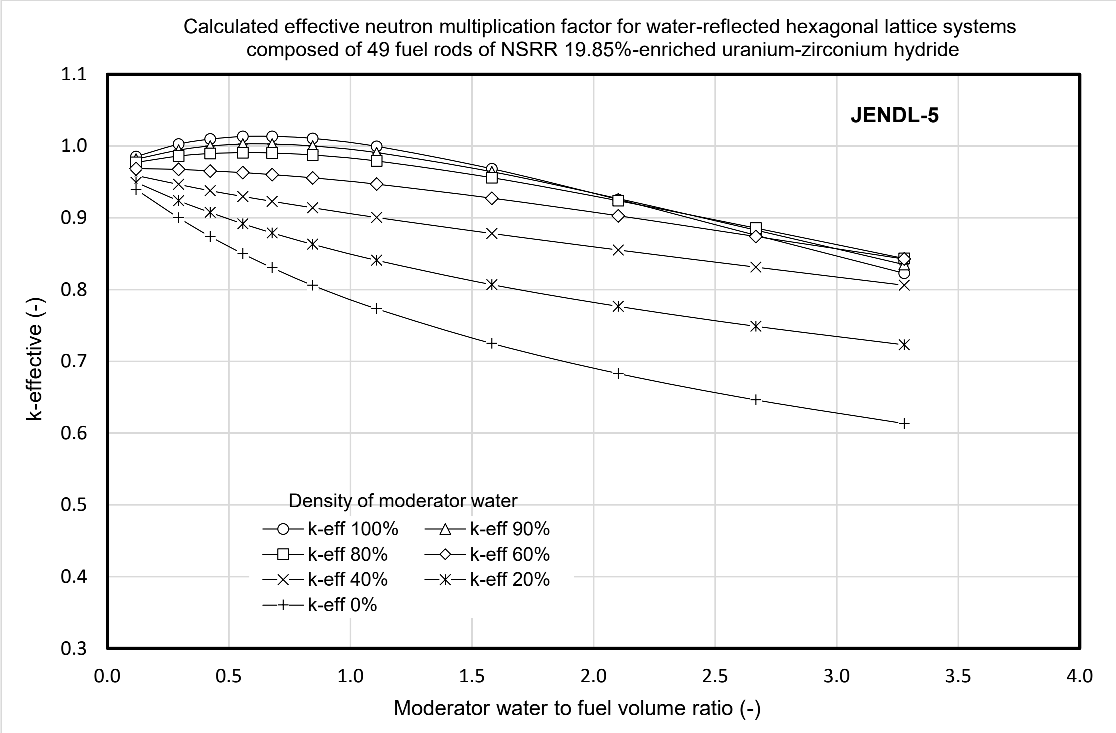


Fig.3.2.1.2(1) Effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 49 fuel rods as function of VR, using JENDL-5.

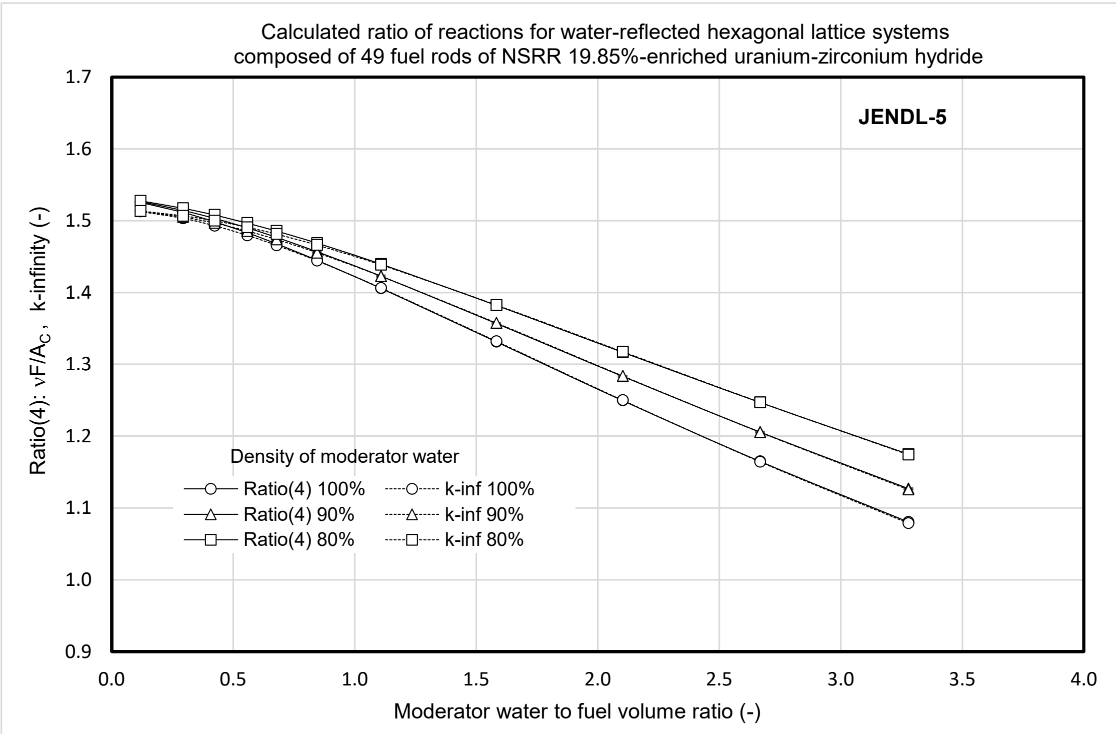


Fig.3.2.1.2(2) Ratio(4) for water-reflected hexagonal lattice systems composed of 49 fuel rods as function of VR, using JENDL-5.

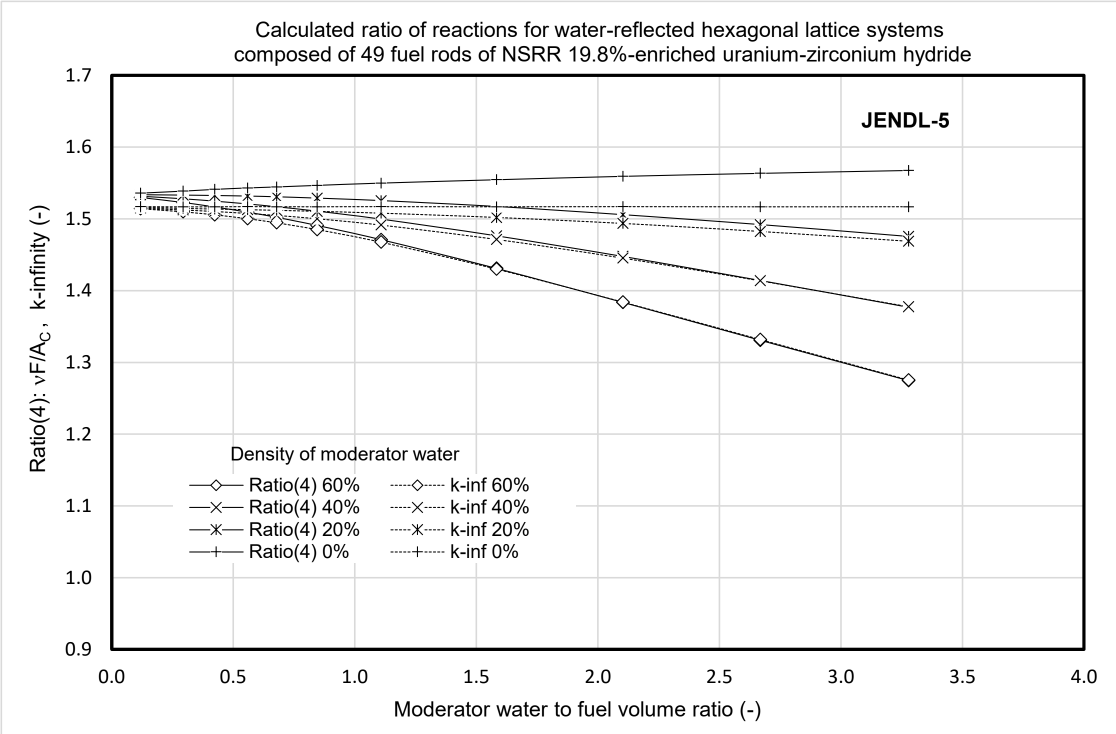


Fig.3.2.1.2(2)(contd.) Ratio(4) for water-reflected hexagonal lattice systems composed of 49 fuel rods as function of VR, using JENDL-5.

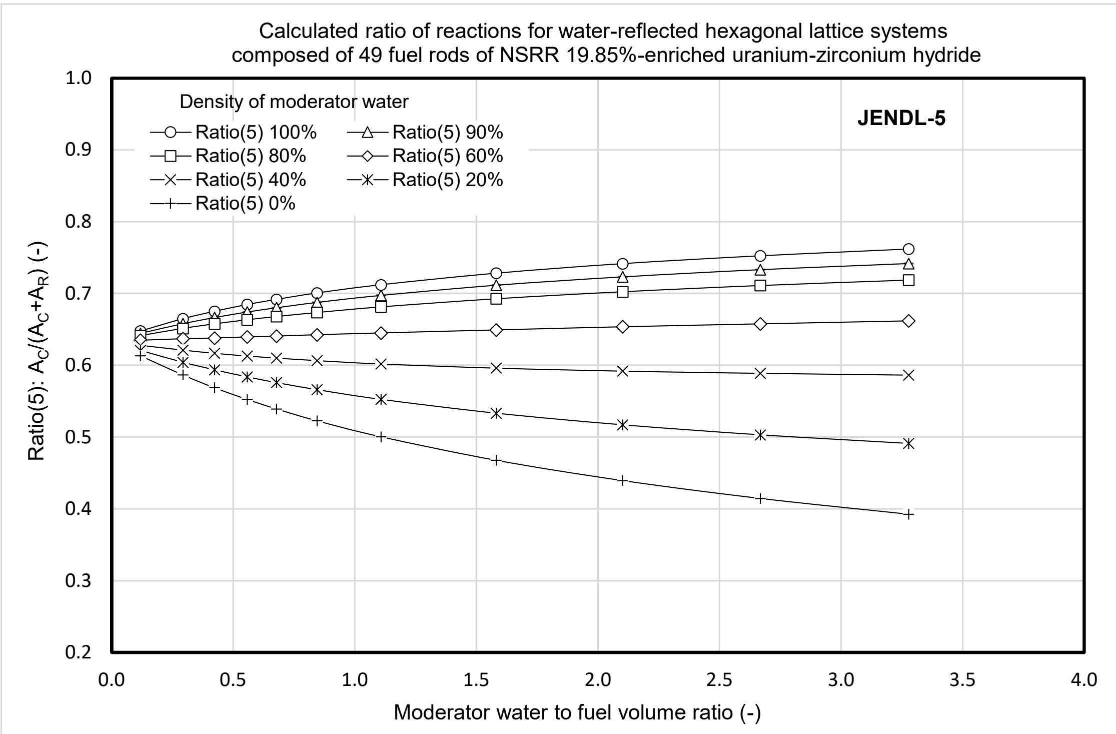


Fig.3.2.1.2(3) Ratio(5) for water-reflected hexagonal lattice systems composed of 49 fuel rods as function of VR, using JENDL-5.

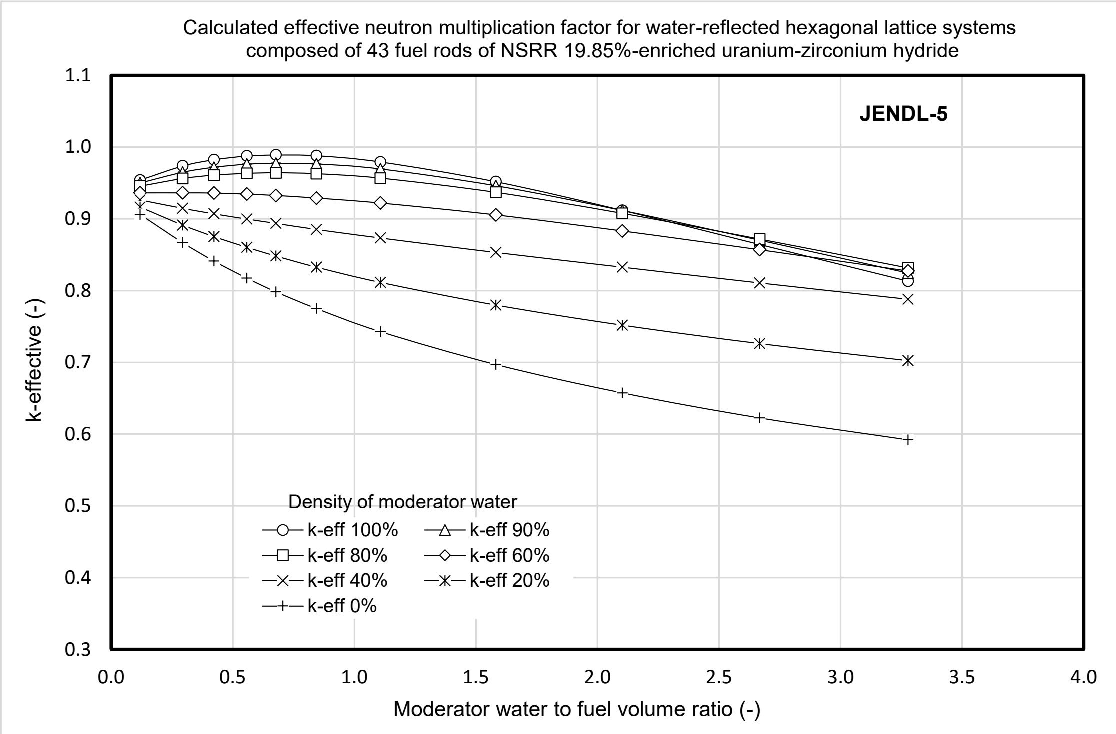


Fig.3.2.1.3(1) Effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 43 fuel rods as function of VR, using JENDL-5.

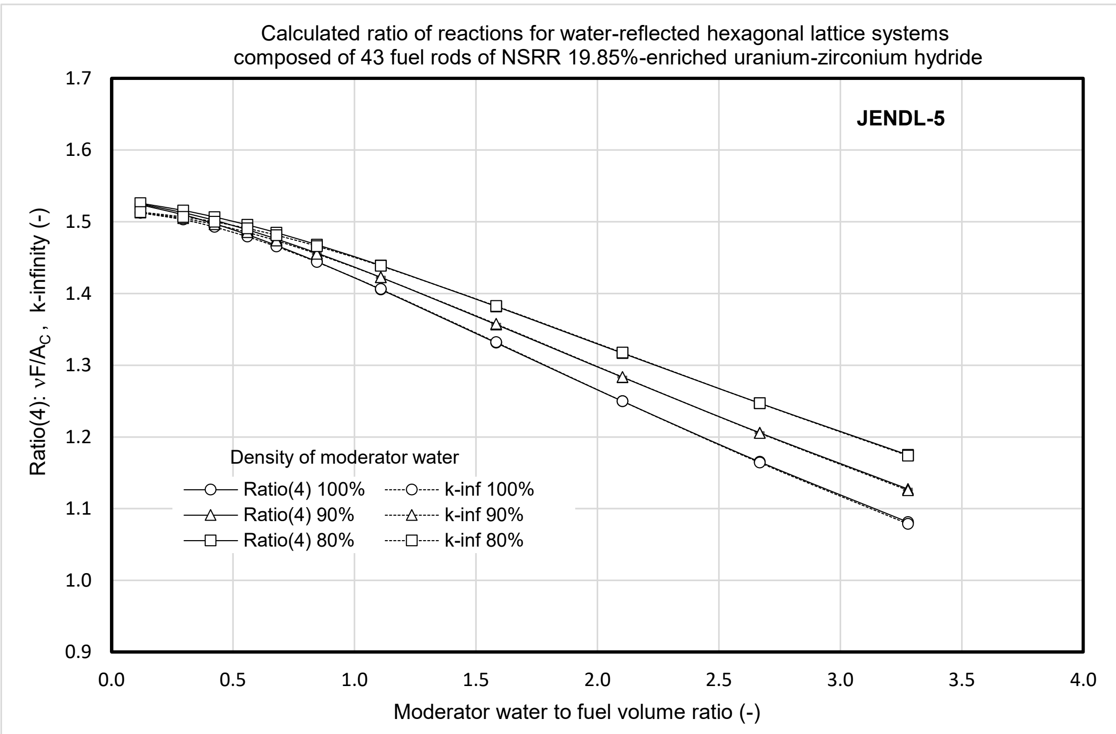


Fig.3.2.1.3(2) Ratio(4) for water-reflected hexagonal lattice systems composed of 43 fuel rods as function of VR, using JENDL-5.

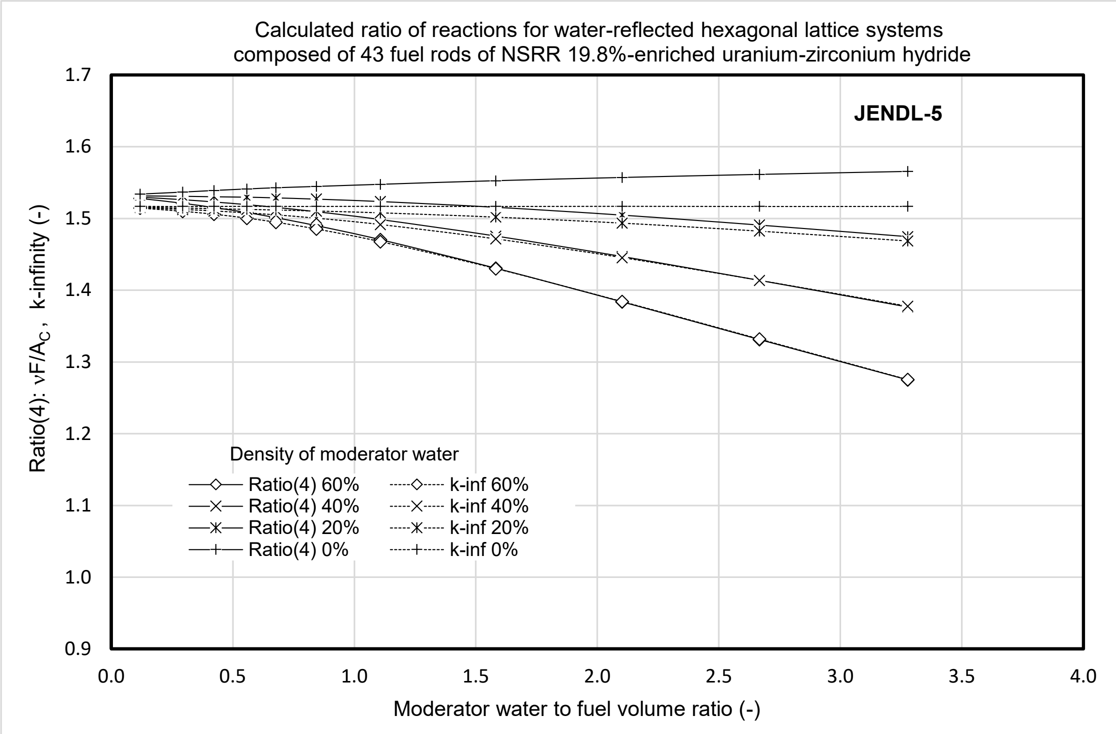


Fig.3.2.1.3(2)(contd.) Ratio(4) for water-reflected hexagonal lattice systems composed of 43 fuel rods as function of VR, using JENDL-5.

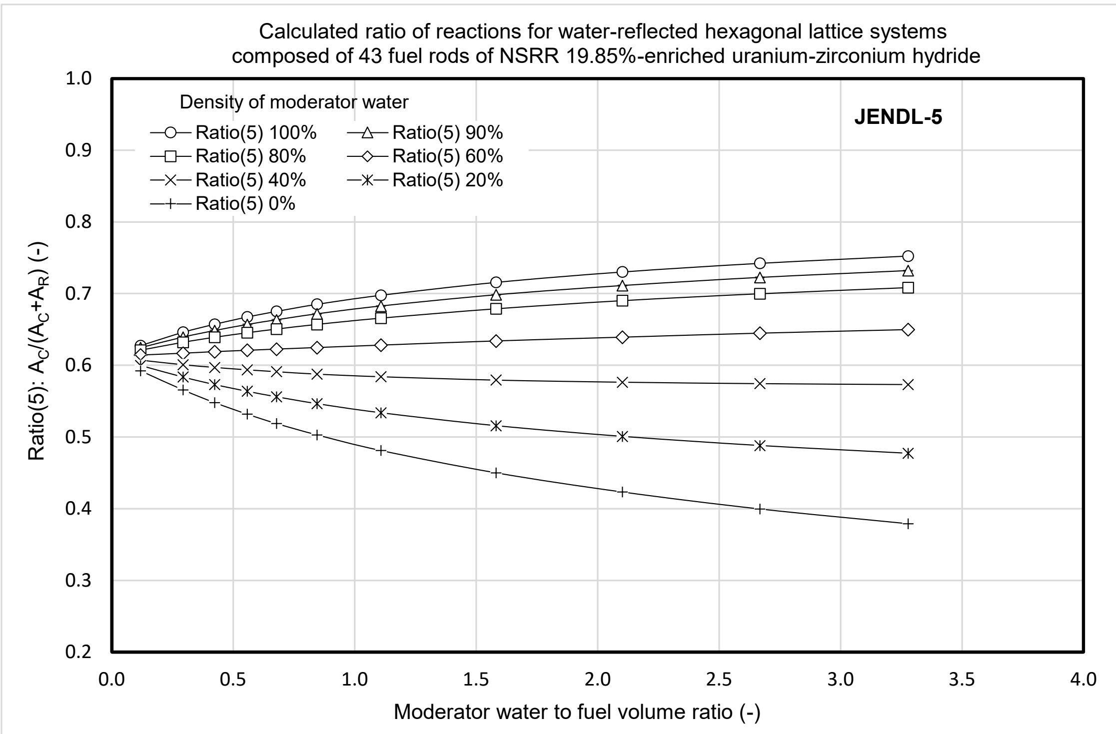


Fig.3.2.1.3(3) Ratio(5) for water-reflected hexagonal lattice systems composed of 43 fuel rods as function of VR, using JENDL-5.

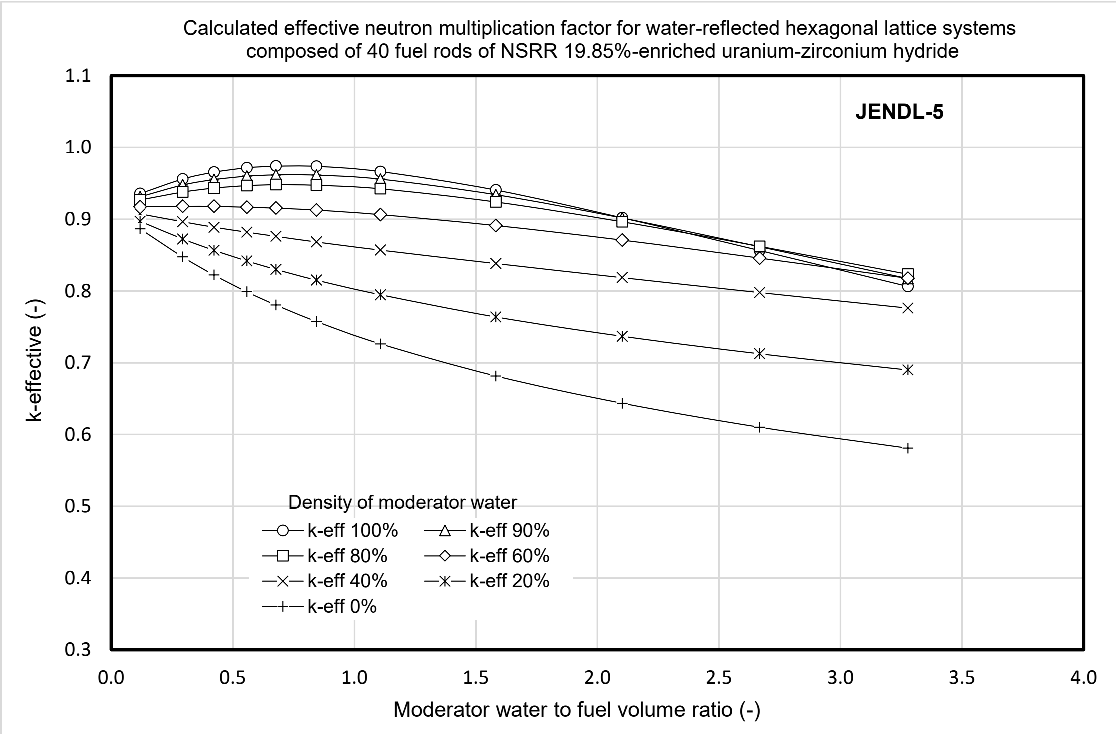


Fig.3.2.1.4(1) Effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 40 fuel rods as function of VR, using JENDL-5.

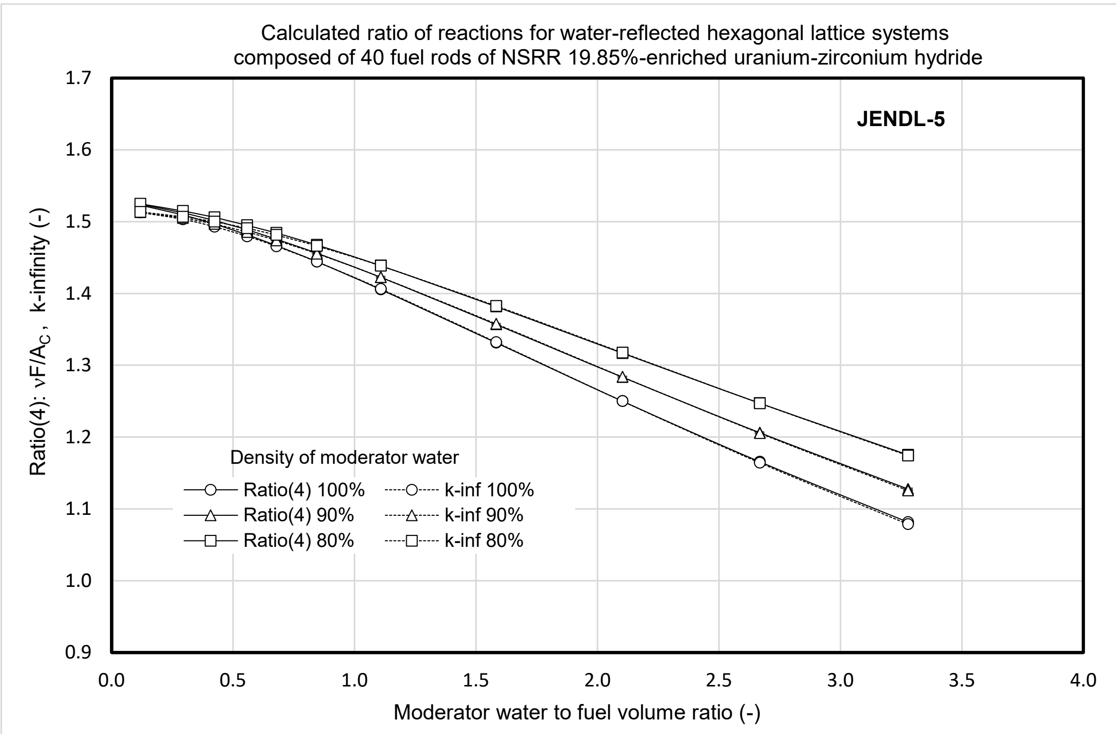


Fig.3.2.1.4(2) Ratio(4) for water-reflected hexagonal lattice systems composed of 40 fuel rods as function of VR, using JENDL-5.

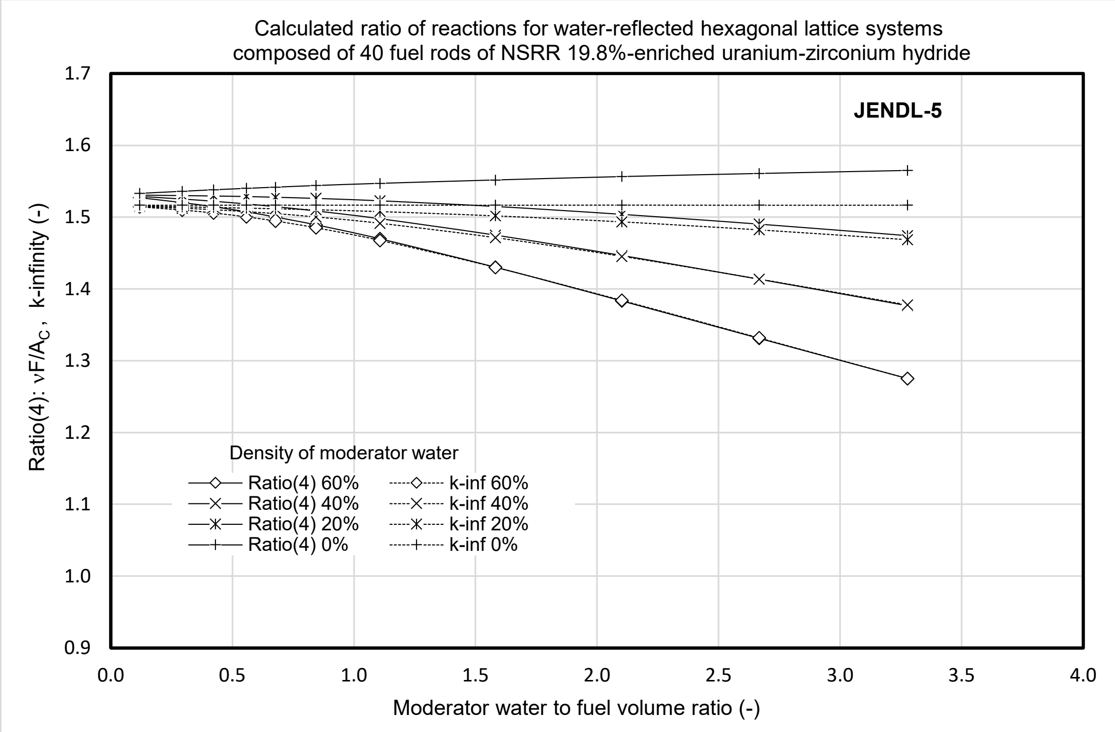


Fig.3.2.1.4(2)(contd.) Ratio(4) for water-reflected hexagonal lattice systems composed of 40 fuel rods as function of VR, using JENDL-5.

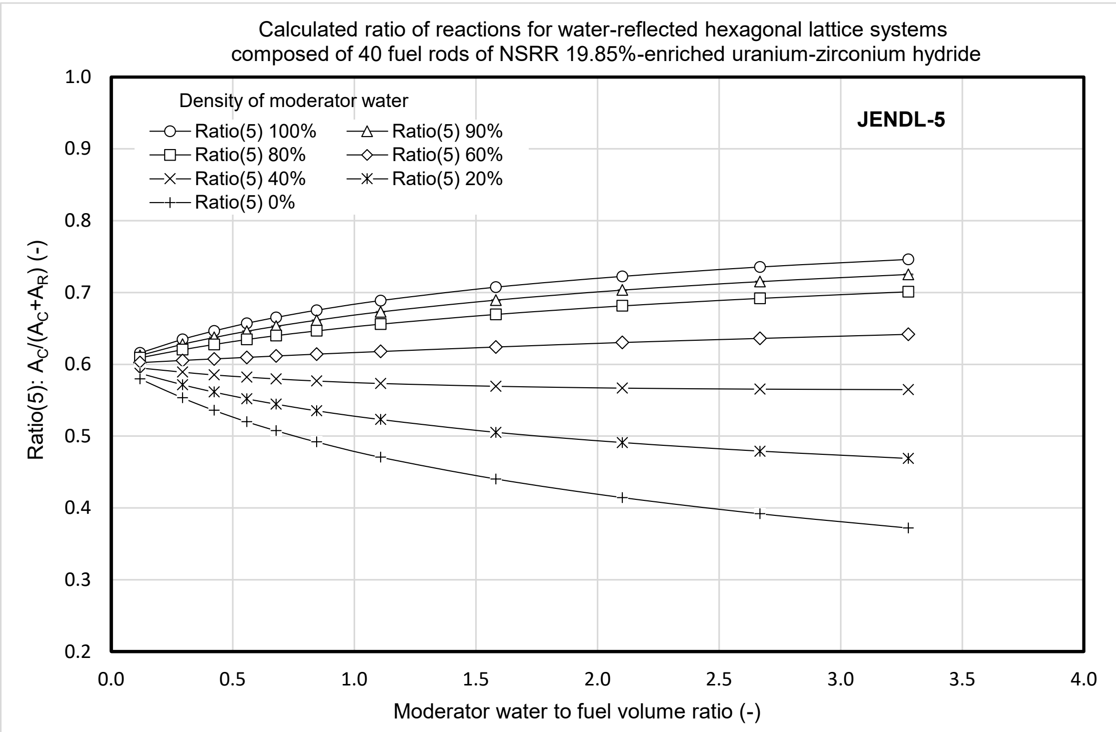


Fig.3.2.1.4(3) Ratio(5) for water-reflected hexagonal lattice systems composed of 40 fuel rods as function of VR, using JENDL-5.

It is confirmed from Figs. 3.2.1.1(1), 3.2.1.2(1), 3.2.1.3(1) and 3.2.1.4(1) that k_{eff} becomes larger as the number of fuel rods and is changed along a convex upward curve as VR increases under the condition of 100, 90 and 80 % of the density of the moderator water, but k_{eff} decreases monotonically as VR increases under the condition of the smaller density than 60 %. It is also found in the range of VR smaller than 1.6 that k_{eff} increases monotonically as the density of the moderator water, but k_{eff} is not changed monotonically as the density in the range of VR larger than 1.6. This is more clearly found in Figs. 3.2.1.5 to 3.2.1.8 showing k_{eff} varying as function of the density of the moderator water. This implies that the moderator water functions mainly as neutron absorber rather than moderator in the case of the larger VR, thus the value of k_{eff} becomes the maximum at a certain intermediate density by the partial moderation. It is seen that the intermediate density resulting in the peak of k_{eff} is 60 to 80 % of the density of the moderator water in the case of 3.28 of VR and the peak becomes unclear as VR decreases.

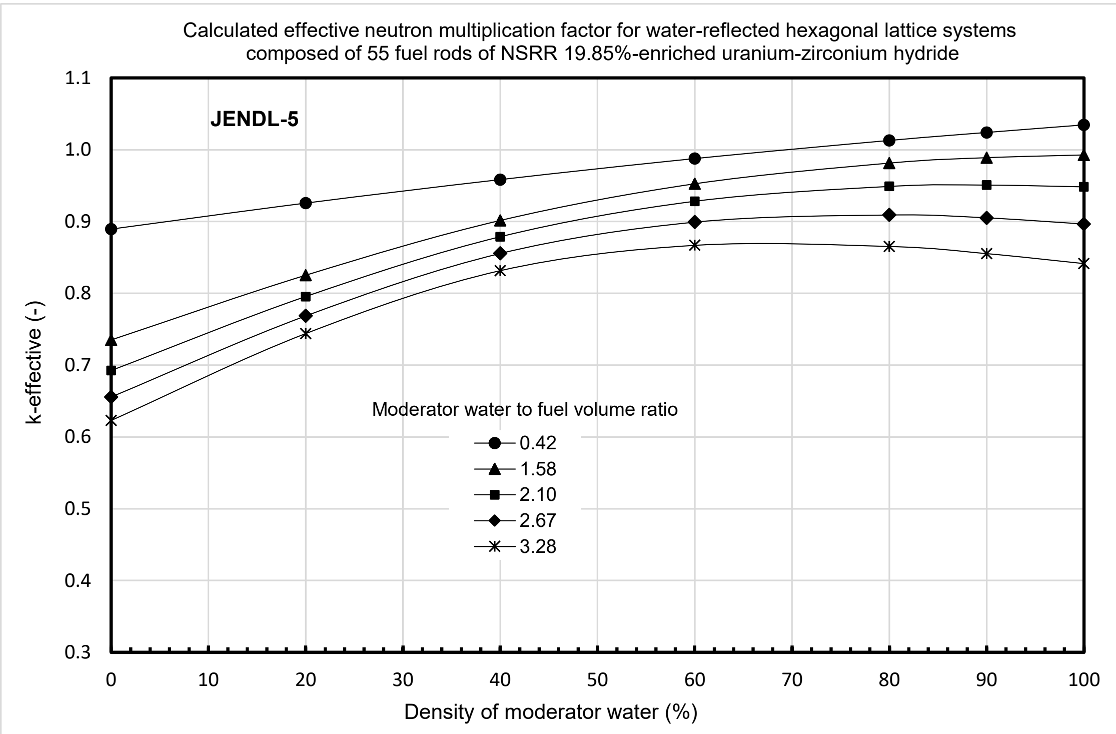


Fig.3.2.1.5 Effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 55 fuel rods as function of density of moderator water, using JENDL-5.

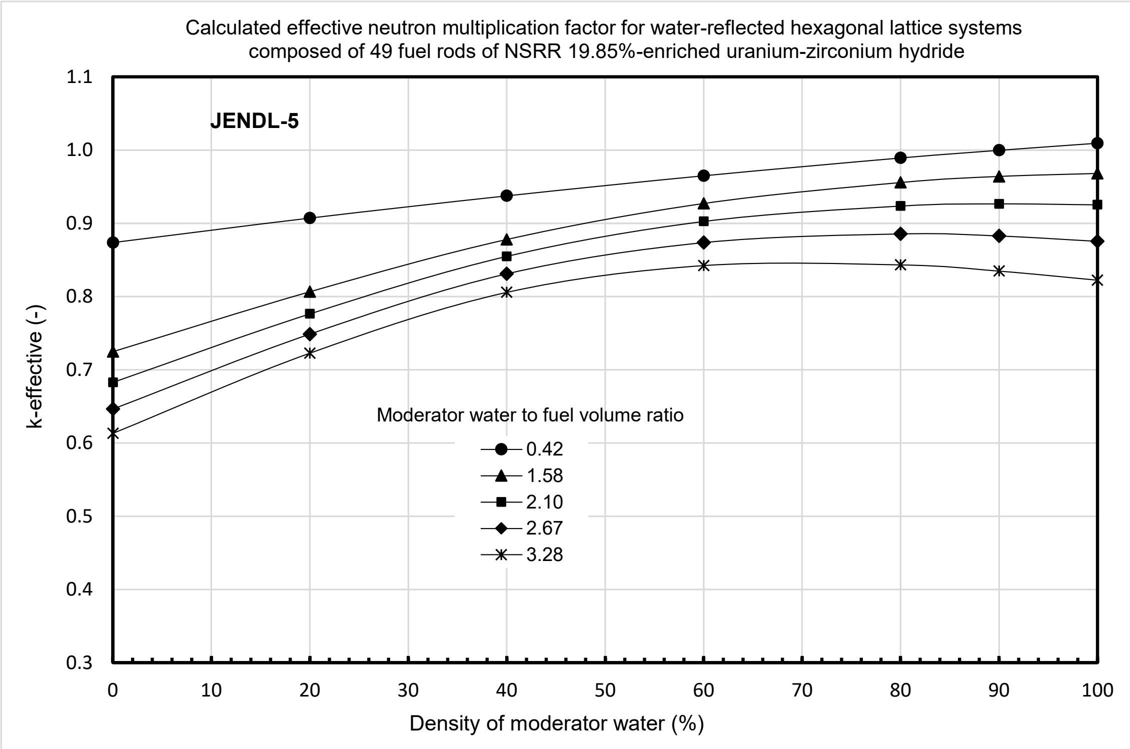


Fig.3.2.1.6 Effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 49 fuel rods as function of density of moderator water, using JENDL-5.

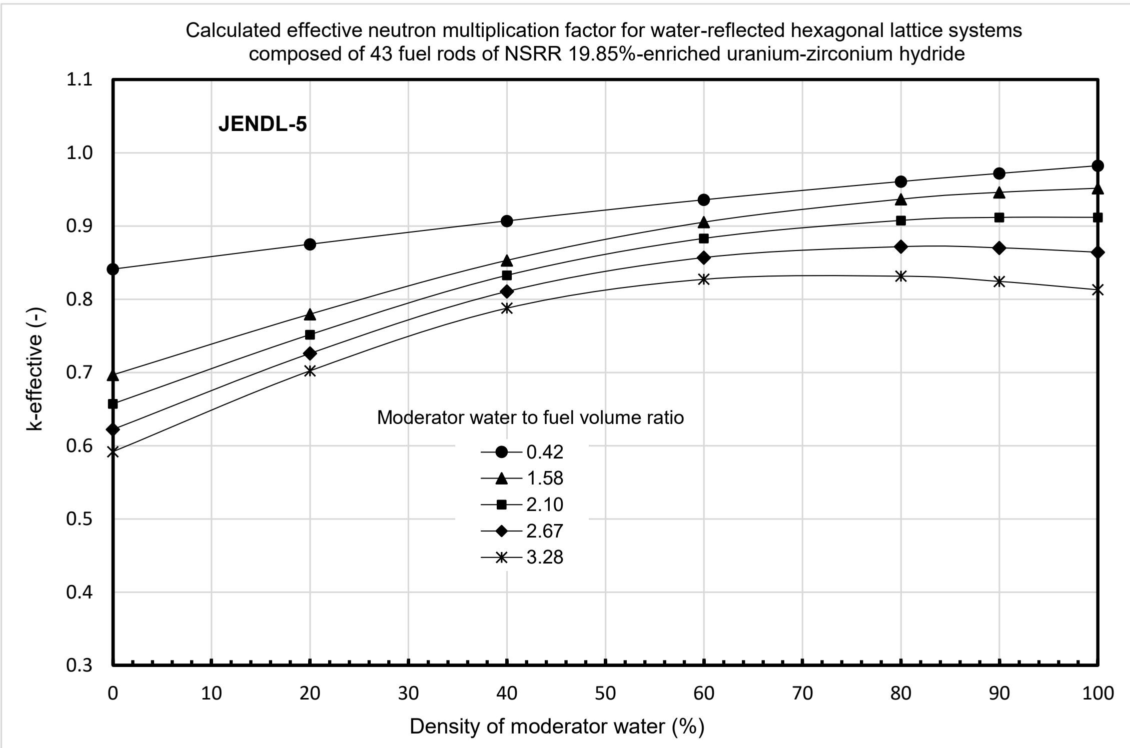


Fig.3.2.1.7 Effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 43 fuel rods as function of density of moderator water, using JENDL-5.

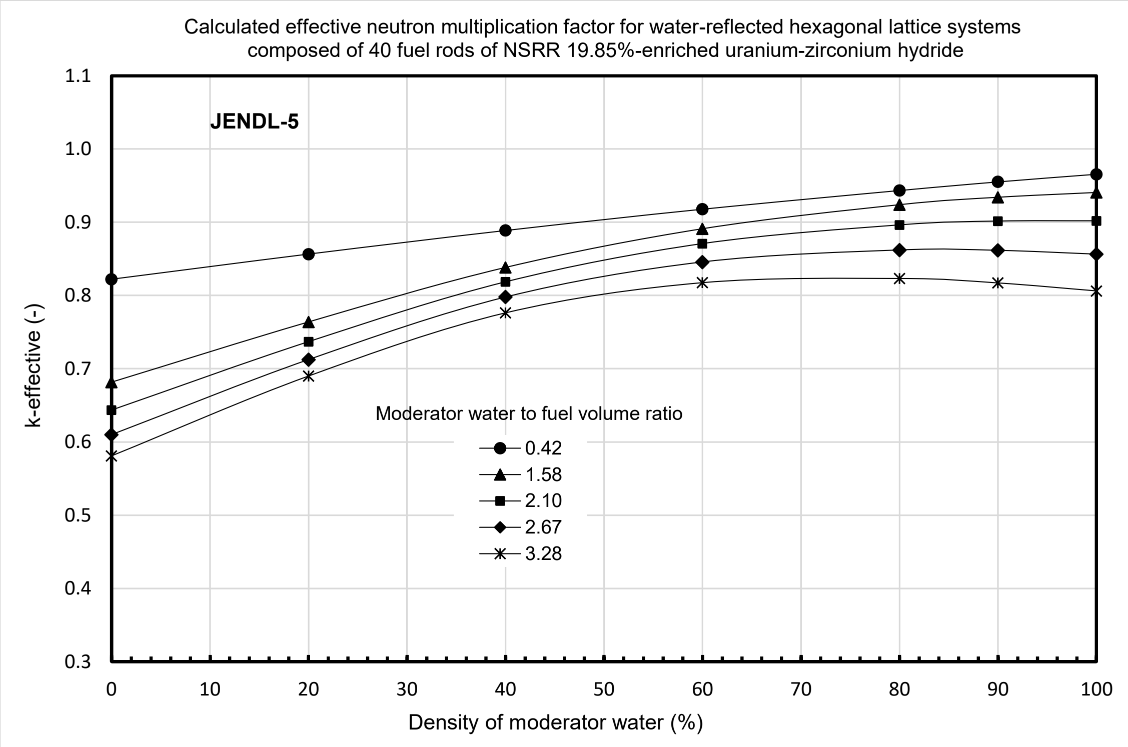


Fig.3.2.1.8 Effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 40 fuel rods as function of density of moderator water, using JENDL-5.

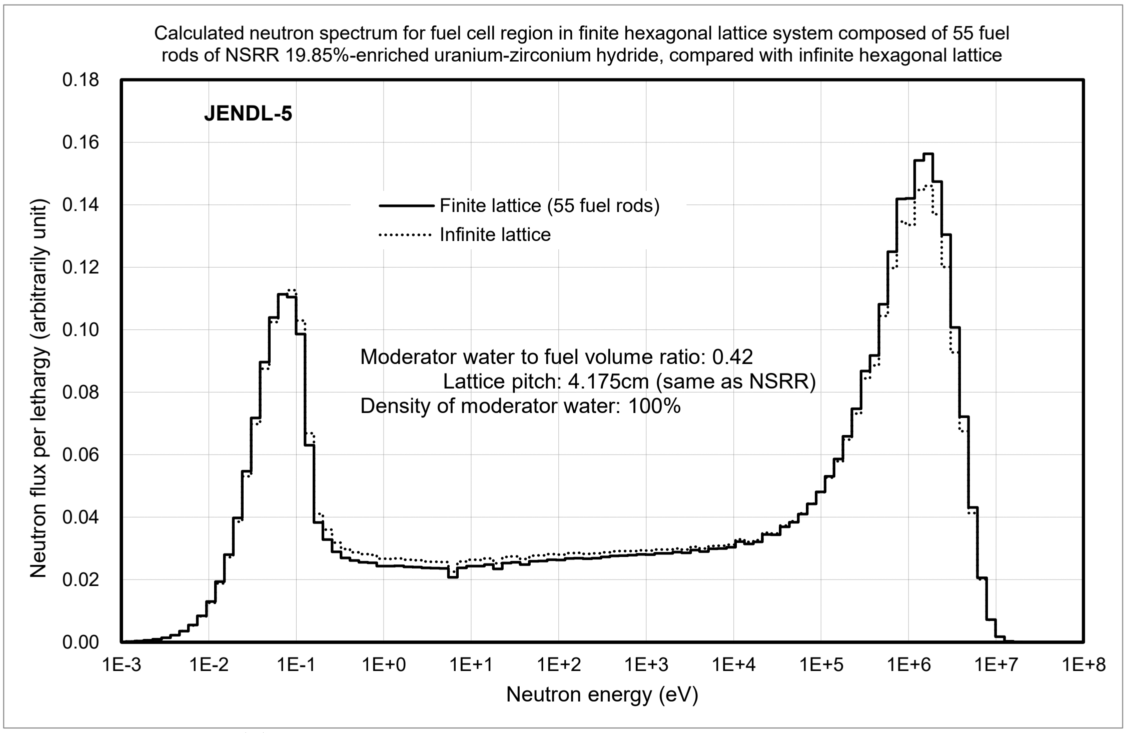
As seen in Figs. 3.2.1.1(2), 3.2.1.2(2), 3.2.1.3(2) and 3.2.1.4(2), it is confirmed that Ratio(4) decreases as VR increases and well agrees with k_{inf} under the condition of the larger moderator density than 40 %. For the smaller moderator density, it is also confirmed that Ratio(4) is larger than k_{inf} and the differences between Ratio(4) and k_{inf} tend to be expanded as the density decreases. It is considered that the differences are caused by the effect of incurrent thermal neutrons from the reflector region in the finite system.

Figures 3.2.1.9 to 3.2.1.12 show neutron spectra for the fuel cell region of both the hexagonal finite and infinite systems. It is confirmed from Figs. 3.2.1.9 to 3.2.1.12 that there are not large differences in the thermal neutron spectra between the finite and infinite systems in the case of 100 % of the density whilst the thermal neutron energy at the peak of its flux of the finite systems in the case of 0 % of the density is smaller than that of the infinite systems due to the incurrent thermal neutrons from the reflector region. For this reason, it is considered that Ratio(4) becomes larger than k_{inf} for the smaller density of the moderator water.

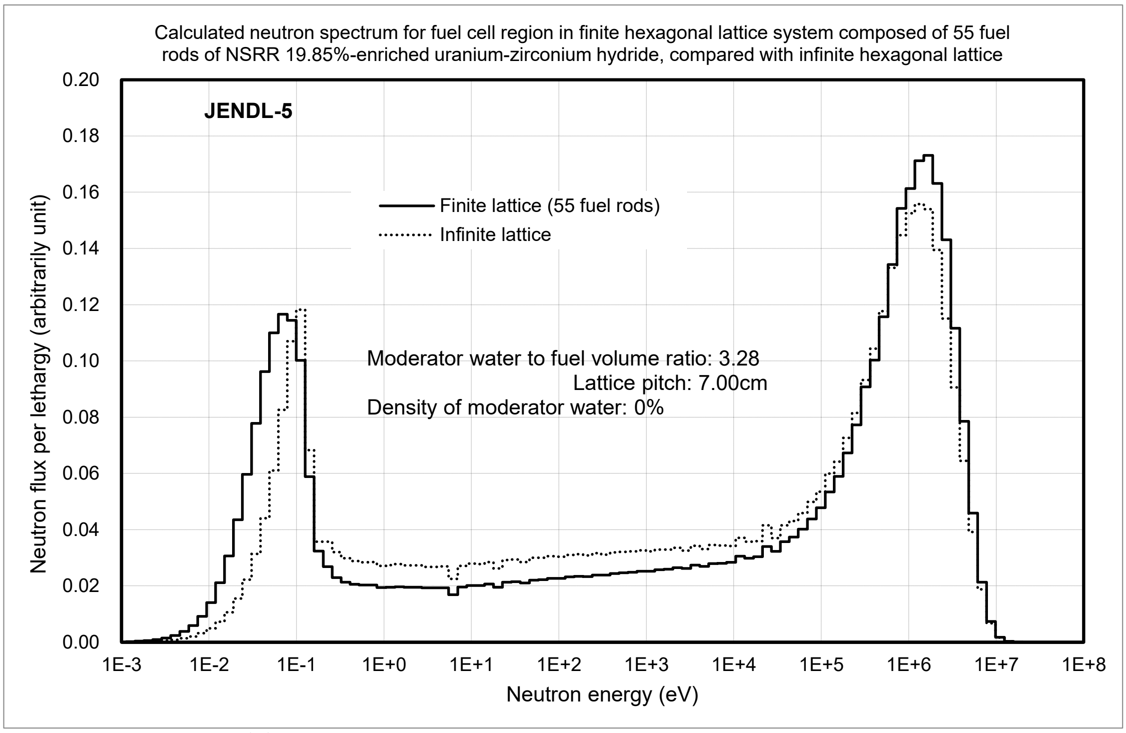
As seen in Figs.3.2.1.1(3), 3.2.1.2(3), 3.2.1.3(3) and 3.2.1.4(3), it is confirmed that Ratio(5) increases monotonically as VR increases under the larger density than 60 %, whilst it decreases monotonically under the condition of the smaller density than 60 %. In general, it is considered that the horizontal geometrical buckling decreases as VR increases since the volume of the fuel cell region is enlarged. For this reason, it is considered that the increase of VR brings larger Ratio(5) due to decrease of the neutron leakage along the horizontal direction from the fuel cell region in the case of the larger density of the moderator water which functions sufficiently as neutron absorber and moderator. Hence, it is considered for the larger density of the moderator water that the variation of Ratio(5) can be explained by the horizontal buckling varying with VR.

On the other hand, it is considered in the case of the smaller density of the moderator water that the amount of the neutron leakage along the vertical direction from the place of the moderator water between the fuel rods increases as VR. This may result in increase of the neutron absorption in the top/bottom reflector regions and monotonical decrease of Ratio(5) as VR. It is considered that the effect of the vertical neutron leakage is dominant in the variations of Ratio(5) with VR for the smaller density of the moderator water.

From the definition in Eq.(3.2.3), k_{eff} is determined mainly by the product of Ratio(4) and Ratio(5). Also, it is understood as mentioned above that Ratio(4) monotonically decreases as VR increases and the variations of Ratio(5) with VR are different in the larger and smaller density of the moderator water. For this reason, it is considered that k_{eff} is changed along a convex upward curve as VR increases for the larger density of the moderator water whilst k_{eff} decreases monotonically as VR increases for the smaller density of that.

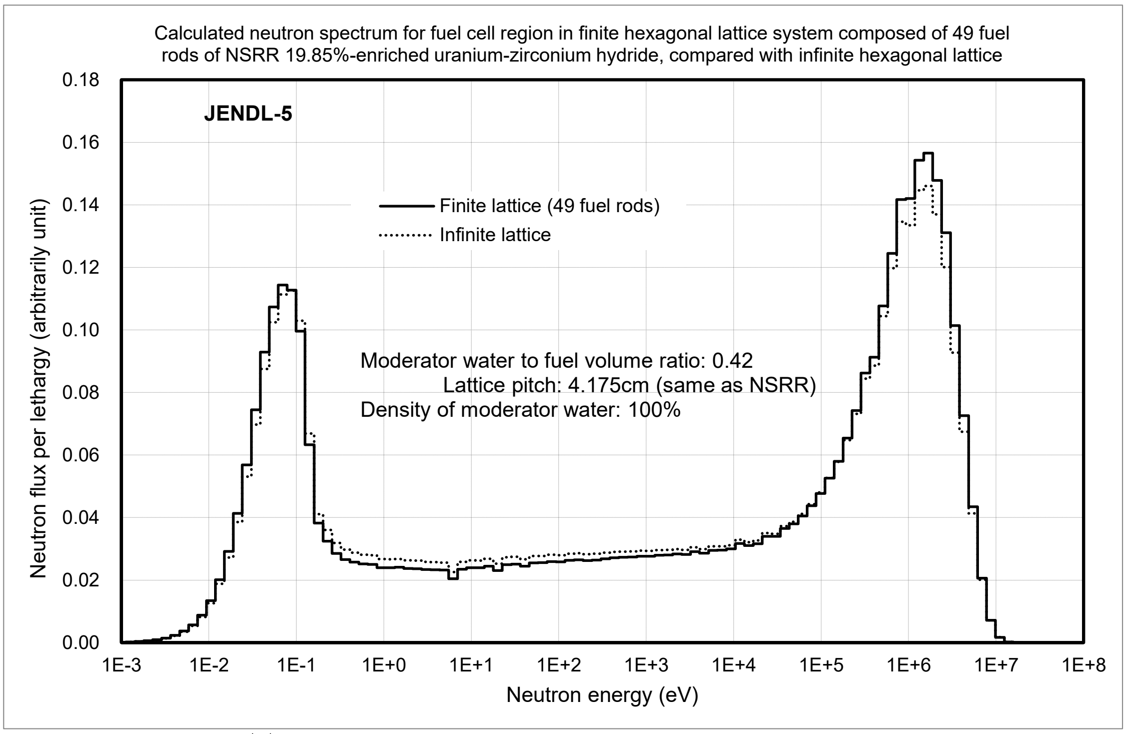


(a) Density of moderator water: 100 %, VR=0.42.

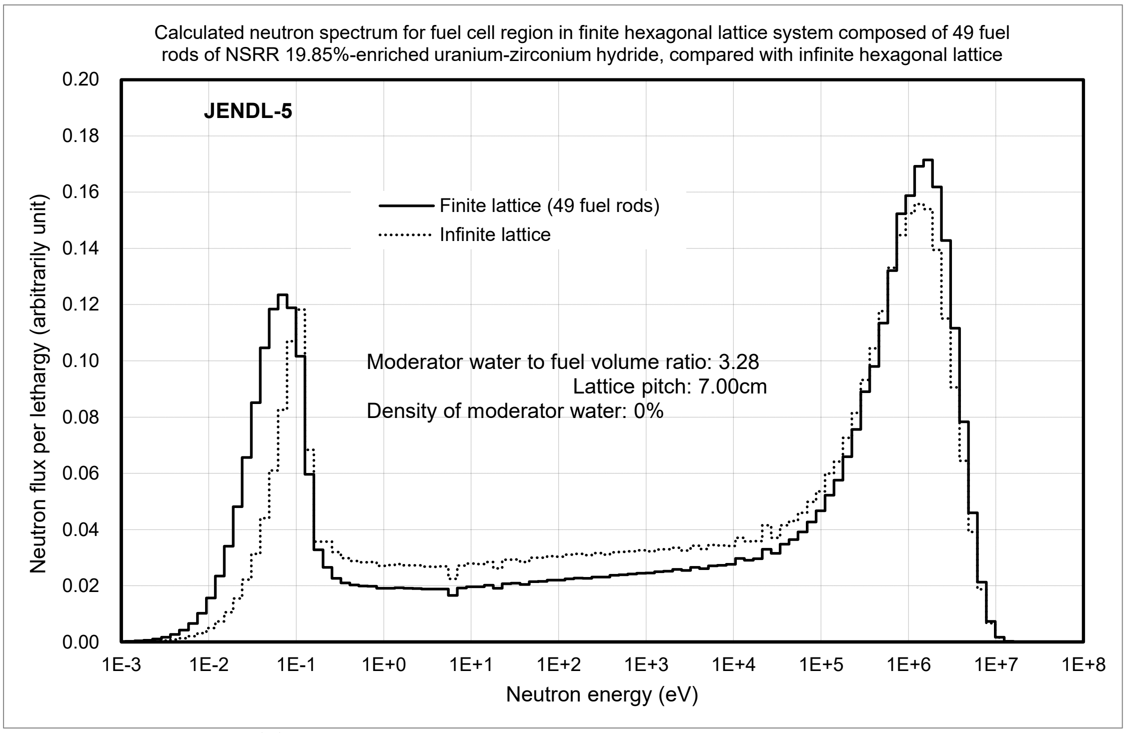


(b) Density of moderator water: 0 %, VR=3.28.

Fig.3.2.1.9 Comparison of neutron spectra for fuel cell region between water-reflected finite hexagonal lattice system composed of 55 fuel rods and infinite hexagonal lattice system, using JENDL-5.

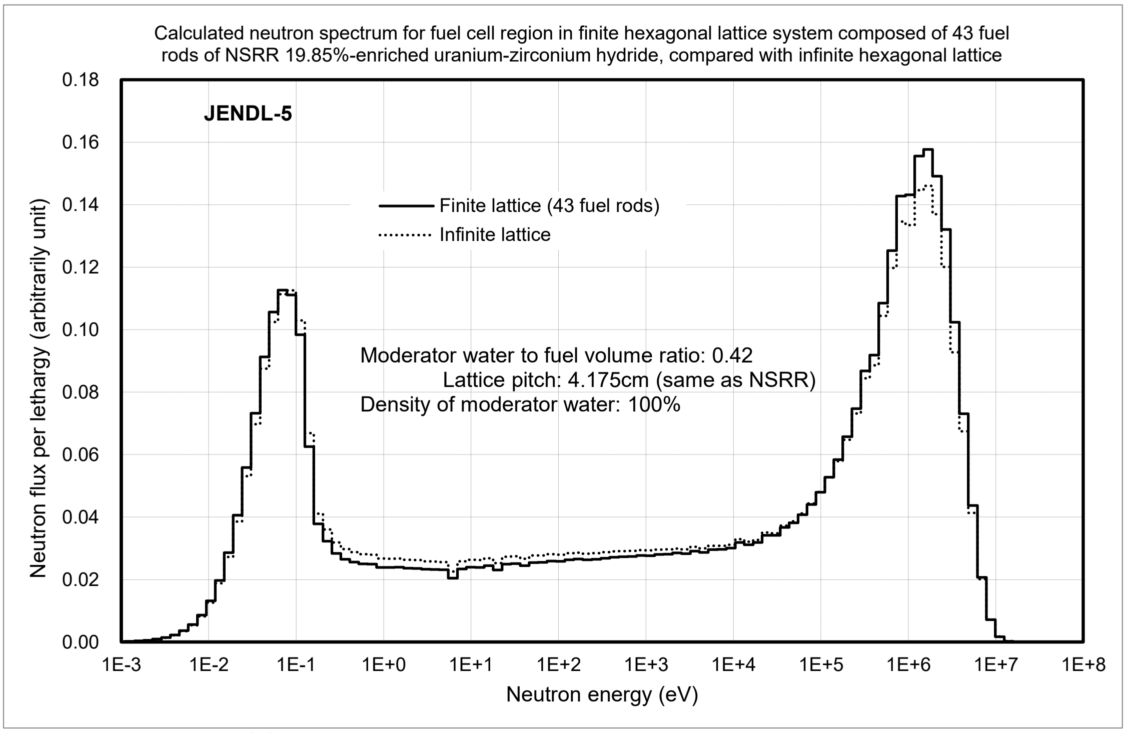


(a) Density of moderator water: 100 %, VR=0.42.

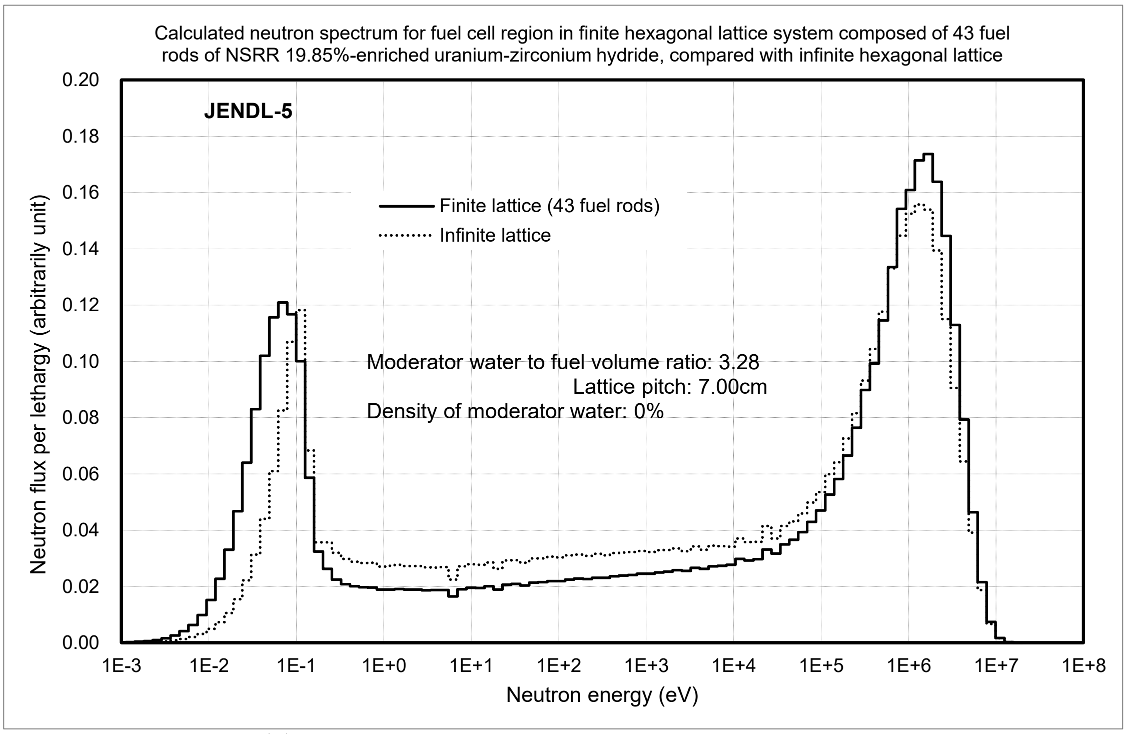


(b) Density of moderator water: 0 %, VR=3.28.

Fig.3.2.1.10 Comparison of neutron spectra for fuel cell region between water-reflected finite hexagonal lattice system composed of 49 fuel rods and infinite hexagonal lattice system, using JENDL-5.

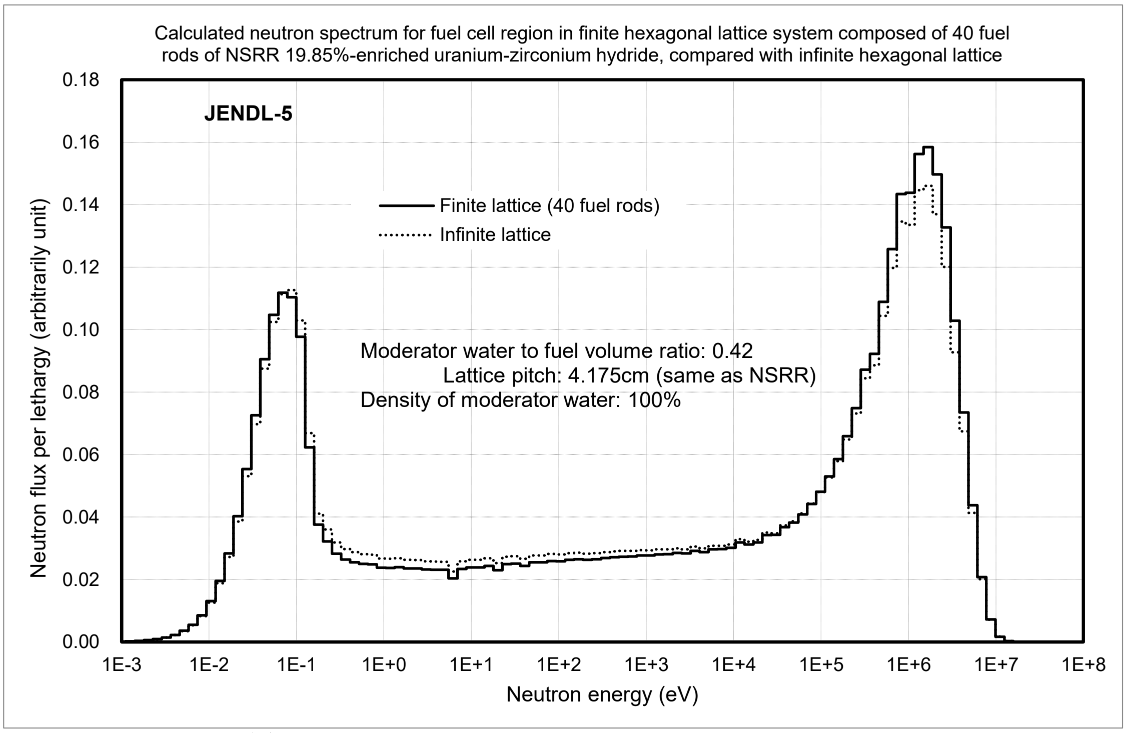


(a) Density of moderator water: 100 %, VR=0.42.

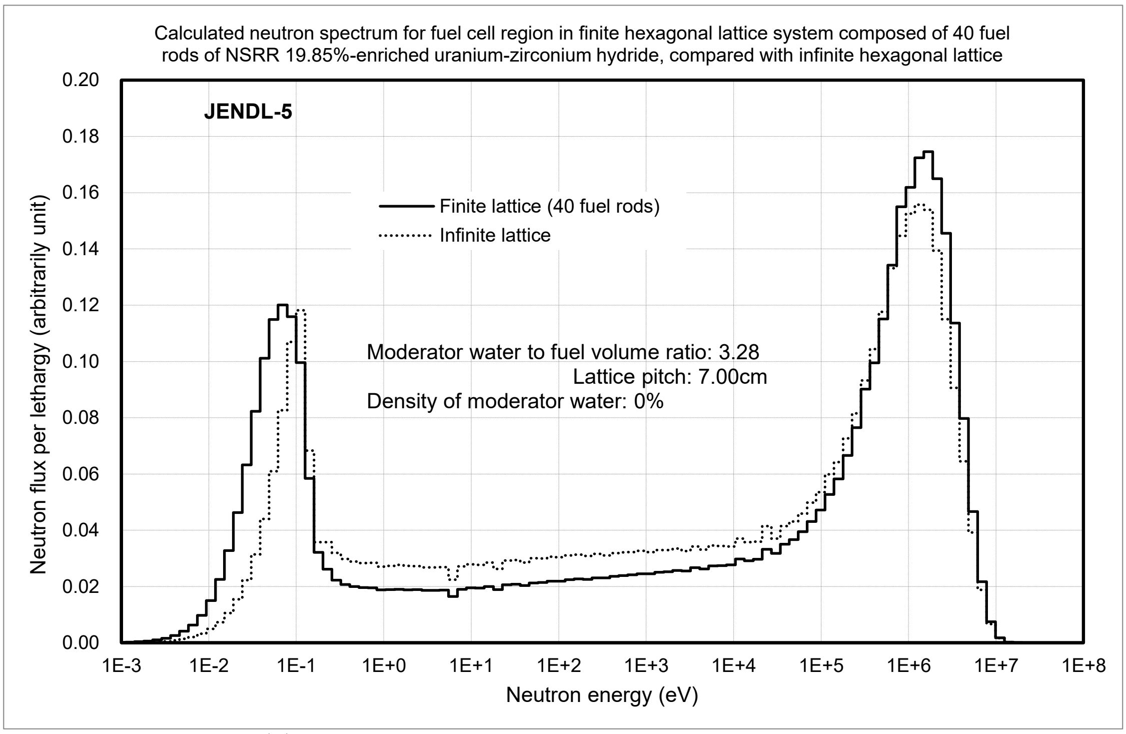


(b) Density of moderator water: 0 %, VR=3.28.

Fig.3.2.1.11 Comparison of neutron spectra for fuel cell region between water-reflected finite hexagonal lattice system composed of 43 fuel rods and infinite hexagonal lattice system, using JENDL-5.



(a) Density of moderator water: 100 %, VR=0.42.



(b) Density of moderator water: 0 %, VR=3.28.

Fig.3.2.1.12 Comparison of neutron spectra for fuel cell region between water-reflected finite hexagonal lattice system composed of 40 fuel rods and infinite hexagonal lattice system, using JENDL-5.

For the finite square lattice systems, k_{eff}, Ratio(4), and Ratio(5) using the JENDL-5 library for the lattices composed of 57, 49, 44 and 40 fuel rods are also shown in Figs.3.2.1.13(1) to 3.2.1.13(3), Figs.3.2.1.14(1) to 3.2.1.14(3), Figs.3.2.1.15(1) to 3.2.1.15(3) and Figs.3.2.1.16(1) to 3.2.1.16(3), respectively. It is confirmed that the characteristics of k_{eff}, Ratio(4), and Ratio(5) are same as those for the finite hexagonal lattice systems as mentioned above.

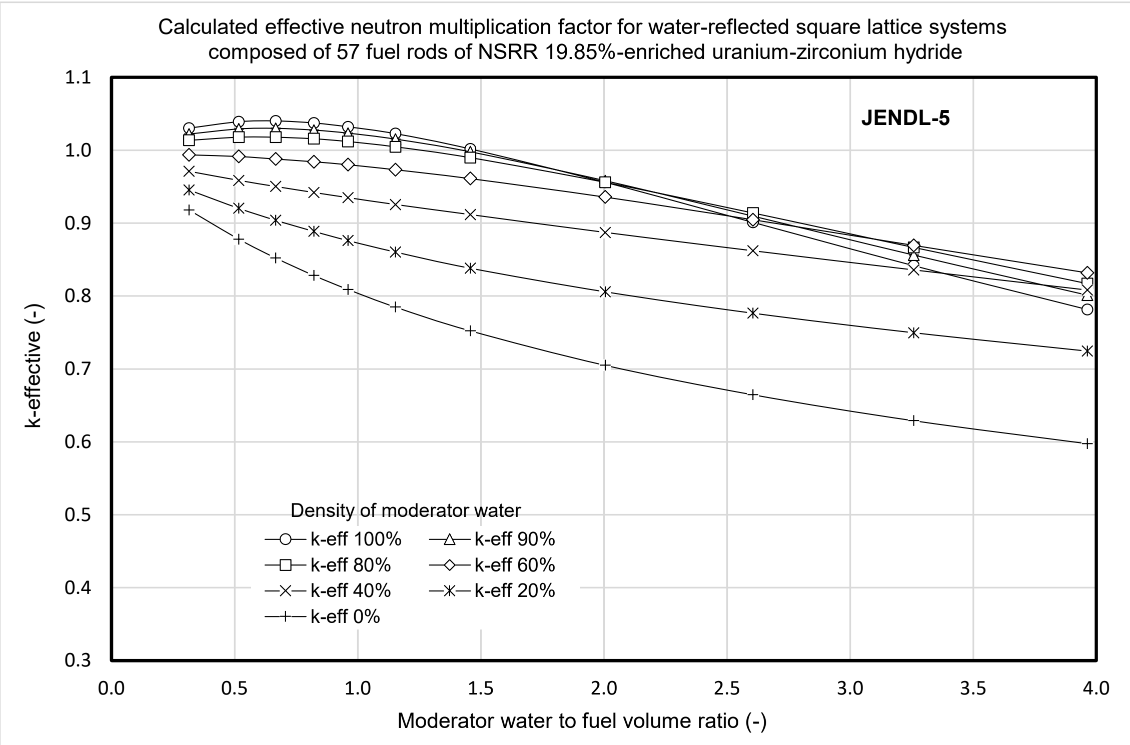


Fig.3.2.1.13(1) Effective neutron multiplication factor for water-reflected square lattice systems composed of 57 fuel rods as function of VR, using JENDL-5.

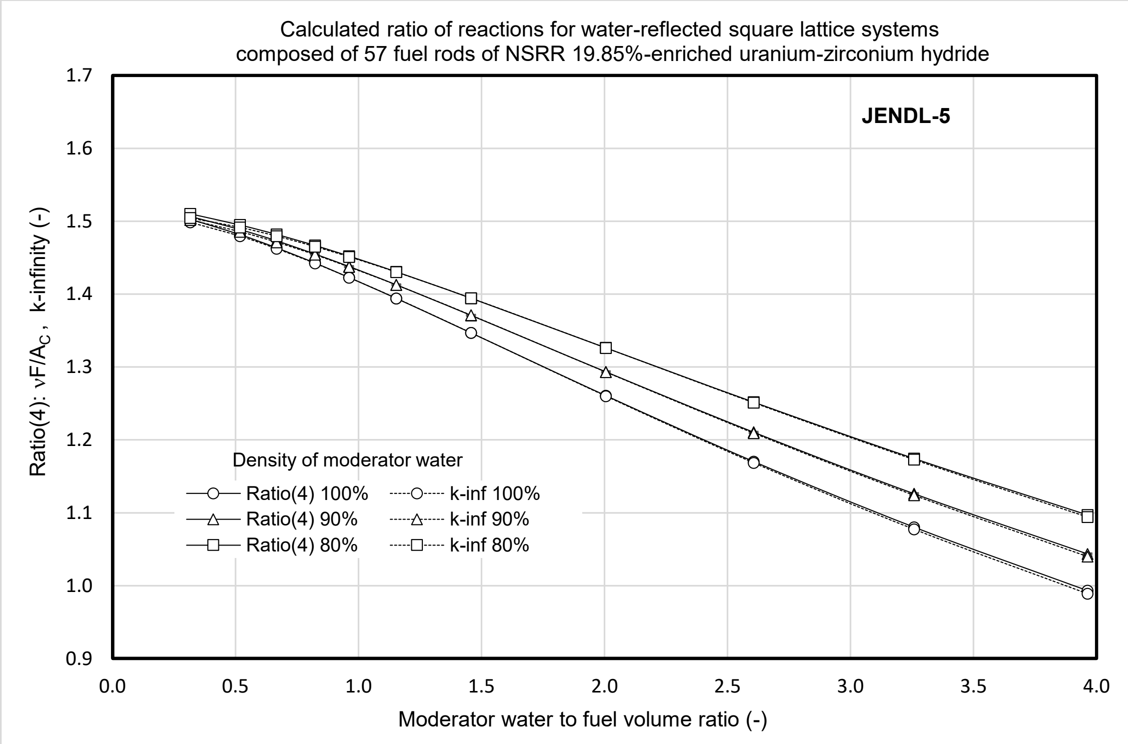


Fig.3.2.1.13(2) Ratio(4) for water-reflected square lattice systems composed of 57 fuel rods as function of VR, using JENDL-5.

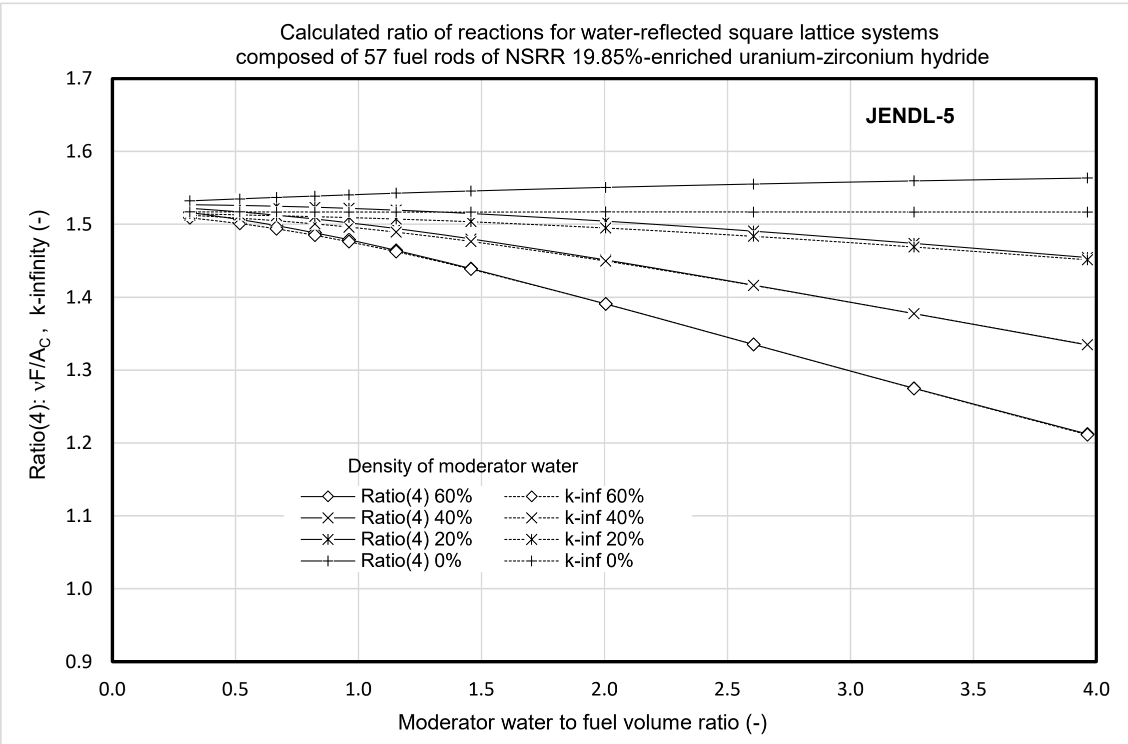


Fig.3.2.1.13(2)(contd.) Ratio(4) for water-reflected square lattice systems composed of 57 fuel rods as function of VR, using JENDL-5.

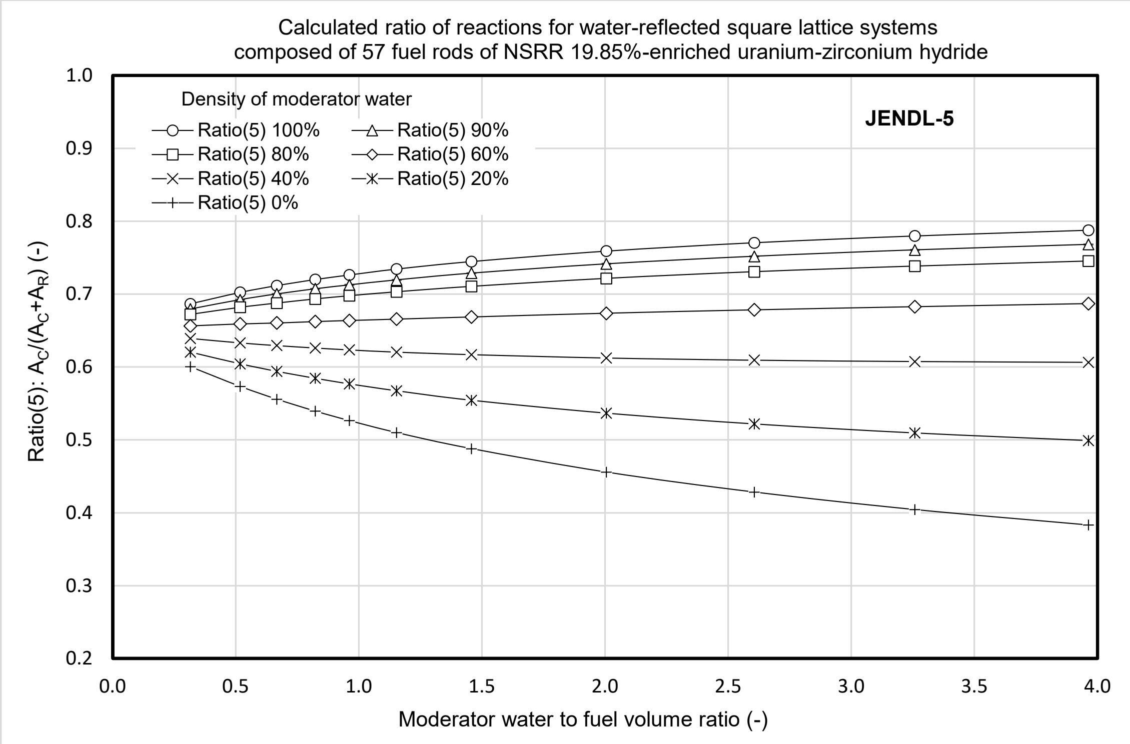


Fig.3.2.1.13(3) Ratio(5) for water-reflected square lattice systems composed of 57 fuel rods as function of VR, using JENDL-5.

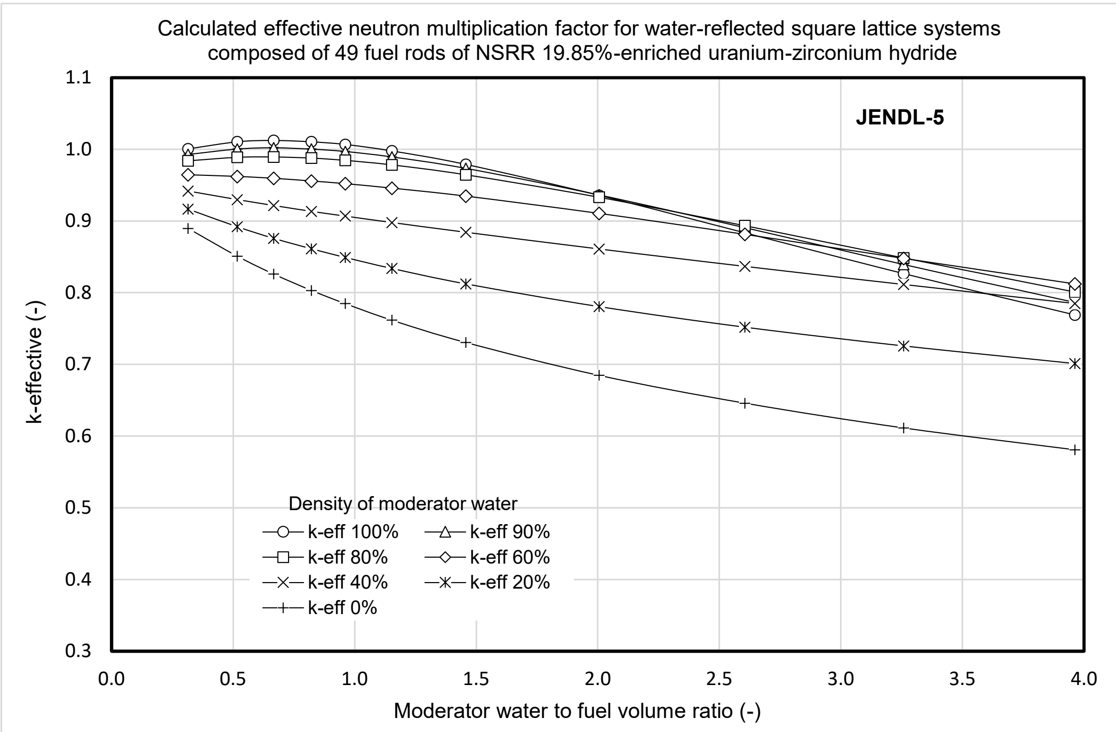


Fig.3.2.1.14(1) Effective neutron multiplication factor for water-reflected square lattice systems composed of 49 fuel rods as function of VR, using JENDL-5.

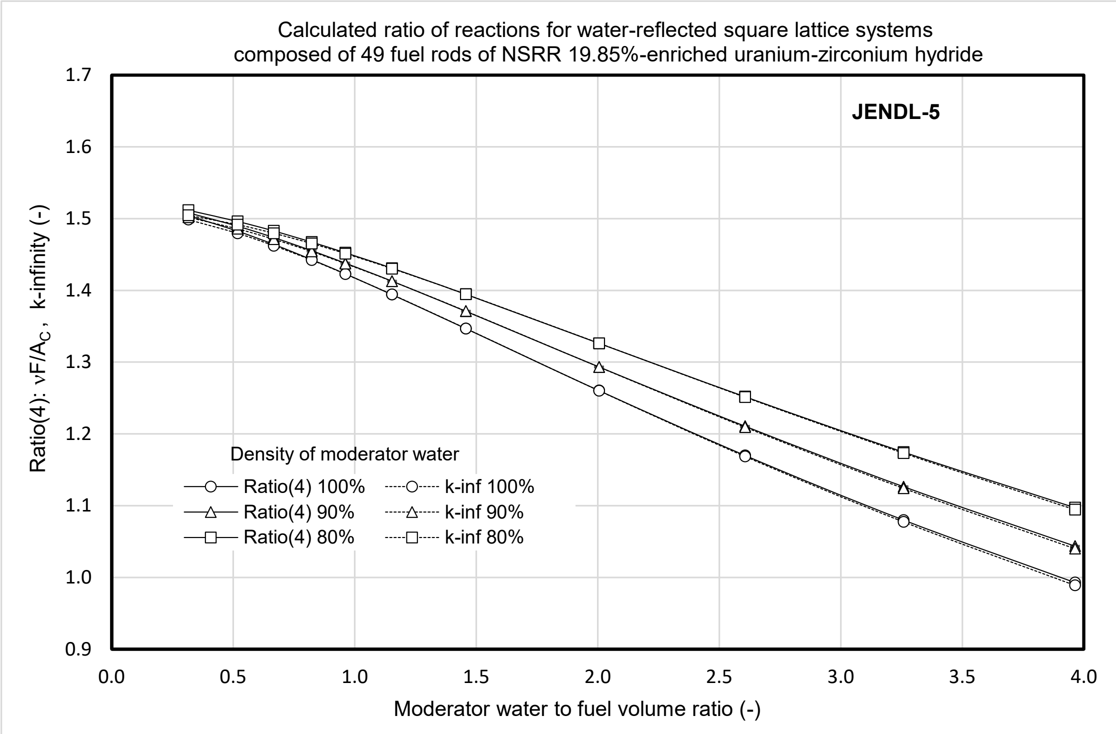


Fig.3.2.1.14(2) Ratio(4) for water-reflected square lattice systems composed of 49 fuel rods as function of VR, using JENDL-5.

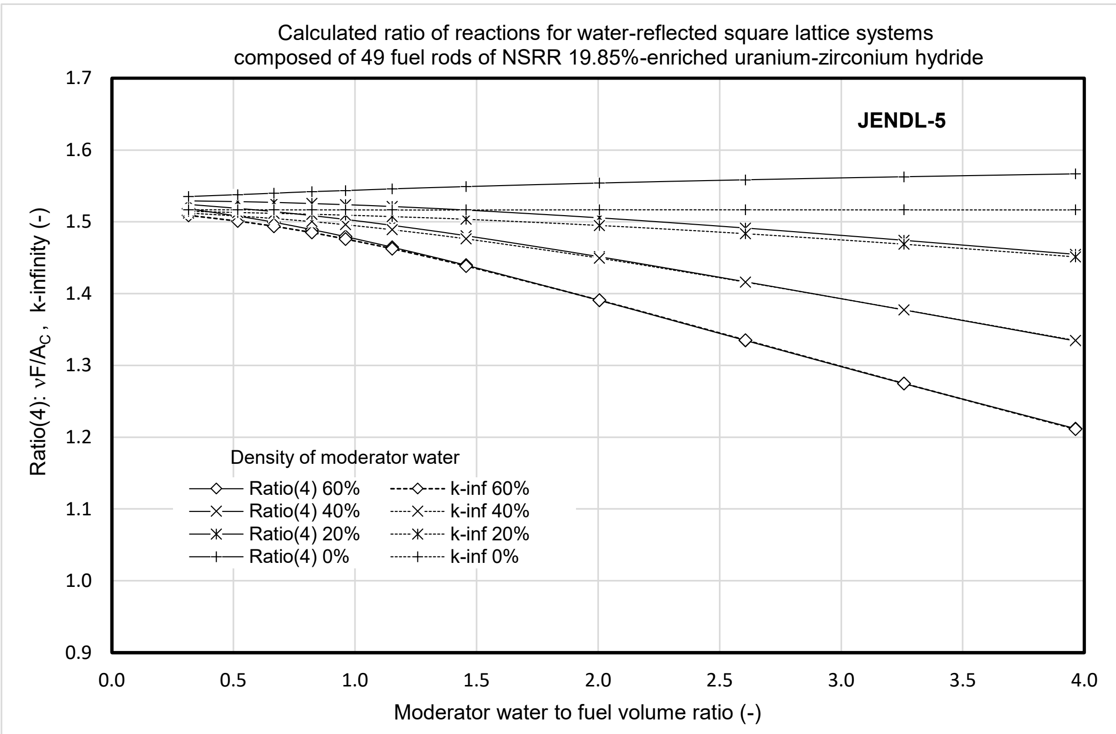


Fig.3.2.1.14(2)(contd.) Ratio(4) for water-reflected square lattice systems composed of 49 fuel rods as function of VR, using JENDL-5.

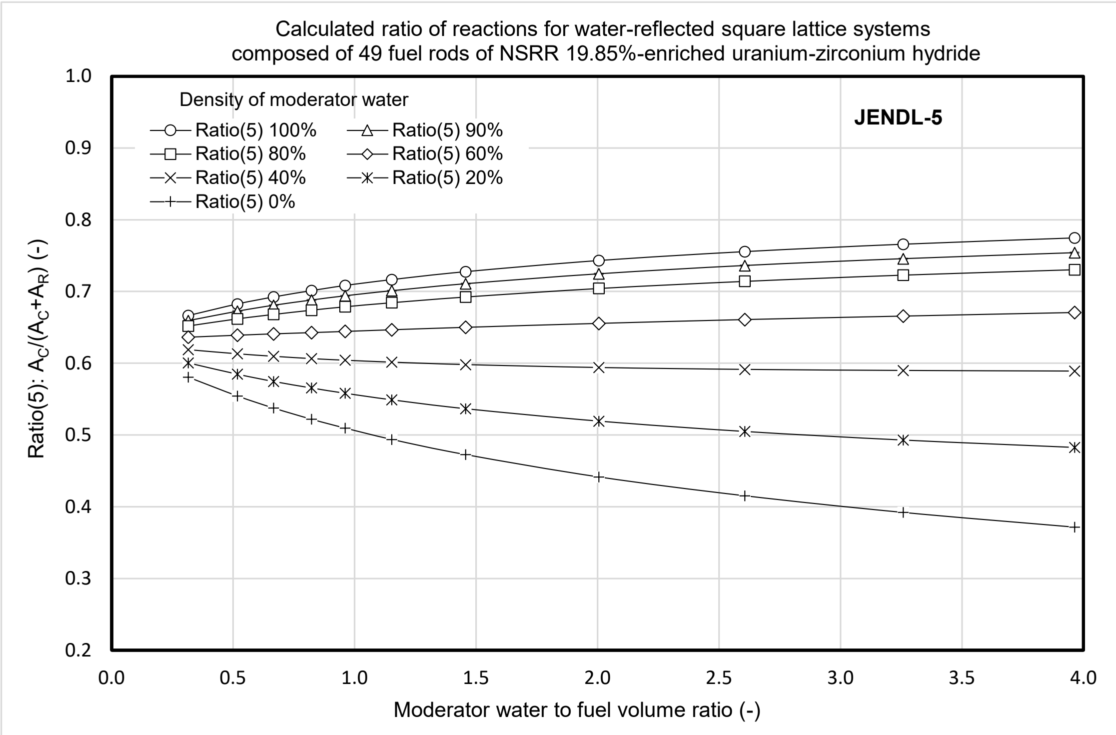


Fig.3.2.1.14(3) Ratio(5) for water-reflected square lattice systems composed of 49 fuel rods as function of VR, using JENDL-5.

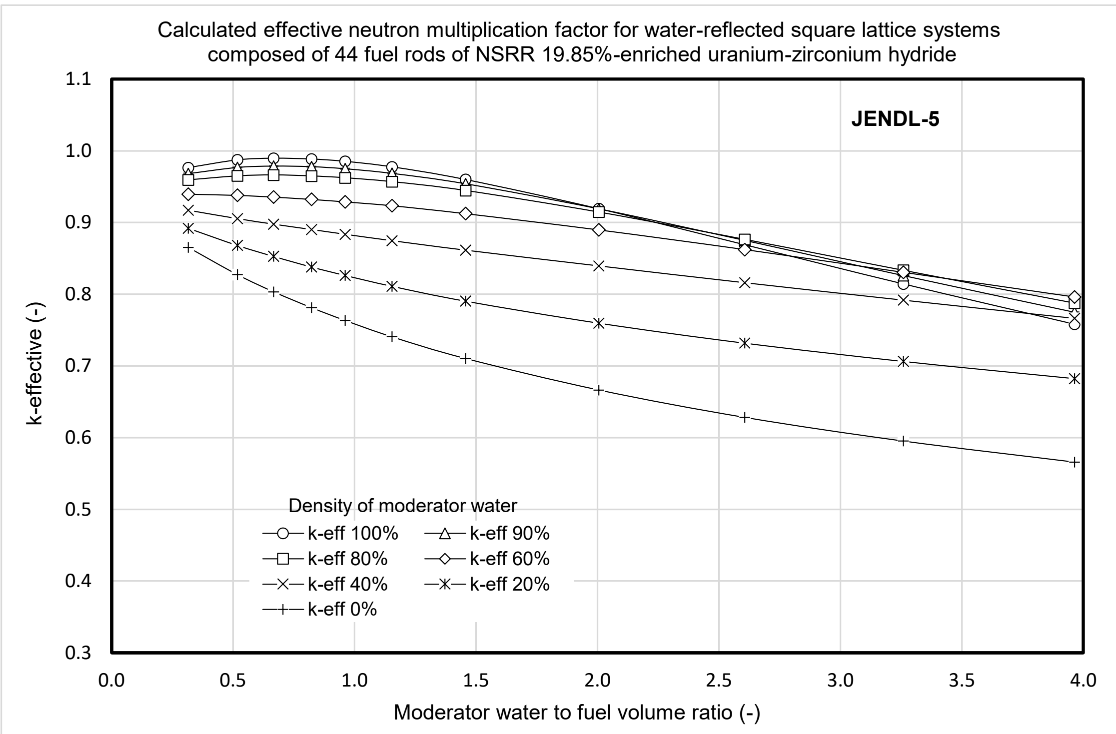


Fig.3.2.1.15(1) Effective neutron multiplication factor for water-reflected square lattice systems composed of 44 fuel rods as function of VR, using JENDL-5.

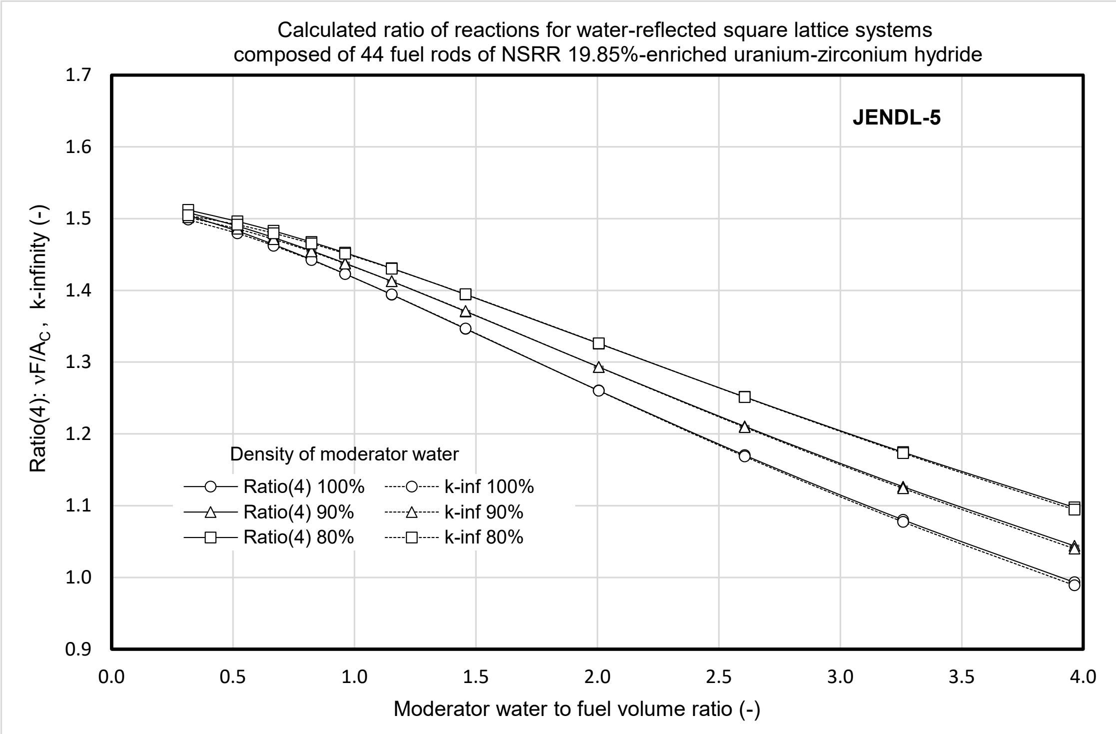


Fig.3.2.1.15(2) Ratio(4) for water-reflected square lattice systems composed of 44 fuel rods as function of VR, using JENDL-5.

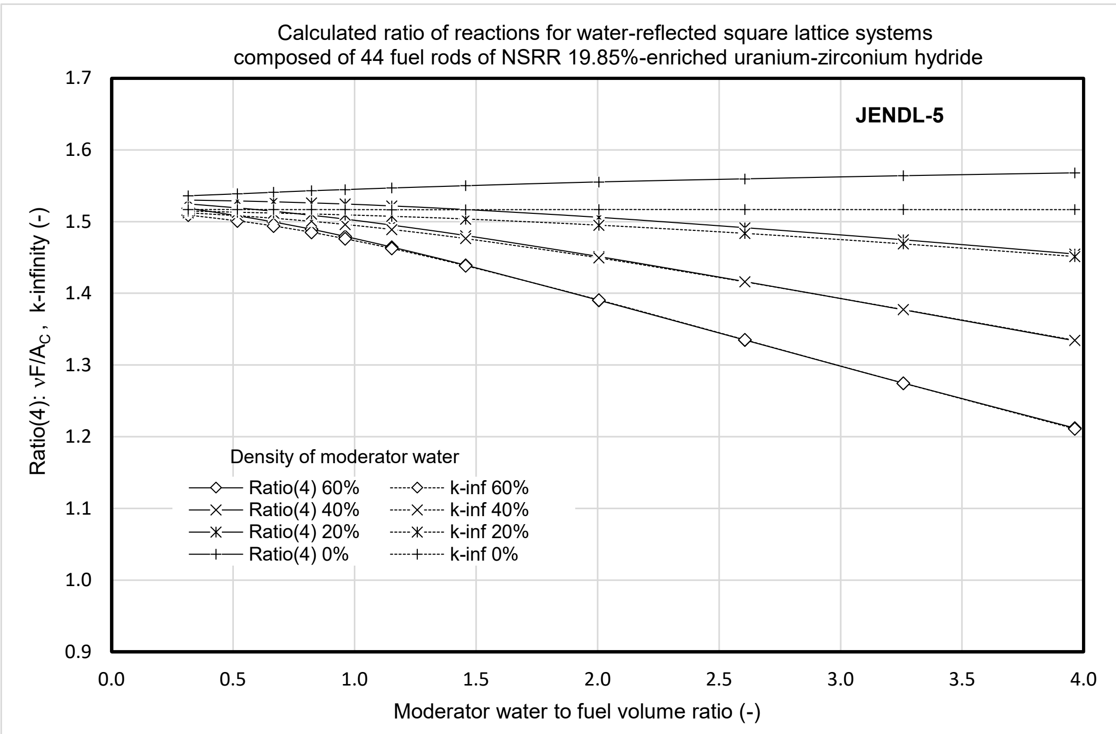


Fig.3.2.1.15(2)(contd.) Ratio(4) for water-reflected square lattice systems composed of 44 fuel rods as function of VR, using JENDL-5.

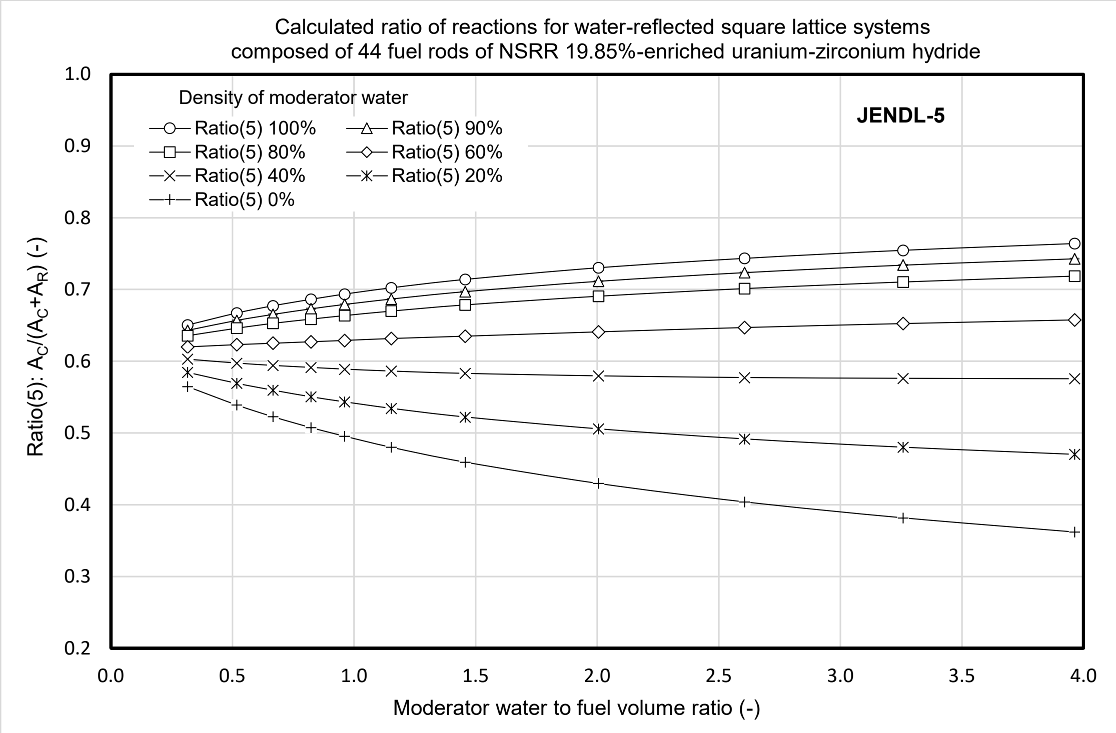


Fig.3.2.1.15(3) Ratio(5) for water-reflected square lattice systems composed of 44 fuel rods as function of VR, using JENDL-5.

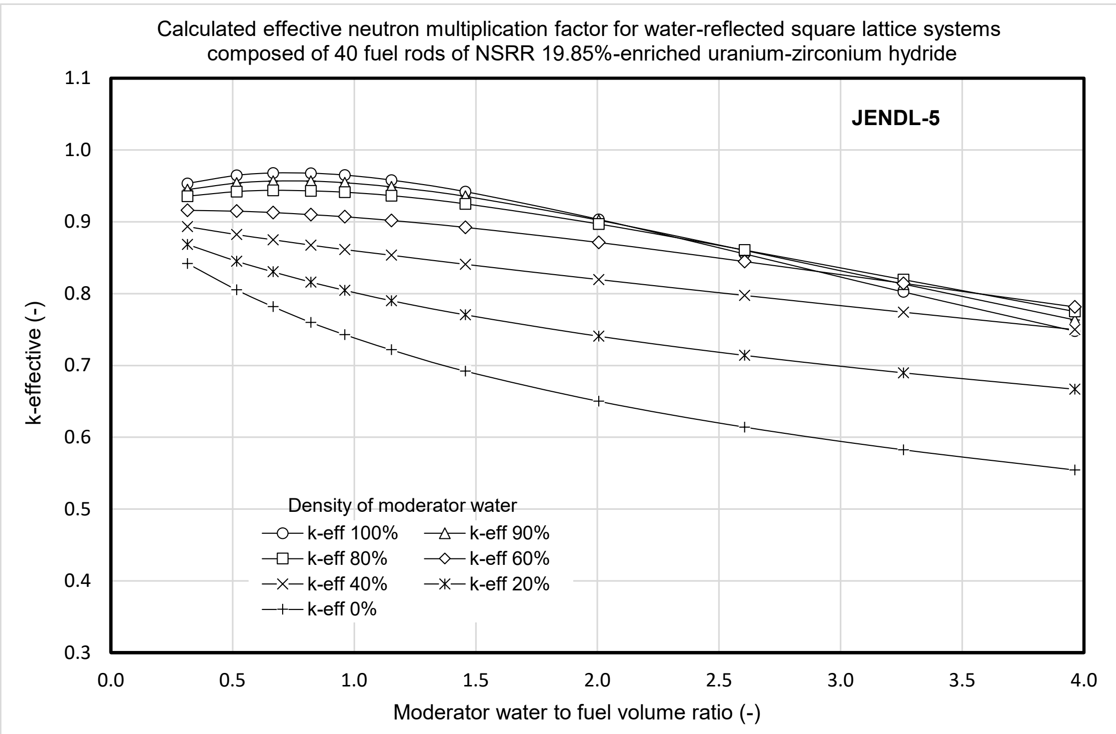


Fig.3.2.1.16(1) Effective neutron multiplication factor for water-reflected square lattice systems composed of 40 fuel rods as function of VR, using JENDL-5.

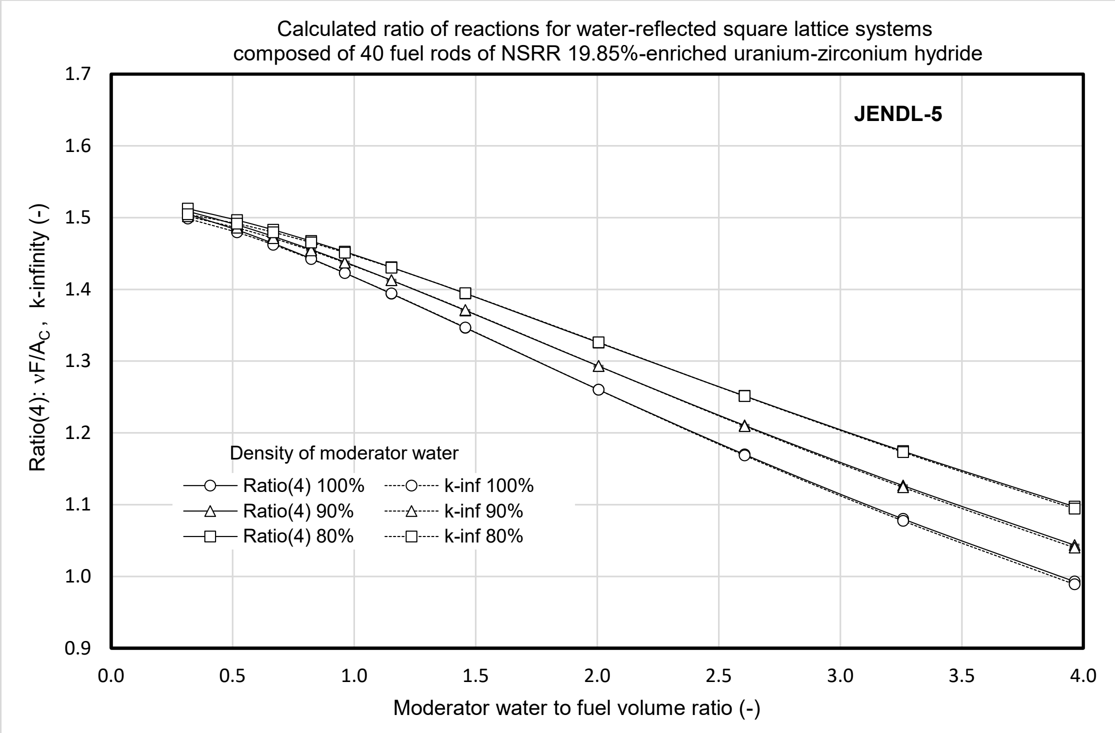


Fig.3.2.1.16(2) Ratio(4) for water-reflected square lattice systems composed of 40 fuel rods as function of VR, using JENDL-5.

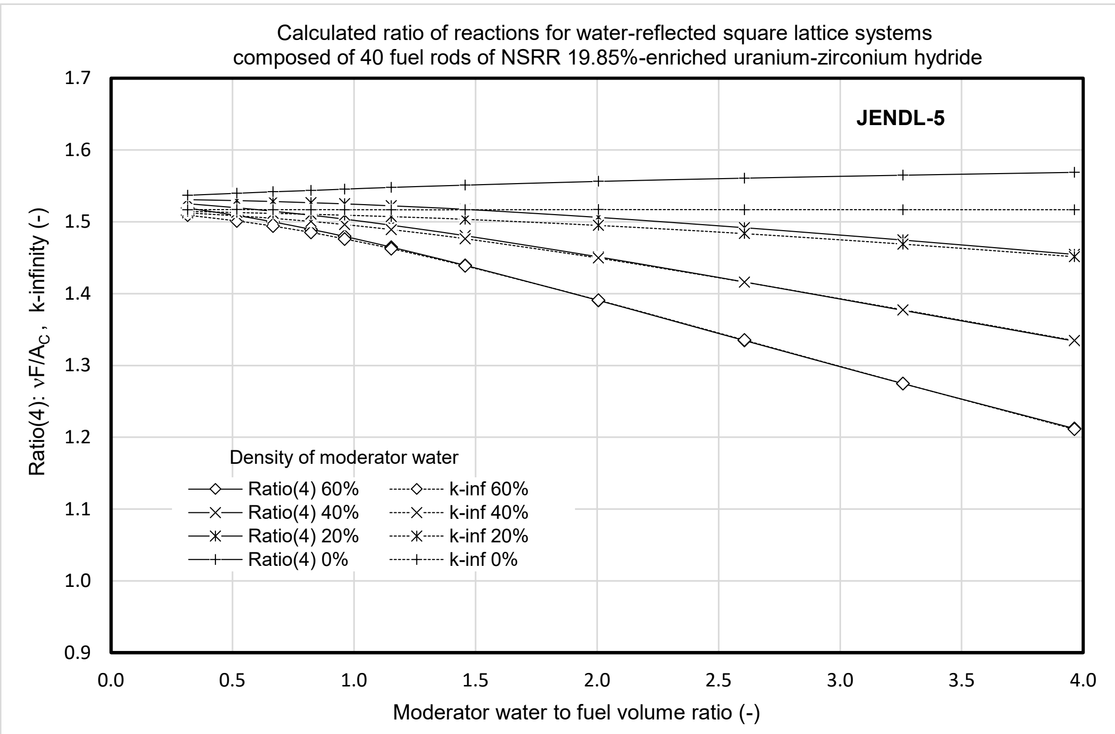


Fig.3.2.1.16(2)(contd.) Ratio(4) for water-reflected square lattice systems composed of 40 fuel rods as function of VR, using JENDL-5.

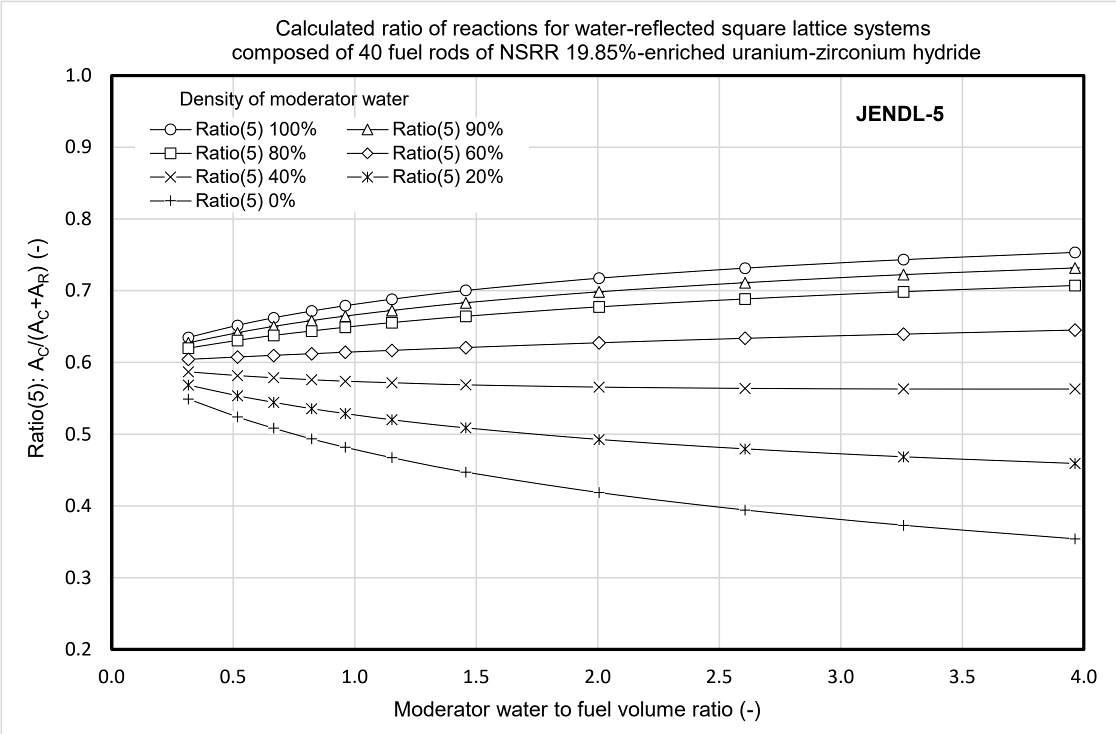


Fig.3.2.1.16(3) Ratio(5) for water-reflected square lattice systems composed of 40 fuel rods as function of VR, using JENDL-5.

Similar to the hexagonal lattice systems as described above, Figs.3.2.1.17 to 3.2.1.20 show k_{eff} varying as function of the density of the moderator water for the finite square lattice systems. It is seen that the intermediate density resulting in the peak of k_{eff} is 50 to 70 % of the density of the moderator water in the case of 3.96 of VR and smaller than that of the hexagonal lattice system of which VR is 3.28.

Figures 3.2.1.21 to 3.2.1.24 show neutron spectra for the fuel cell region of both the finite and infinite square lattice systems. It is confirmed that the characteristics of neutron spectra for both 100 and 0 % of the density of the moderator water are same as those for the finite hexagonal lattice systems as mentioned above.

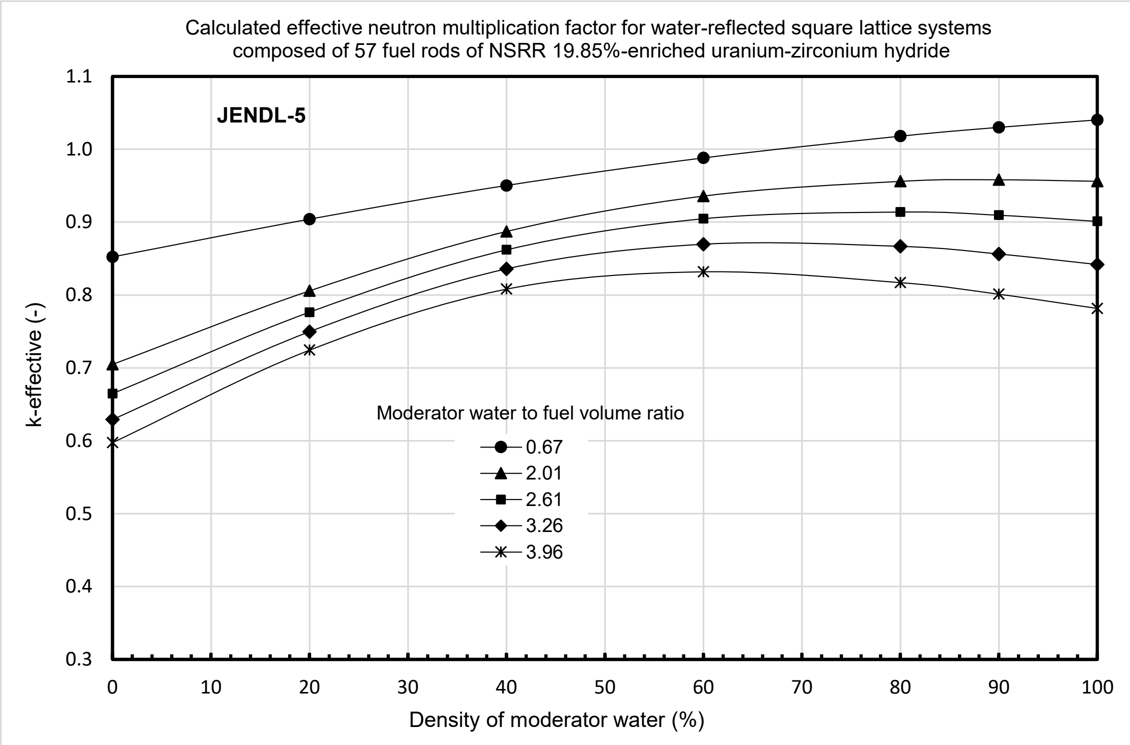


Fig.3.2.1.17 Effective neutron multiplication factor for water-reflected square lattice systems composed of 57 fuel rods as function of density of moderator water, using JENDL-5.

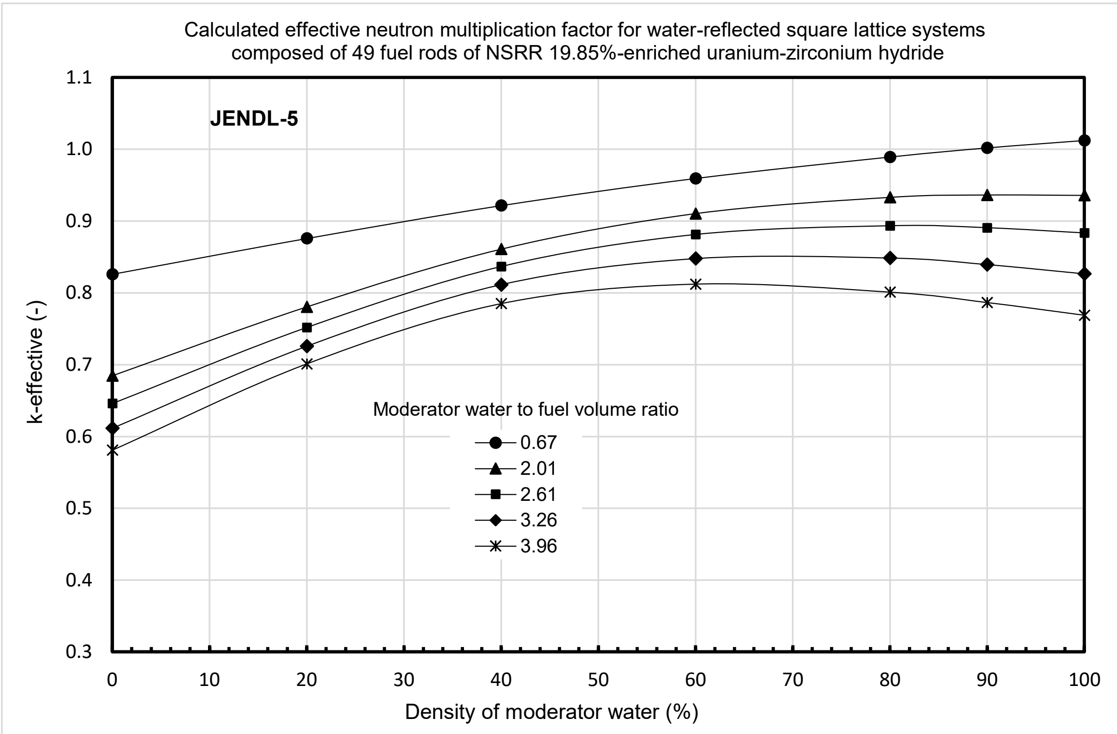


Fig 3.2.1.18 Effective neutron multiplication factor for water-reflected square lattice systems composed of 49 fuel rods as function of density of moderator water, using JENDL-5.

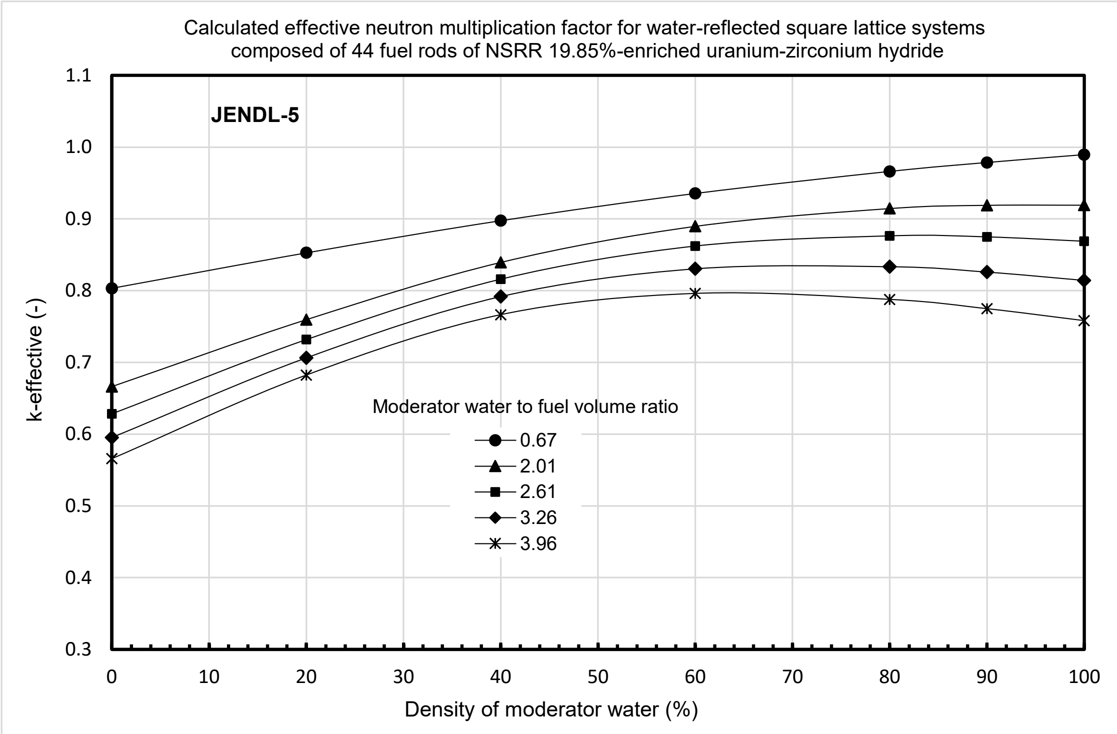


Fig.3.2.1.19 Effective neutron multiplication factor for water-reflected square lattice systems composed of 44 fuel rods as function of density of moderator water, using JENDL-5.

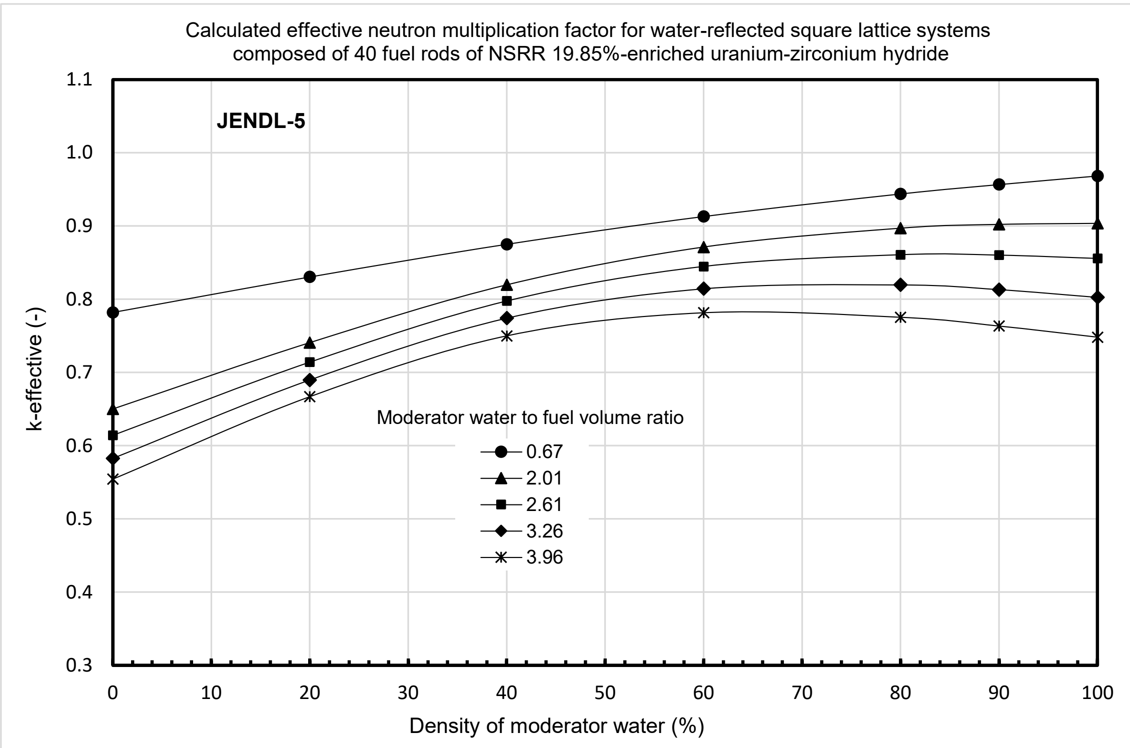
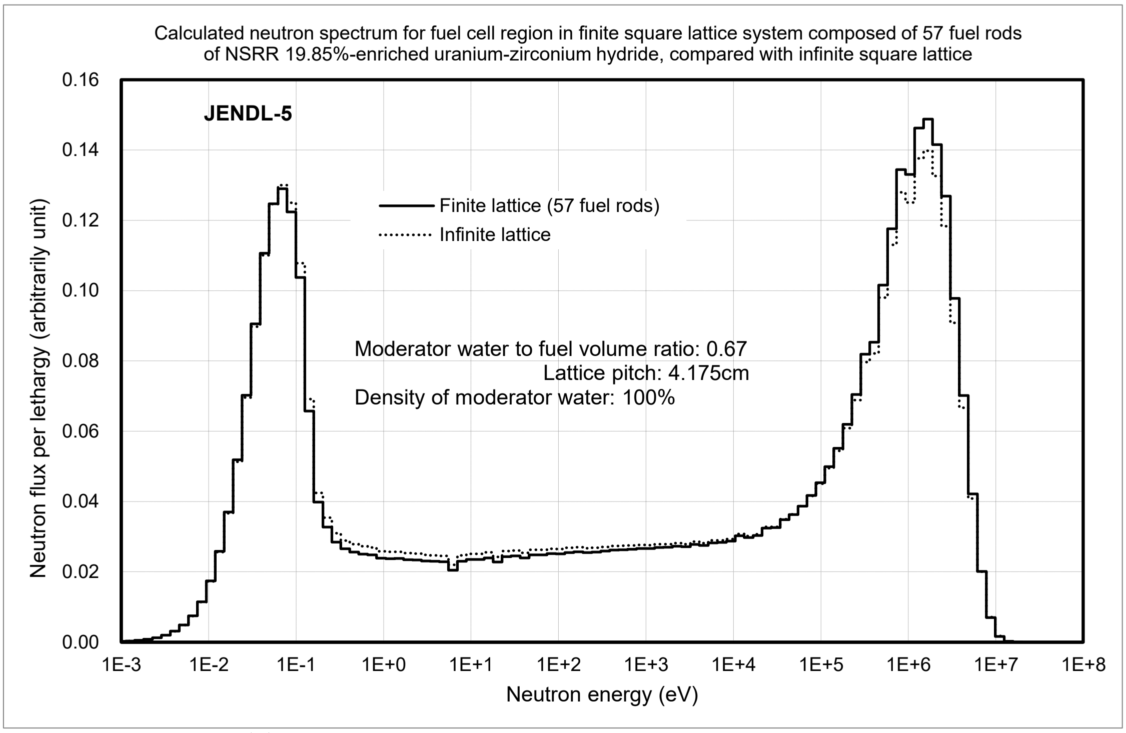
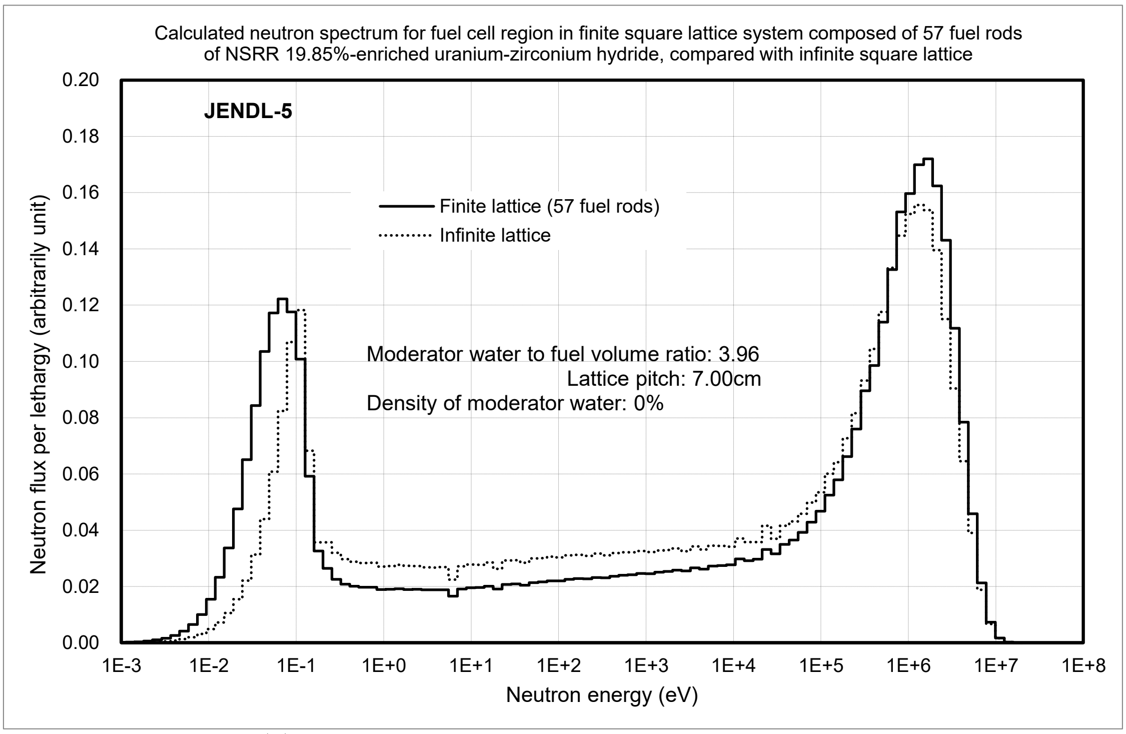


Fig.3.2.1.20 Effective neutron multiplication factor for water-reflected square lattice systems composed of 40 fuel rods as function of density of moderator water, using JENDL-5.

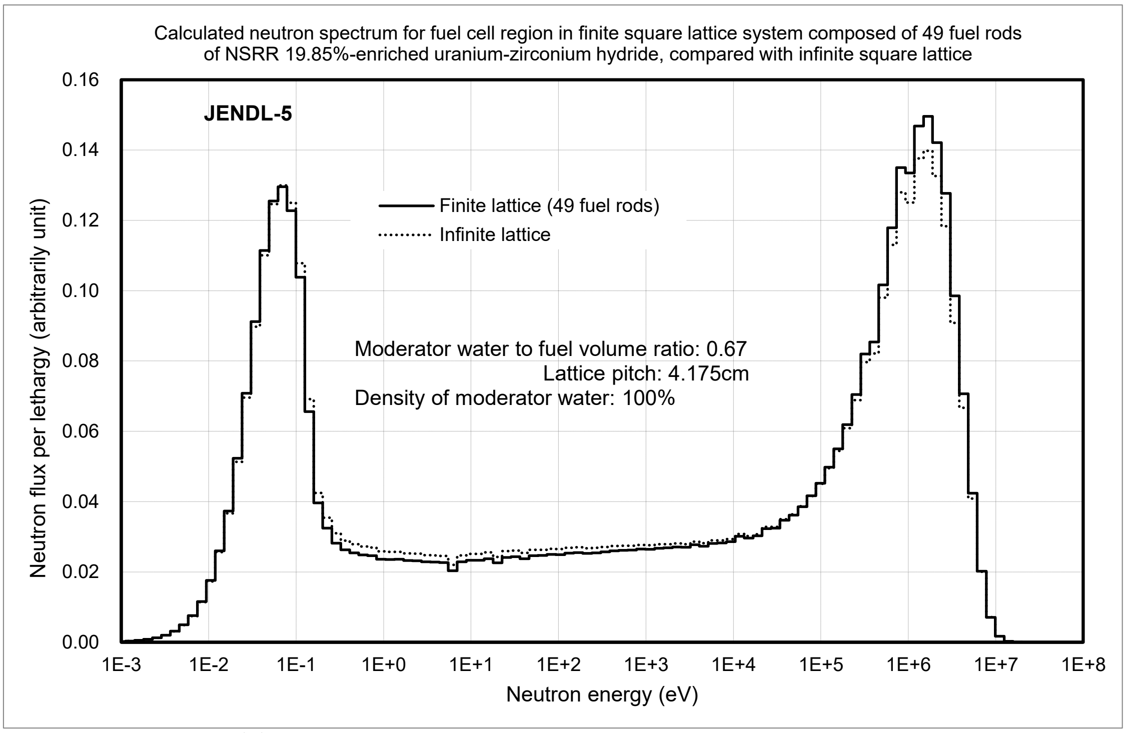


(a) Density of moderator water: 100 %, VR=0.42.

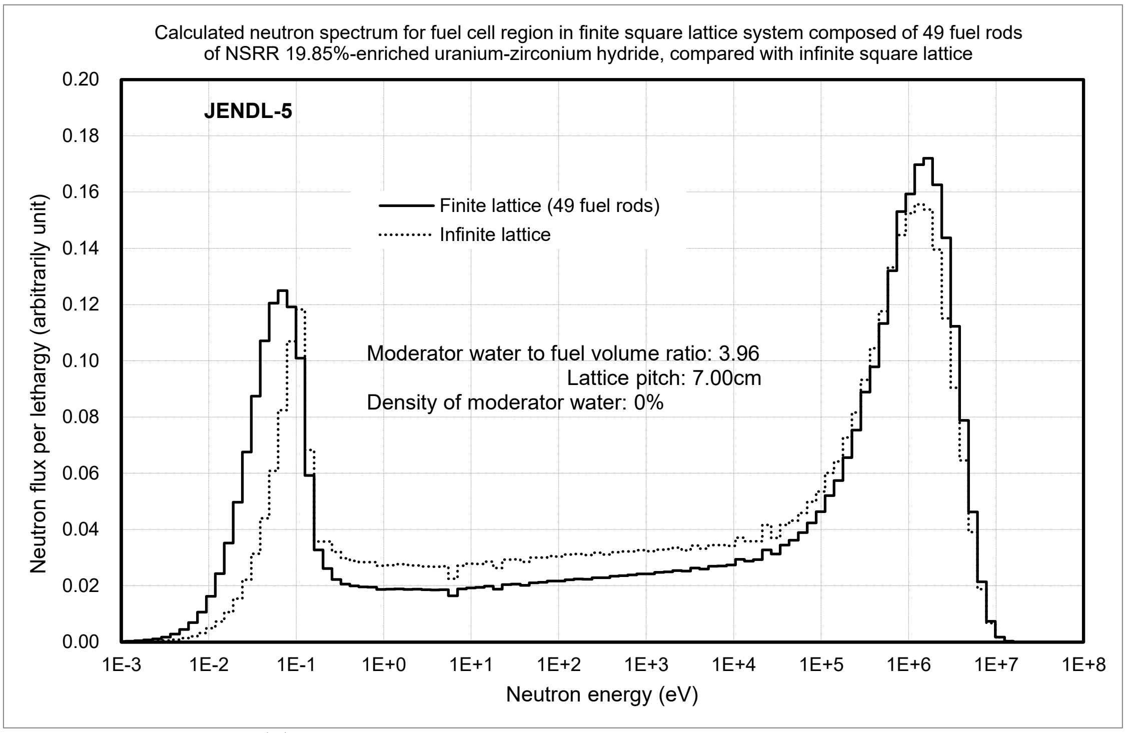


(b) Density of moderator water: 0 %, VR=3.28.

Fig.3.2.1.21 Comparison of neutron spectra for fuel cell region between water-reflected finite square lattice system composed of 57 fuel rods and infinite square lattice system, using JENDL-5.

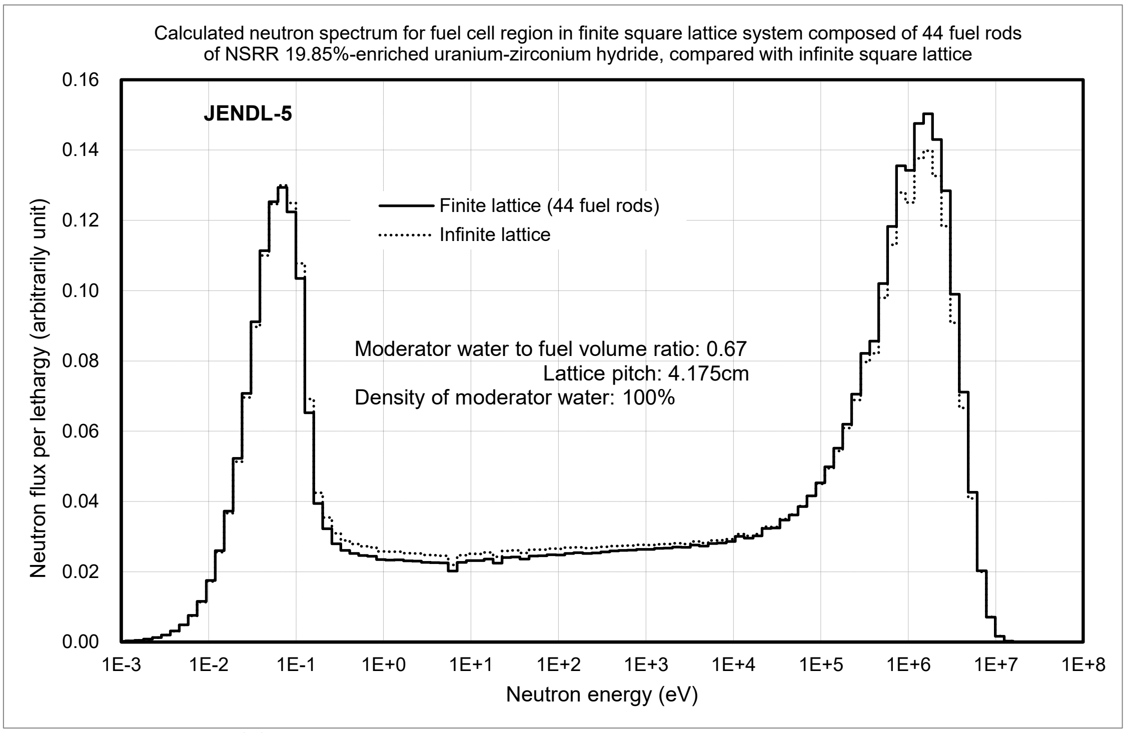


(a) Density of moderator water: 100 %, VR=0.42.

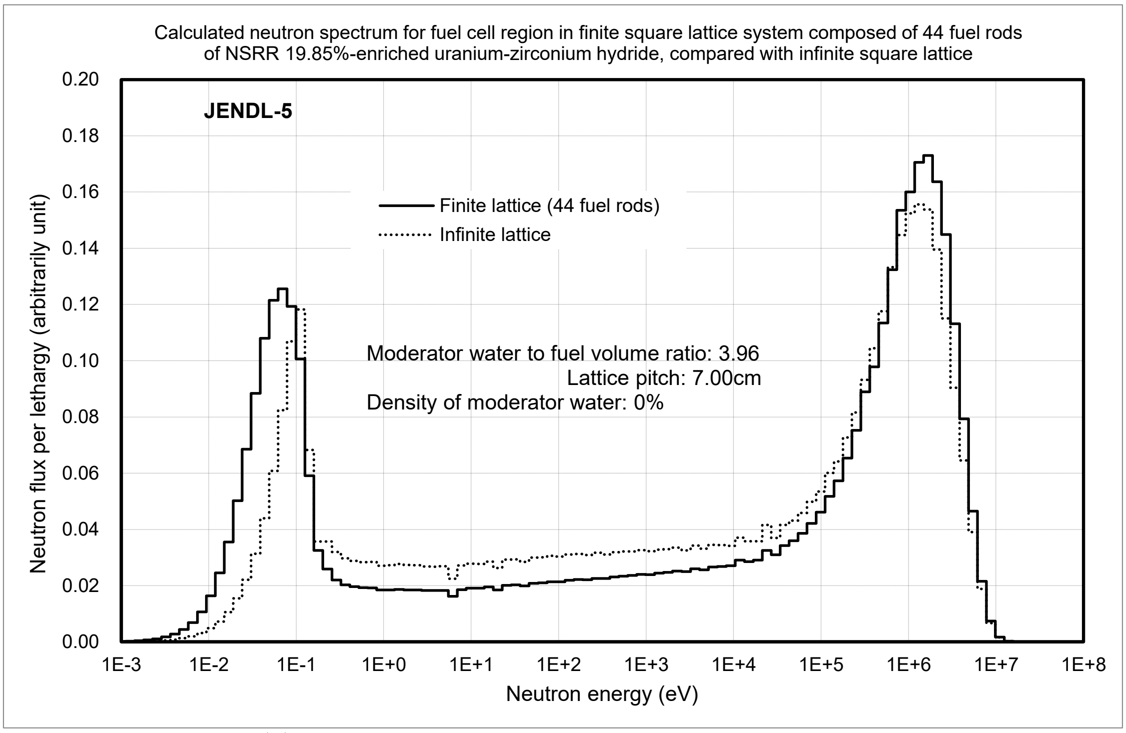


(b) Density of moderator water: 0 %, VR=3.28.

Fig.3.2.1.22 Comparison of neutron spectra for fuel cell region between water-reflected finite square lattice system composed of 49 fuel rods and infinite square lattice system, using JENDL-5.

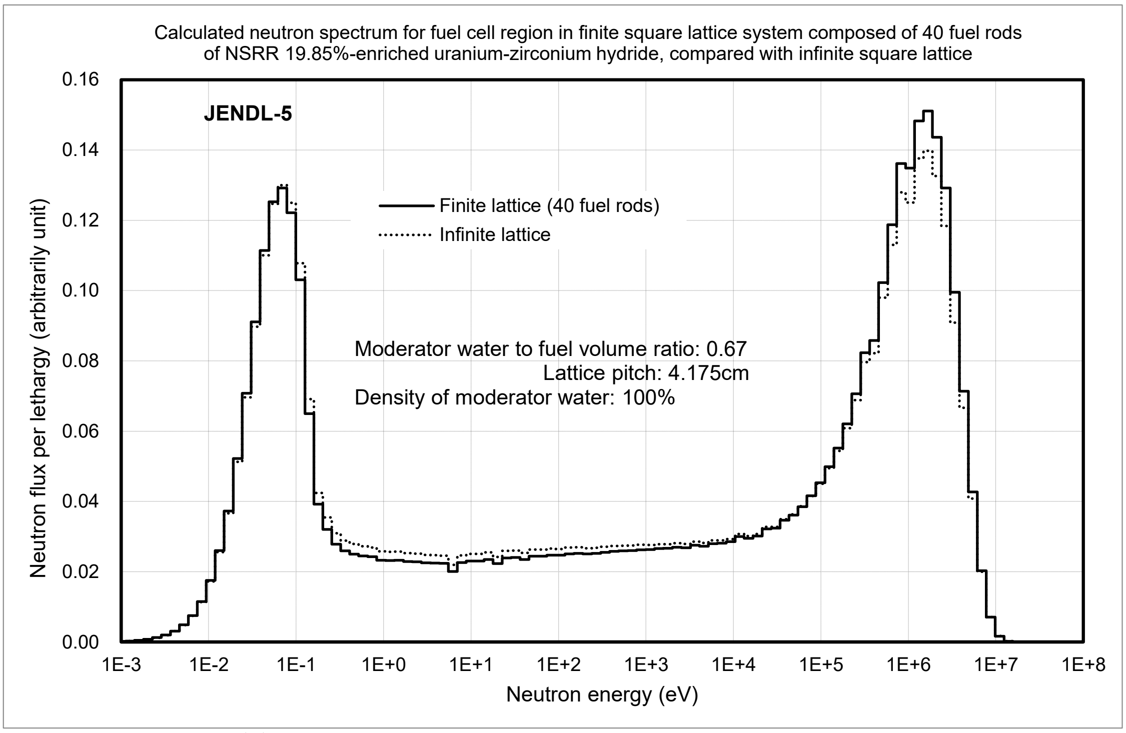


(a) Density of moderator water: 100 %, VR=0.42.

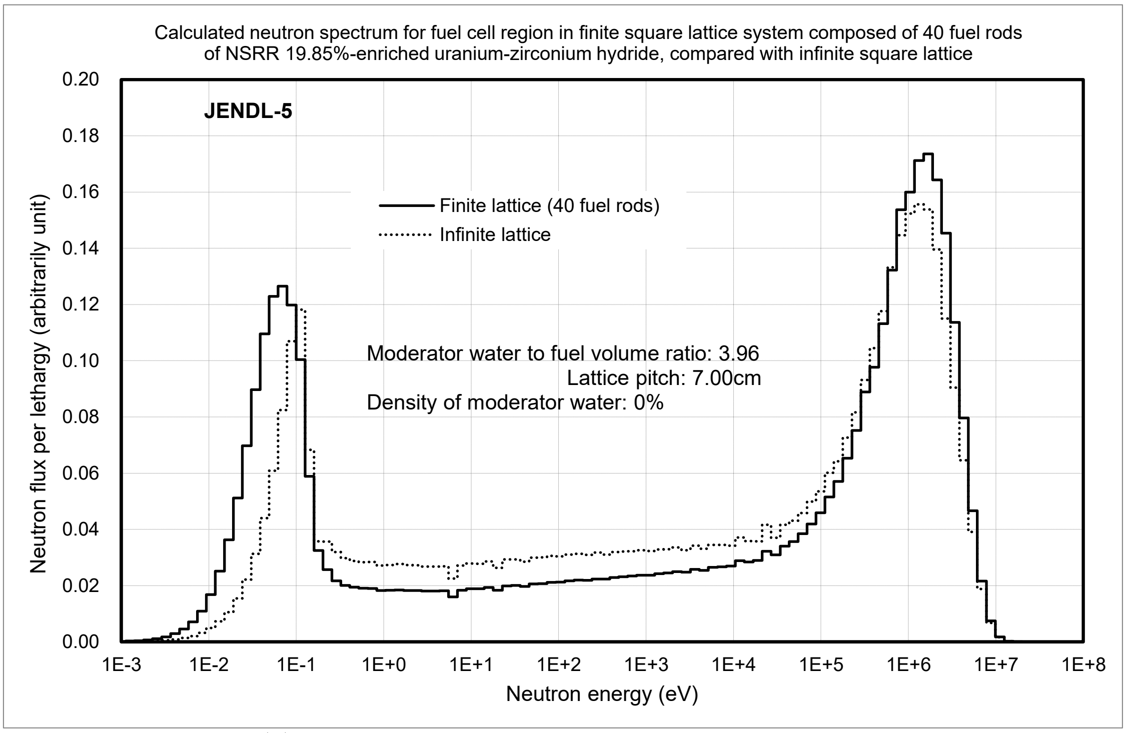


(b) Density of moderator water: 0 %, VR=3.28.

Fig.3.2.1.23 Comparison of neutron spectra for fuel cell region between water-reflected finite square lattice system composed of 44 fuel rods and infinite square lattice system, using JENDL-5.



(a) Density of moderator water: 100 %, VR=0.42.



(b) Density of moderator water: 0 %, VR=3.28.

Fig.3.2.1.24 Comparison of neutron spectra for fuel cell region between water-reflected finite square lattice system composed of 40 fuel rods and infinite square lattice system, using JENDL-5.

3.2.2 Finite lattice systems for search on criticality under no moderator water condition

Figures 3.2.2.1 and 3.2.2.2 show k_{eff}, Ratio(4), and Ratio(5) for the water-reflected and no-water-reflected finite hexagonal lattice systems under the no moderator water condition varying with the number of fuel rods calculated using the JENDL-5 library, respectively. For the no-water-reflected systems, the ratio of Ratio(7) to Ratio(4) is also shown in Fig.3.2.2.2 to compare with Ratio(5). All numerical data are listed in Appendix-3, including the results of both Ratio(6) and Ratio(7). In Appendix-3, calculated results using the JENDL-4.0 and JENDL-4.0u1 libraries are also listed. The comparisons of the results using the JENDL-5 library with those using the JENDL-4.0 and JENDL-4.0u1 libraries are shown in Appendix-4.

The results from the comparison between the JENDL-5 and the previous versions of the JENDL libraries are briefly mentioned here. As presented in Appendix-4, it is clarified for the water-reflected systems that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries decrease gradually as the number of fuel rods increases, but the differences between the JENDL-4.0 and JENDL-4.0u1 libraries are smaller than three times their σ's. It is also confirmed that the differences in Ratio(5) between the JENDL-5 and JENDL-4.0 libraries largely affect those in k_{eff}, similar to the results shown in Sec.3.2.1 under the condition that the density of the moderator water is set to be 0 %. For the no-water-reflected condition, it is also seen that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries decrease gradually as the number of fuel rods increases, but the differences are larger than those of the water-reflected condition. It is found that the differences in the neutron leakage from the system affect largely those in k_{eff} rather than Ratio(4) and Ratio(5).

It is confirmed from Figs.3.2.2.1 and 3.2.2.2 that k_{eff} becomes larger as the number of fuel rods and criticality is possible to be reached using more than 70 and 110 fuel rods for the water-reflected and no-water-reflected conditions, respectively, even though no moderator water exists. This means that those possible critical number of fuel rods are smaller than the standard core [1,6] of NSRR in which 149 fuel rods are loaded. Even if the axial graphite reflector is assumed to be replaced with void, the reactivity effect brought by the replacement is -0.032 to -0.022 $\Delta k_{eff}/k_{eff}$ and criticality is possible to be reached as shown in Appendix-3.

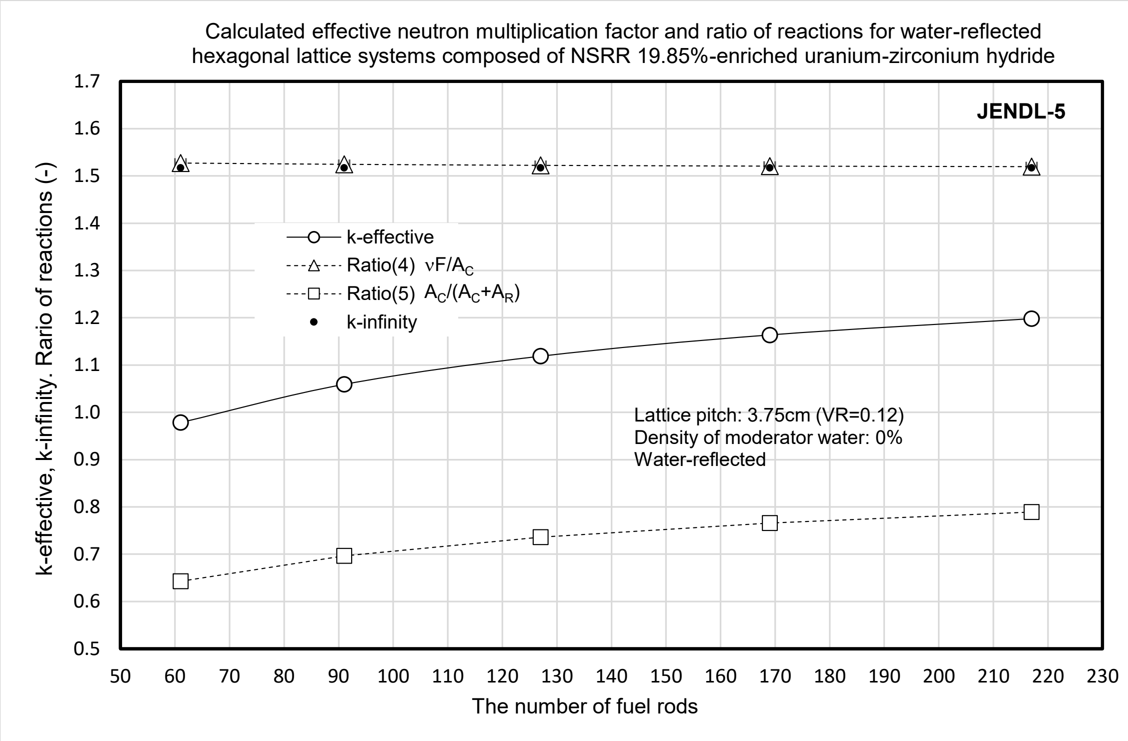


Fig.3.2.2.1 Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems under no moderator water condition, using JENDL-5.

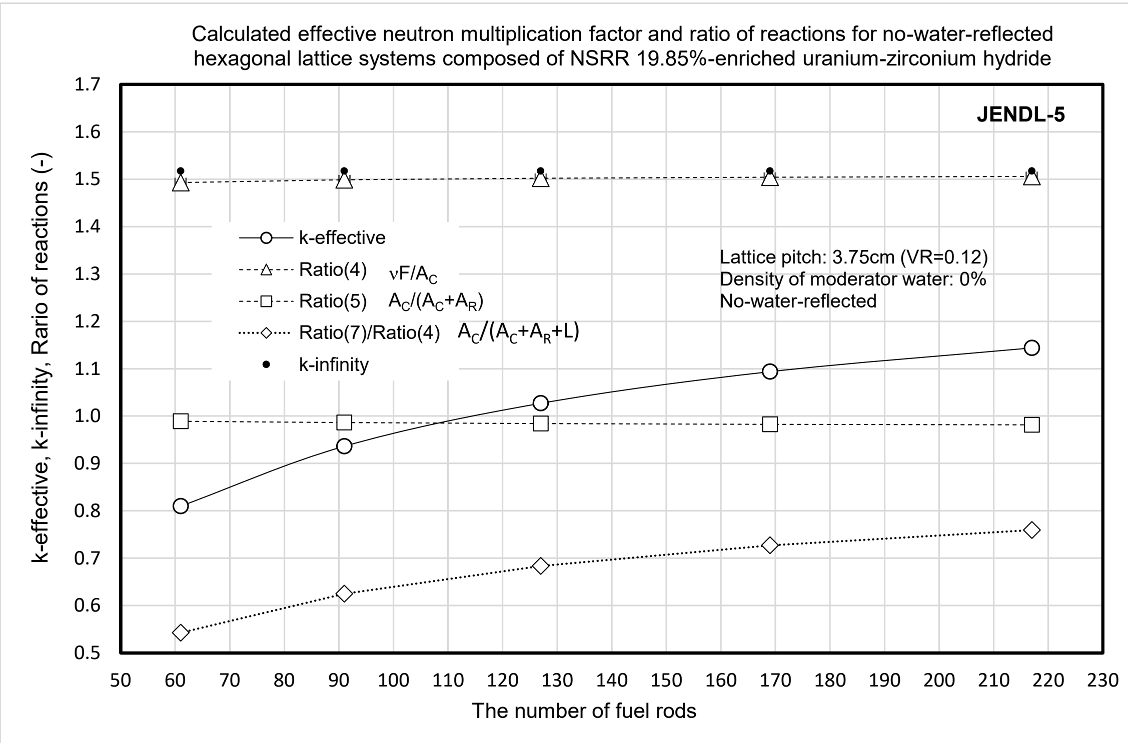
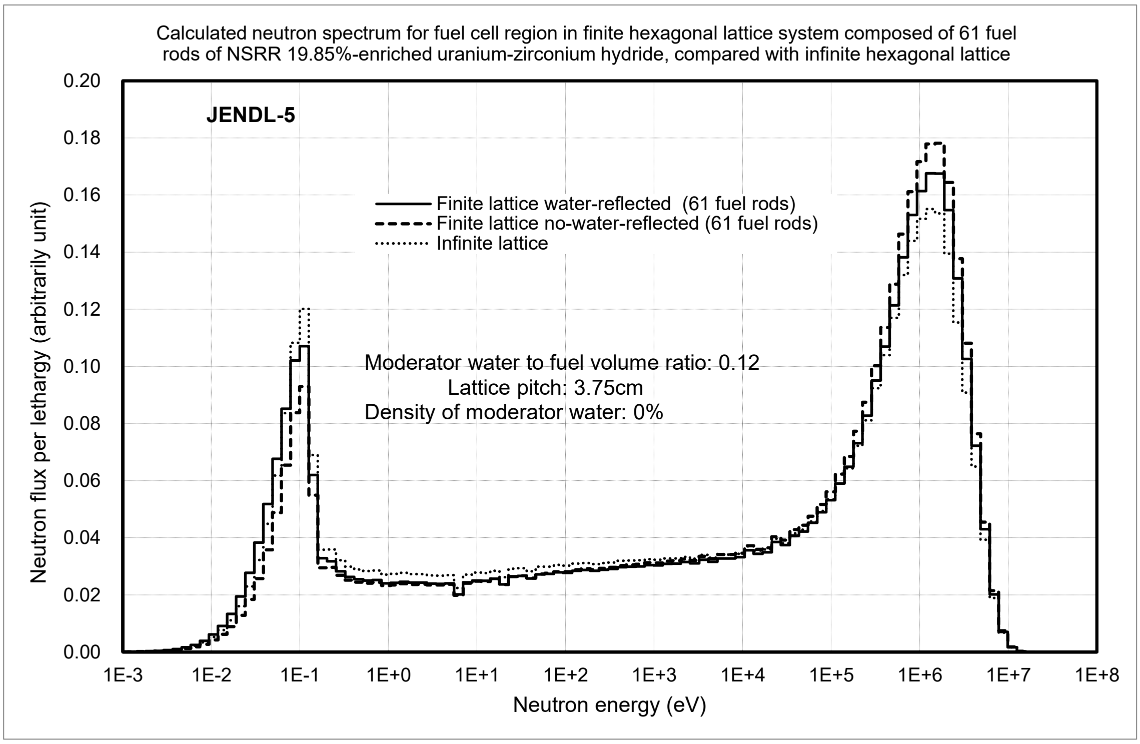


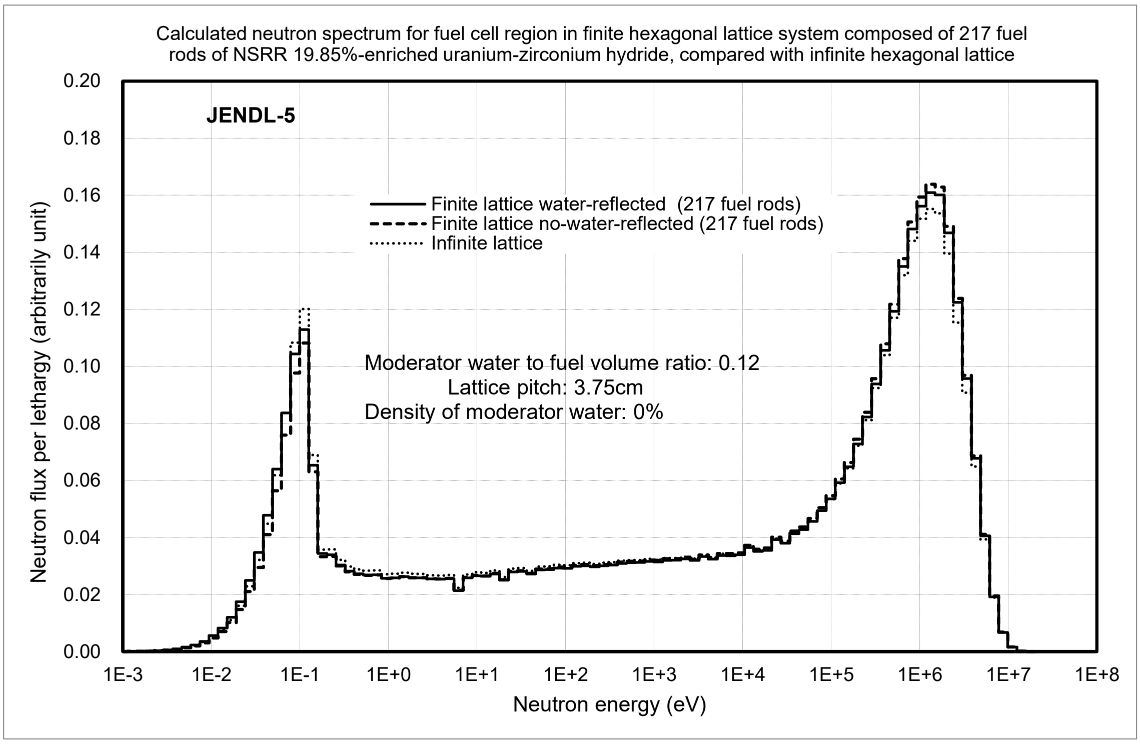
Fig.3.2.2.2 Effective neutron multiplication factor and ratio of reactions for no-water-reflected hexagonal lattice systems under no moderator water condition, using JENDL-5.

It is seen in Figs.3.2.2.1 and 3.2.2.2 that Ratio(4) well agrees with k_{inf}. In detail, it seems that Ratio(4) under the water-reflected condition very slightly decreases as the number of fuel rods. On the contrary, Ratio(4) under the no-water-reflected condition very slightly increases as the number of fuel rods. The reasons of those are explained as follows. It is considered that Ratio(4) may increase caused by the thermal neutrons from the reflector water under the water-reflected condition, and this effect by the reflector water may become larger for the smaller number of fuel rods of which volume of the fuel cell region is smaller. Under the no-water-reflected condition, it is considered that Ratio(4) may become smaller due to the larger neutron leakage to the horizontal direction from the system for the smaller number of fuel rods of which horizontal geometrical buckling becomes larger. For reference, neutron spectra for the fuel cell region of lattice systems having the smallest and largest volume are shown in Fig.3.2.2.3.

It is also seen for the water-reflected condition that Ratio(5) increases monotonically like k_{eff} as the number of fuel rods. The reason for this is that the horizontal geometrical buckling decreases and A_R, representing neutron capture in the reflector regions, becomes smaller than A_C, representing neutron capture in the fuel cell regions, as the number of fuel rods. For the no-water-reflected condition, A_R is quite small due to no reflector water existing. For this reason, Ratio(5) becomes constant and nearly equal to unity as shown in Fig.3.2.2.2. The ratio of Ratio(7) to Ratio(4) considering the neutron leakage from the system is considered to be useful to understanding of the characteristics for the no-water-reflected condition instead of Ratio(5). It is confirmed from Fig.3.2.2.2 that the ratio of Ratio(7) to Ratio(4) increases monotonically like k_{eff} as the number of fuel rods and smaller than Ratio(5) under the water-reflected condition. It is considered that the variation of the ratio of Ratio(7) to Ratio(4) is explained using the variation of the horizontal geometrical buckling to be changed with the number of fuel rods, similar to Ratio(5) under the water-reflected condition. Therefore, it is possible to explain the variation of k_{eff} using Ratio(5) under the water-reflected condition and the ratio of Ratio(7) to Ratio(4) under the no-water-reflected condition.



(a) The number of fuel rods: 61.



(b) The number of fuel rods: 217.

Fig.3.2.2.3 Comparison of neutron spectra for fuel cell region between water-reflected and no-water reflected hexagonal lattice systems under no moderator water condition, using JENDL-5.

3.3 Evaluation of critical number of fuel rods

The critical number of fuel rods is one of fundamental properties needed to examine safety measures for handling the fuel rods. This section presents evaluated results of the critical number of fuel rods based on the criticality characteristics on the finite lattice systems, as described in Sec.3.2.

Prior to the evaluation of the critical number of fuel rods, the criticality biases were evaluated by using the calculated results in the earlier study[6)] on the detailed models of NSRR as benchmarking. As presented in Appendix-6, the criticality biases and their errors were evaluated with two sorts of the different number of benchmark cases accounted for, using the JENDL-5, JENDL-4.0 and JENDL-4.0u1 libraries.

3.3.1 Minimum critical number of fuel rods

As described in Sec.3.2.1, it was found in the range of VR smaller than 1.6 that k_{eff} increases monotonically as the density of the moderator water in the finite lattice systems, and that there exists the maximum value of k_{eff} in that range of VR. For these reasons, the relationship between k_{eff} and the number of fuel rods under the conditions of the density of 100 % and the above-mentioned range of VR was focused on in order to evaluate the minimum critical number of fuel rods.

The relations between k_{eff} and the number of fuel rods using the JENDL-5, JENDL-4.0 and JENDL-4.0u1 libraries are shown in Figs.3.3.1.1 to 3.3.1.2, Figs.3.3.1.3 to 3.3.1.4, and Figs.3.3.1.5 to 3.3.1.6, respectively. The relations were represented as second-degree polynomials by the least square technique. Figures 3.3.1.1 to 3.3.1.6 also show the most probable critical number of fuel rods determined by an intersecting point of the second-degree polynomial and the criticality bias evaluated by 37 benchmark cases shown in Appendix-6.

Similarly, the relations between k_{eff} and the number of fuel rods using the JENDL-5, JENDL-4.0 and JENDL-4.0u1 libraries, together with the criticality bias evaluated by 2 benchmark cases shown in Appendix-6 are shown in Figs.3.3.1.7 to 3.3.1.8, Figs.3.3.1.9 to 3.3.1.10, and Figs.3.3.1.11 to 3.3.1.12, respectively.

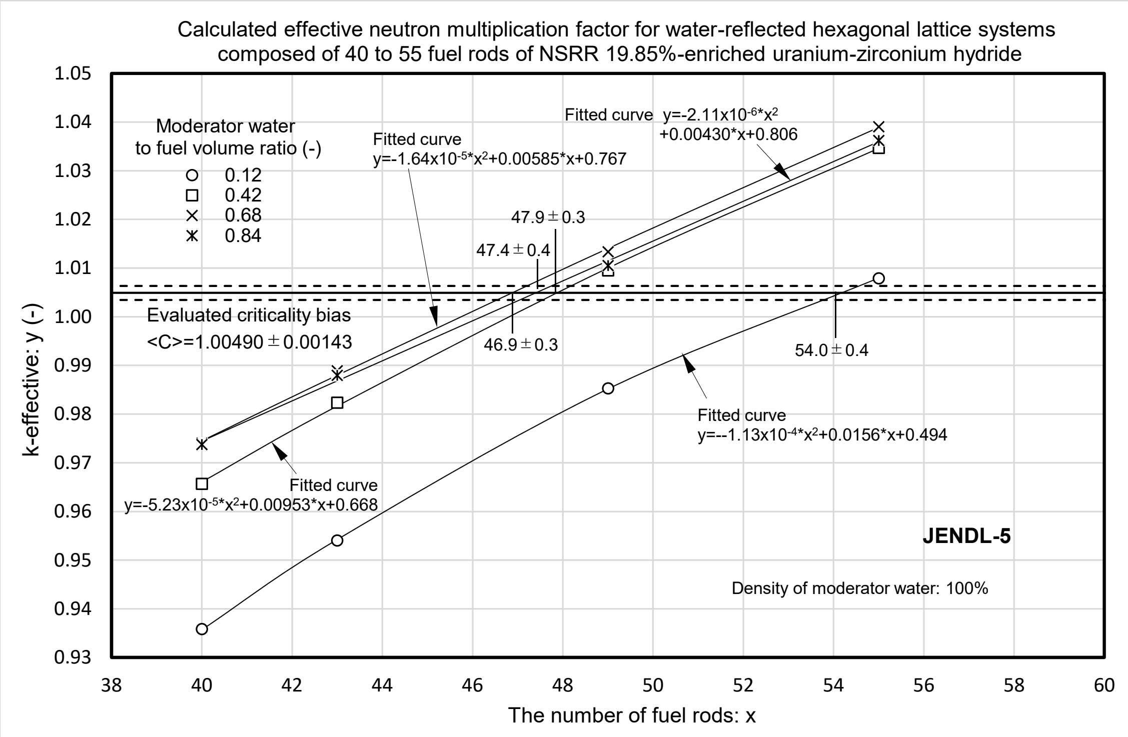


Fig.3.3.1.1 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-5, criticality bias evaluated by 37 benchmark cases.

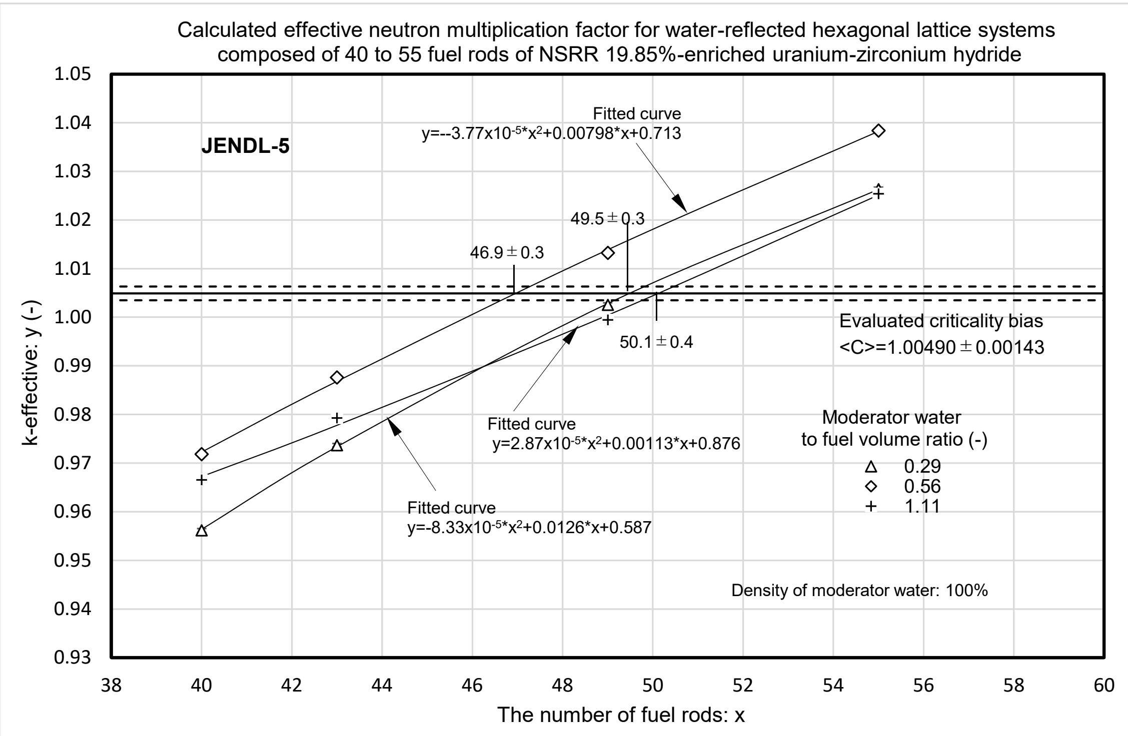


Fig.3.3.1.1(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-5, criticality bias evaluated by 37 benchmark cases.

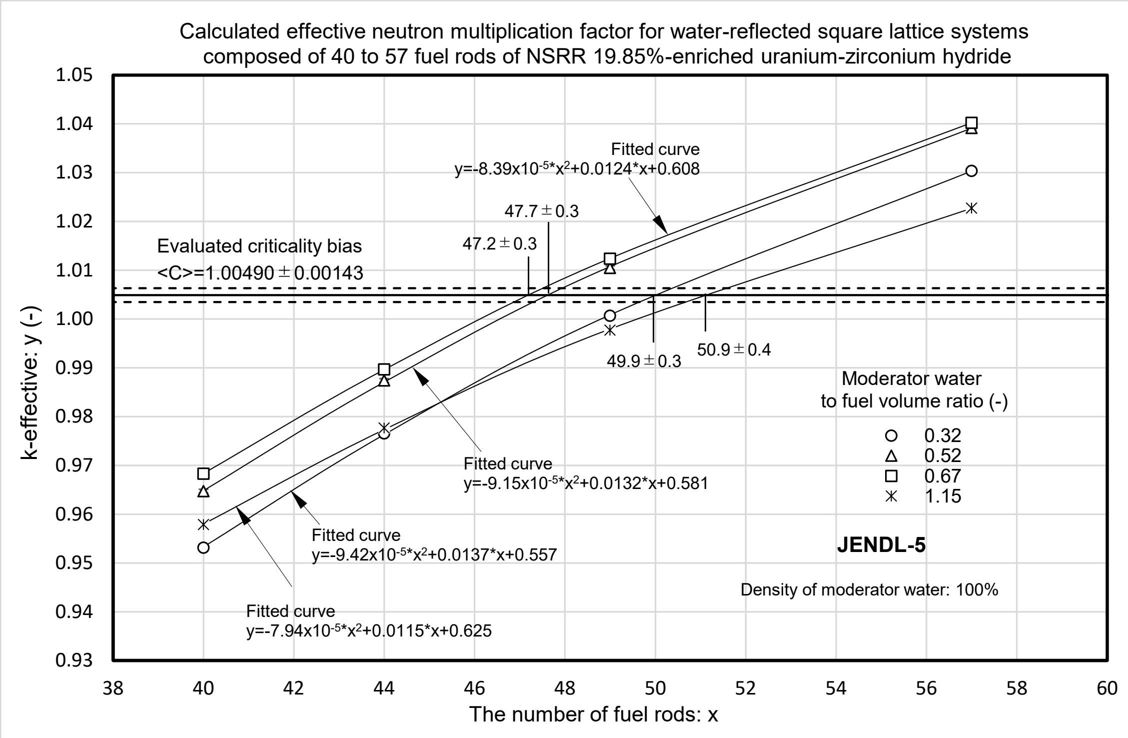


Fig.3.3.1.2 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-5, criticality bias evaluated by 37 benchmark cases.

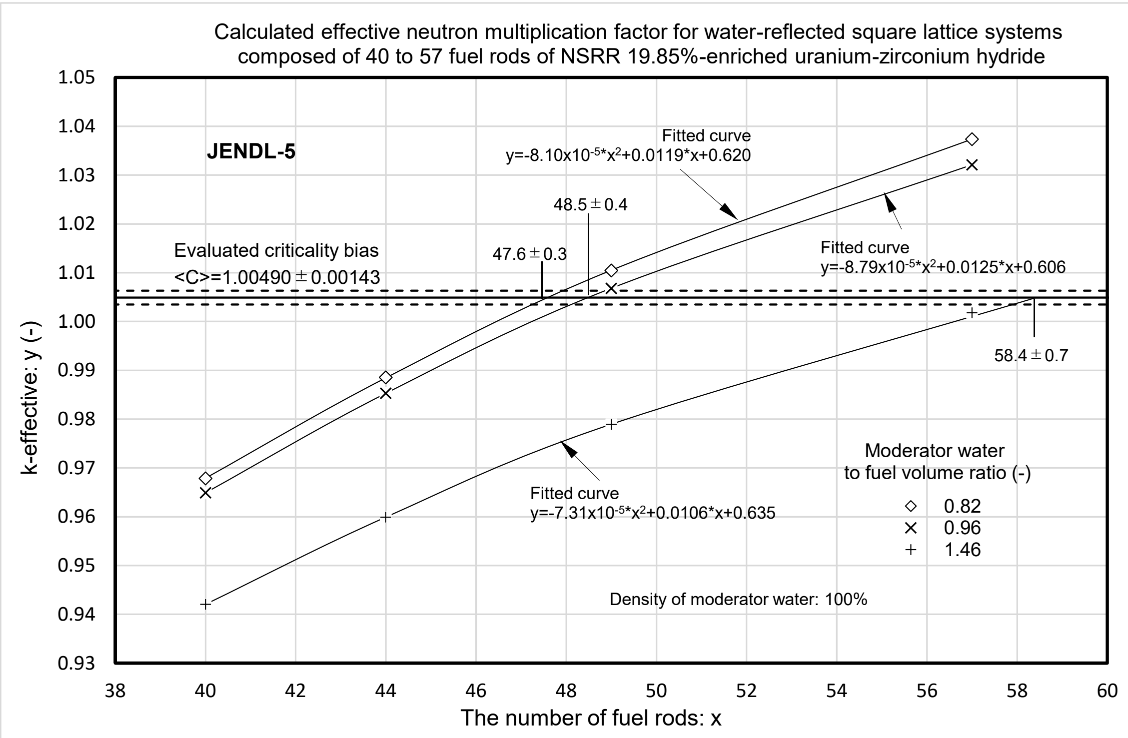


Fig.3.3.1.2(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-5, criticality bias evaluated by 37 benchmark cases.

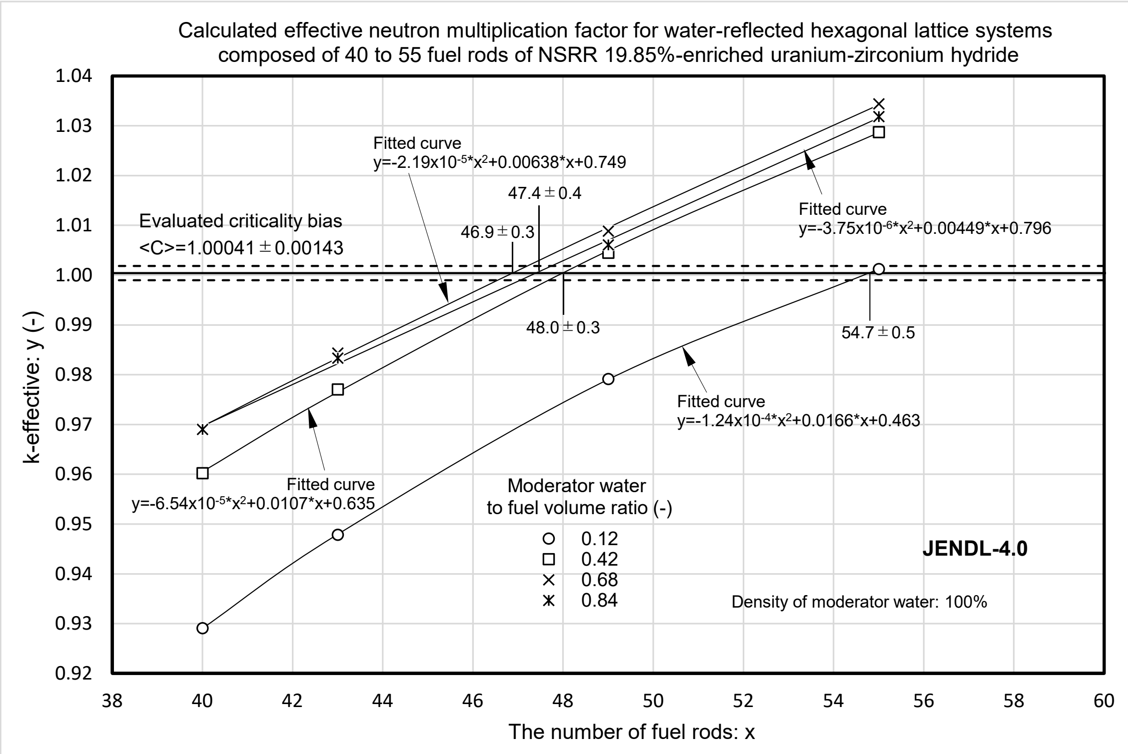


Fig.3.3.1.3 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-4.0, criticality bias evaluated by 37 benchmark cases.

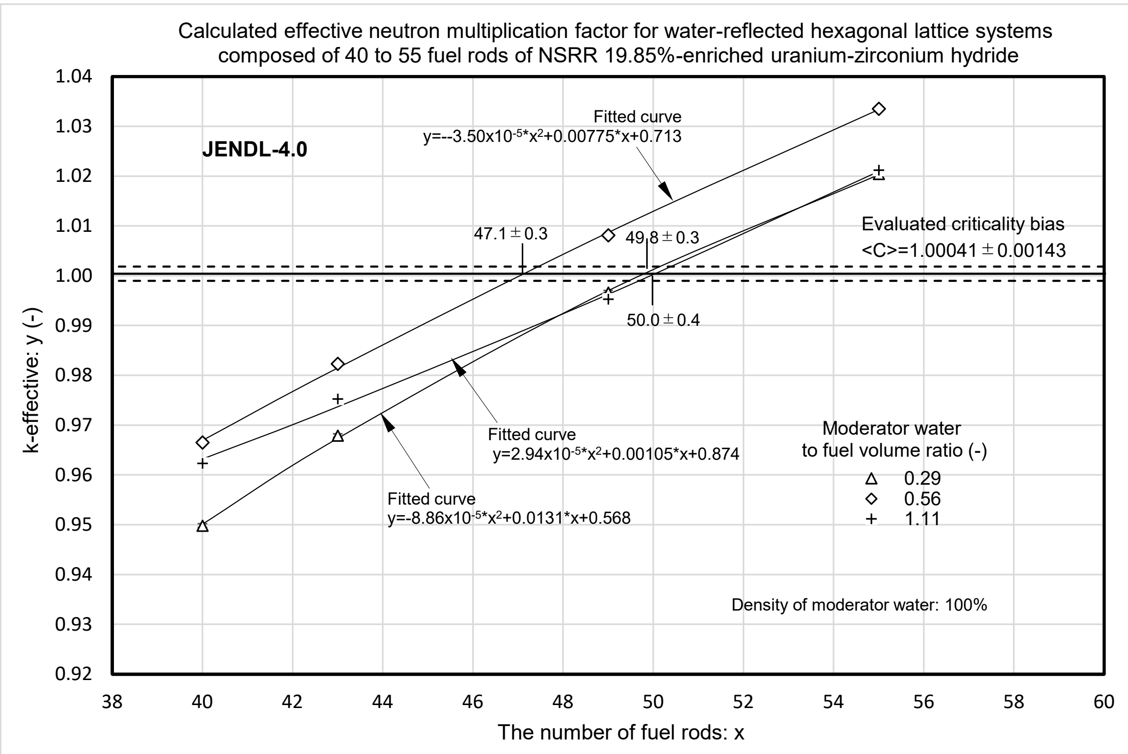


Fig.3.3.1.3(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-4.0, criticality bias evaluated by 37 benchmark cases.

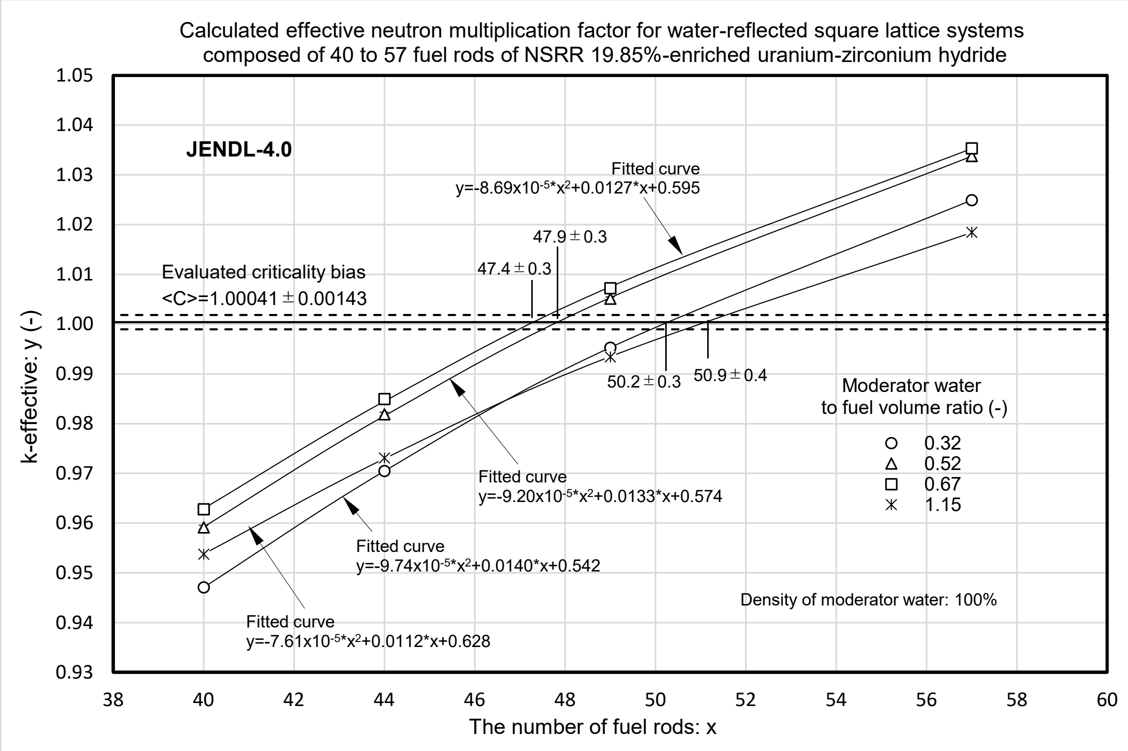


Fig.3.3.1.4 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-4.0, criticality bias evaluated by 37 benchmark cases.

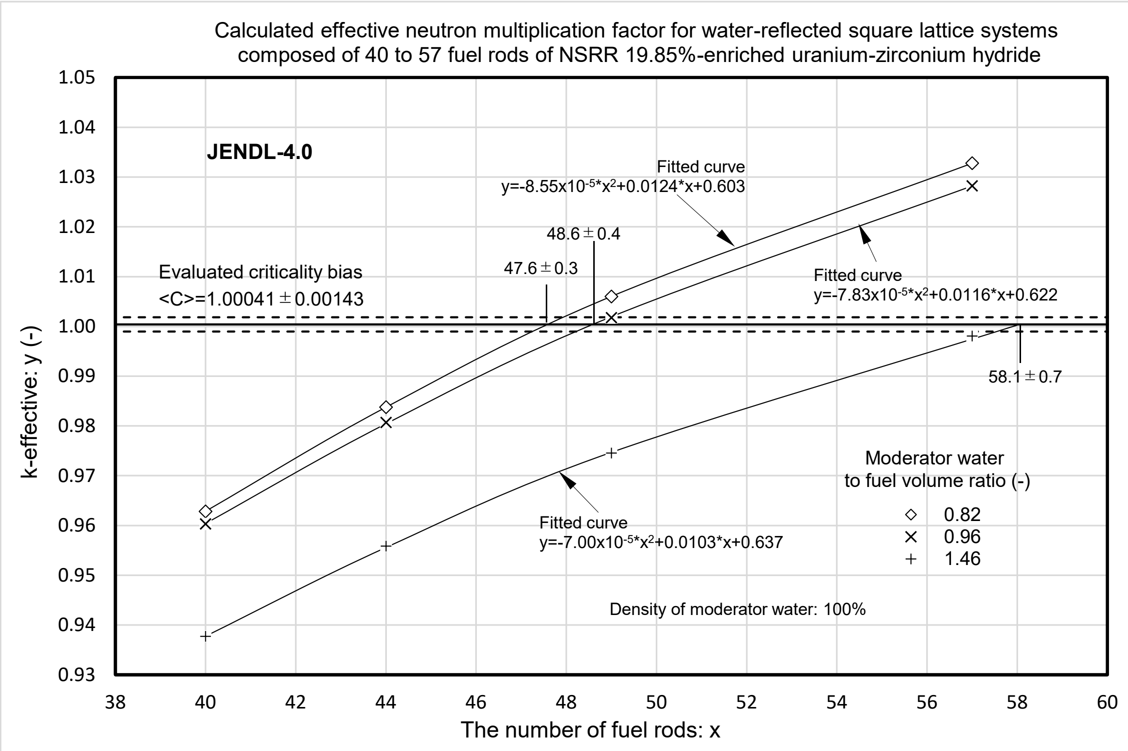


Fig.3.3.1.4(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-4.0, criticality bias evaluated by 37 benchmark cases.

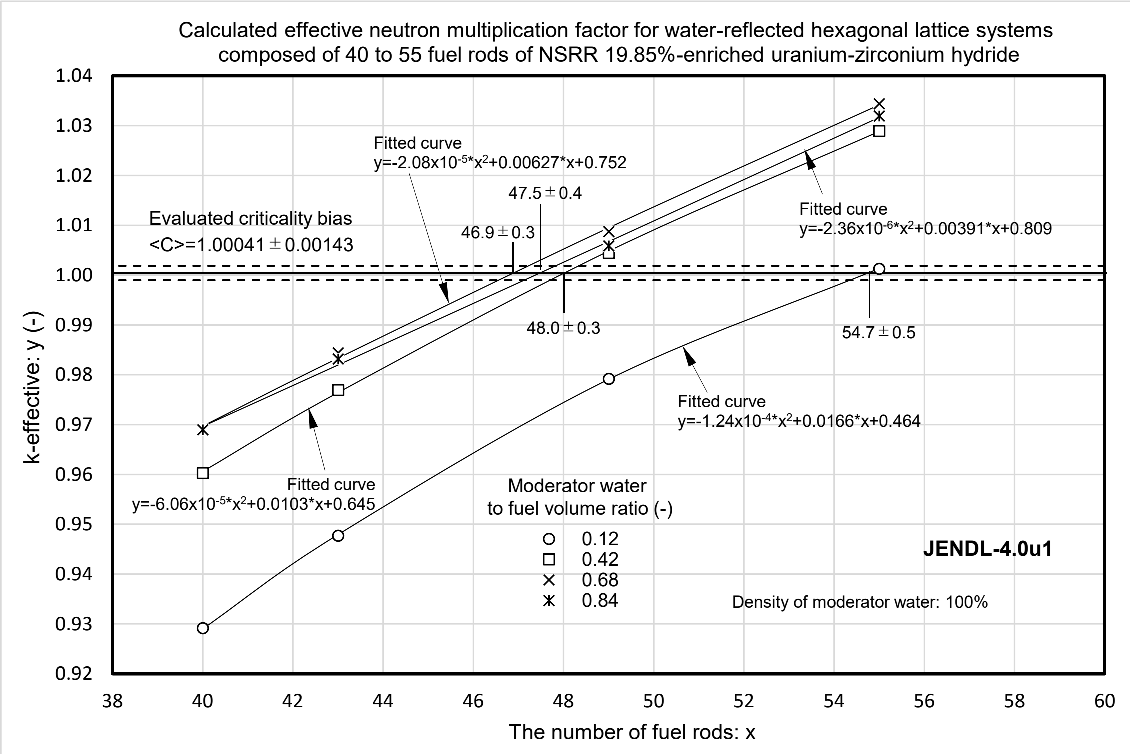


Fig.3.3.1.5 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-4.0u1, criticality bias evaluated by 37 benchmark cases.

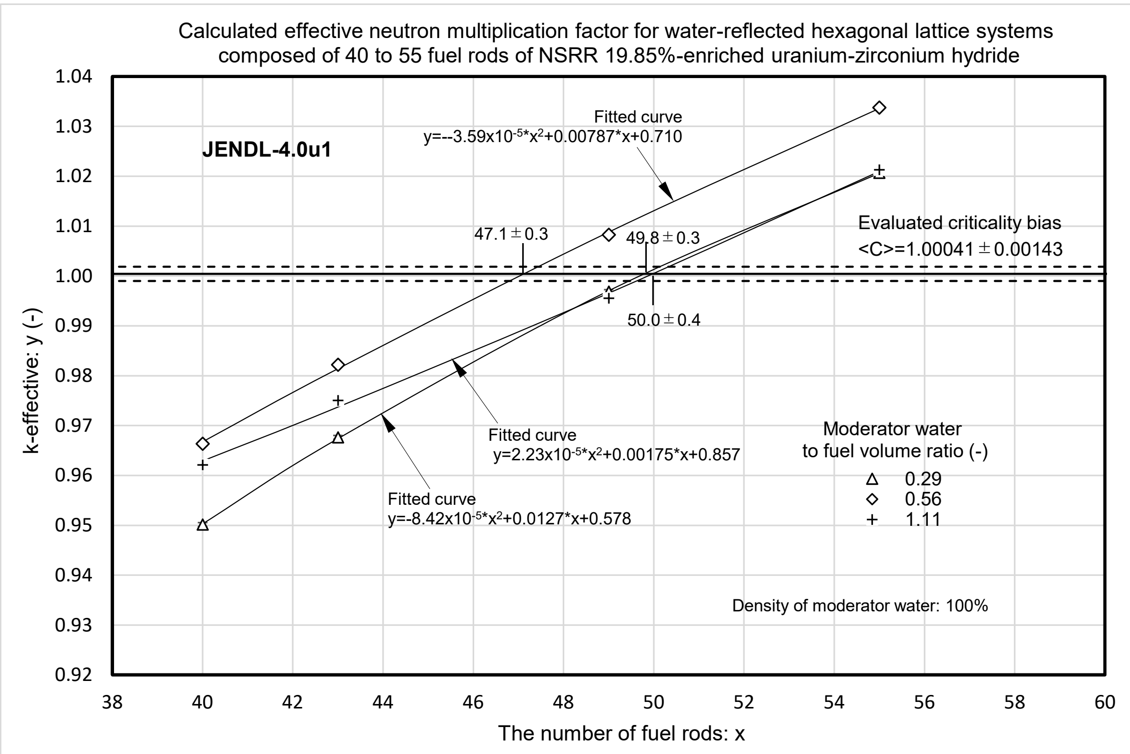


Fig.3.3.1.5(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-4.0u1, criticality bias evaluated by 37 benchmark cases.

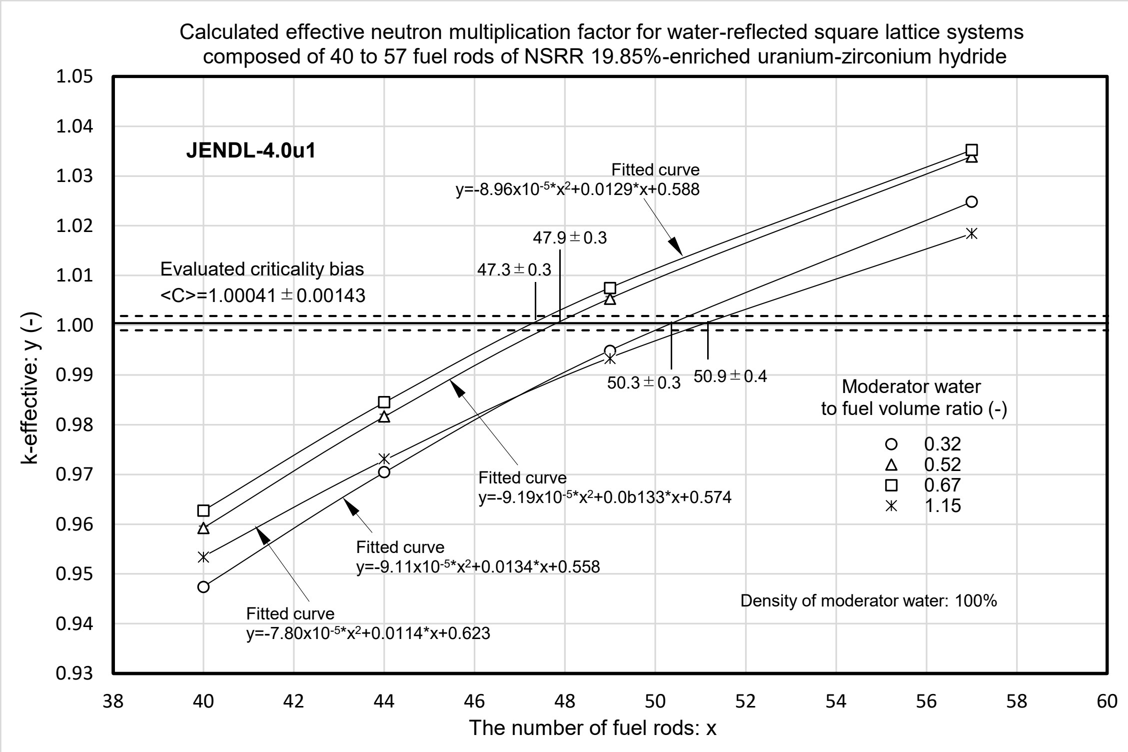


Fig.3.3.1.6 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-4.0u1, criticality bias evaluated by 37 benchmark cases.

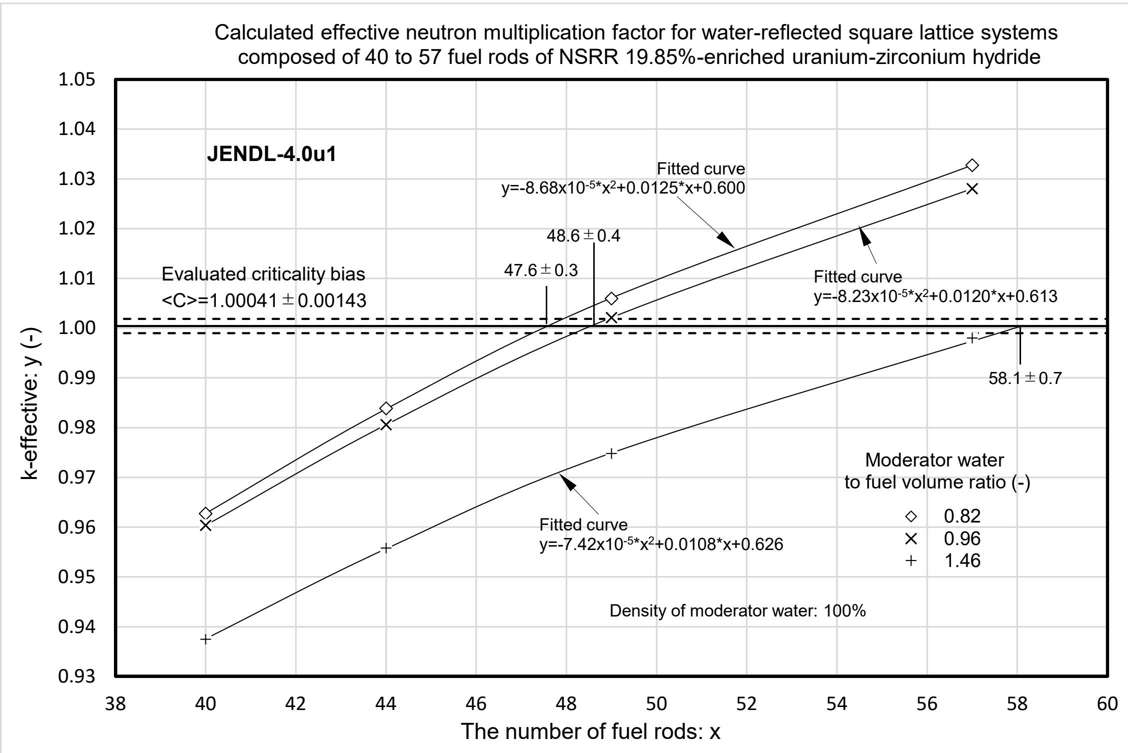


Fig.3.3.1.6(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-4.0u1, criticality bias evaluated by 37 benchmark cases.

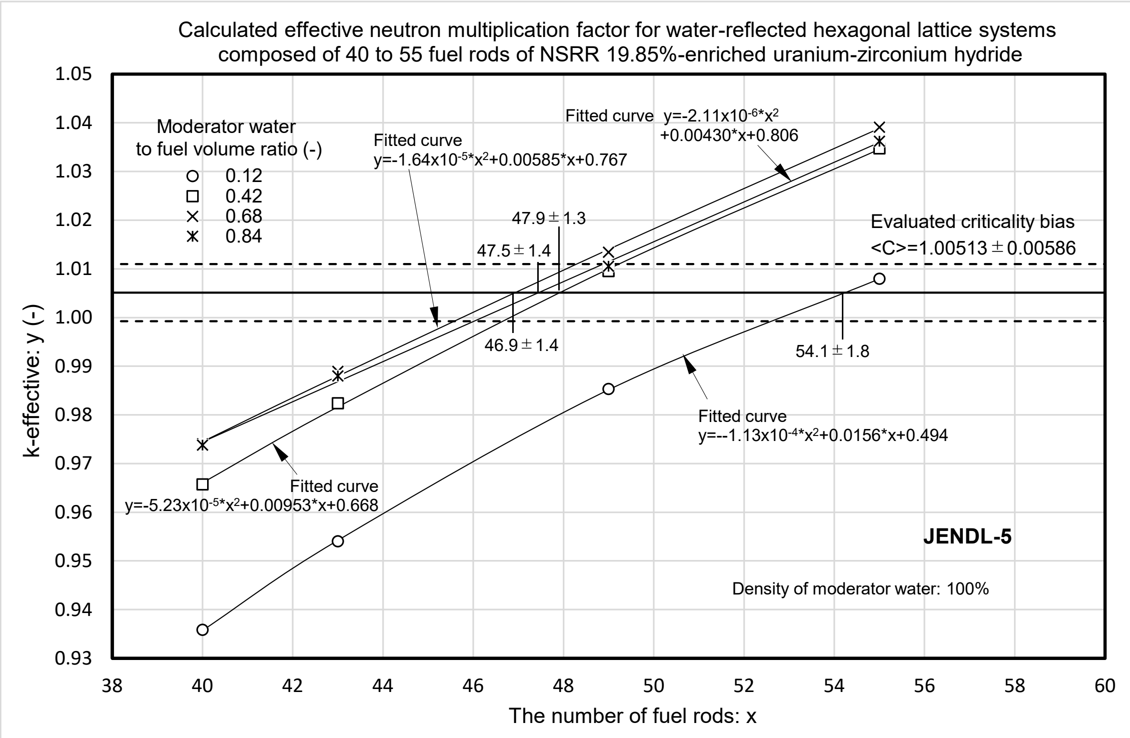


Fig.3.3.1.7 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-5, criticality bias evaluated by 2 benchmark cases.

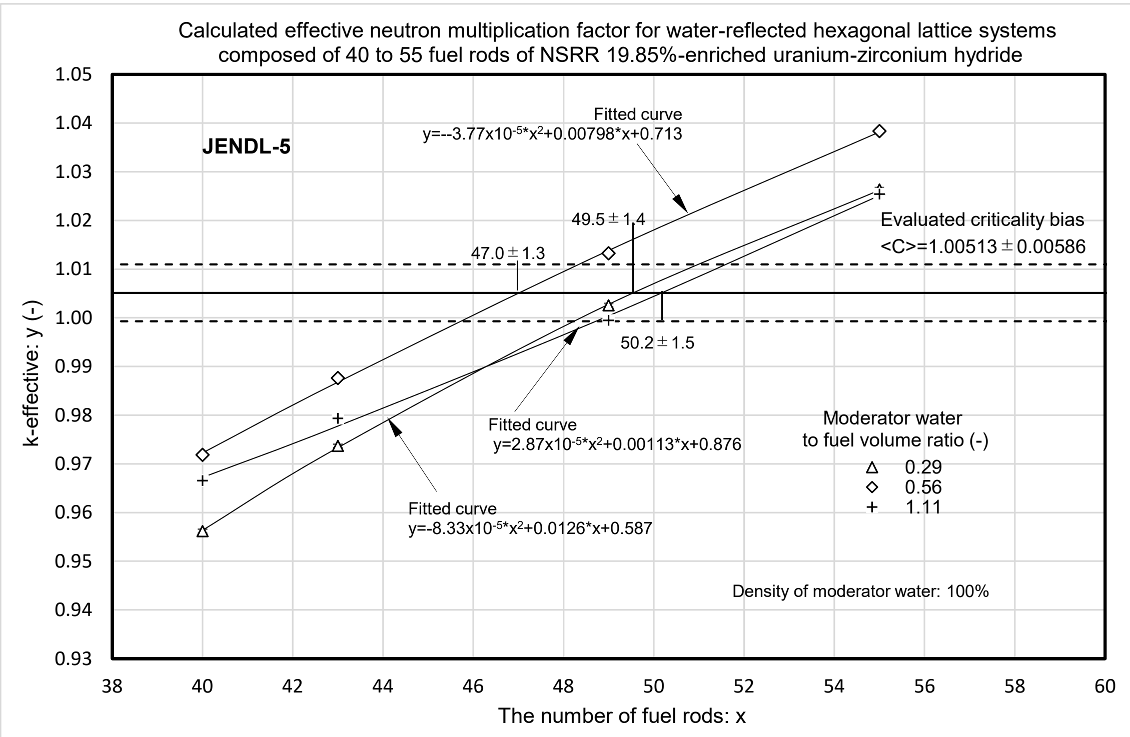


Fig.3.3.1.7(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-5, criticality bias evaluated by 2 benchmark cases.

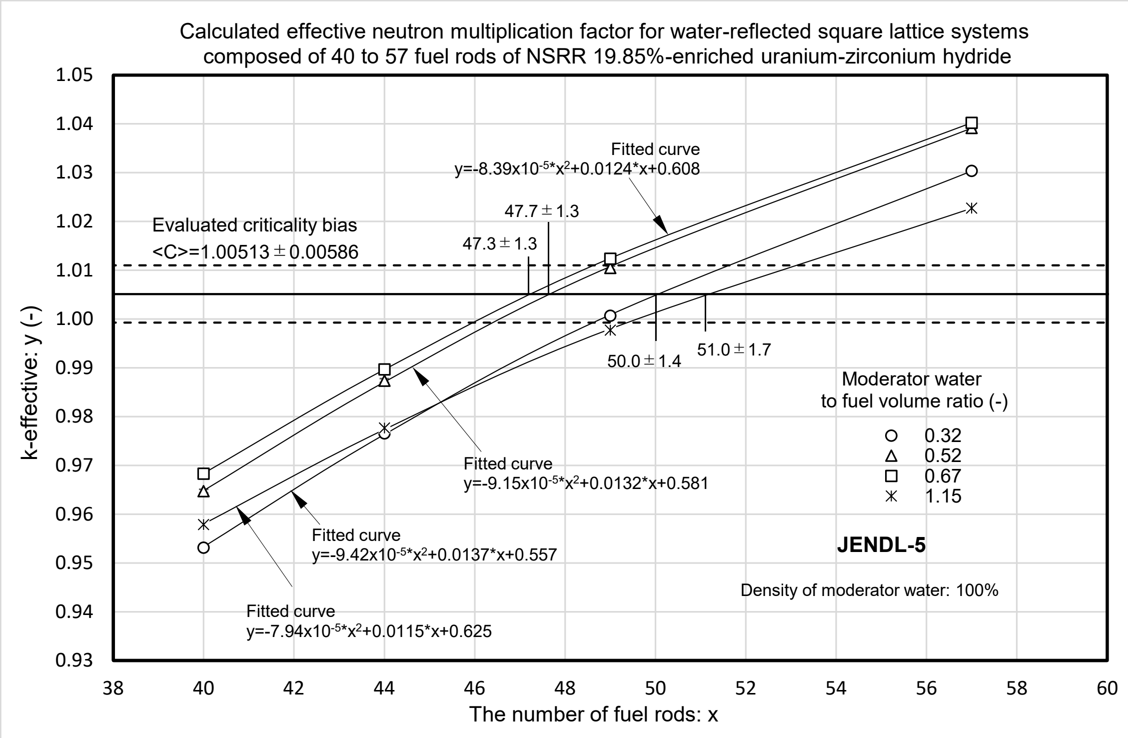


Fig.3.3.1.8 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-5, criticality bias evaluated by 2 benchmark cases.

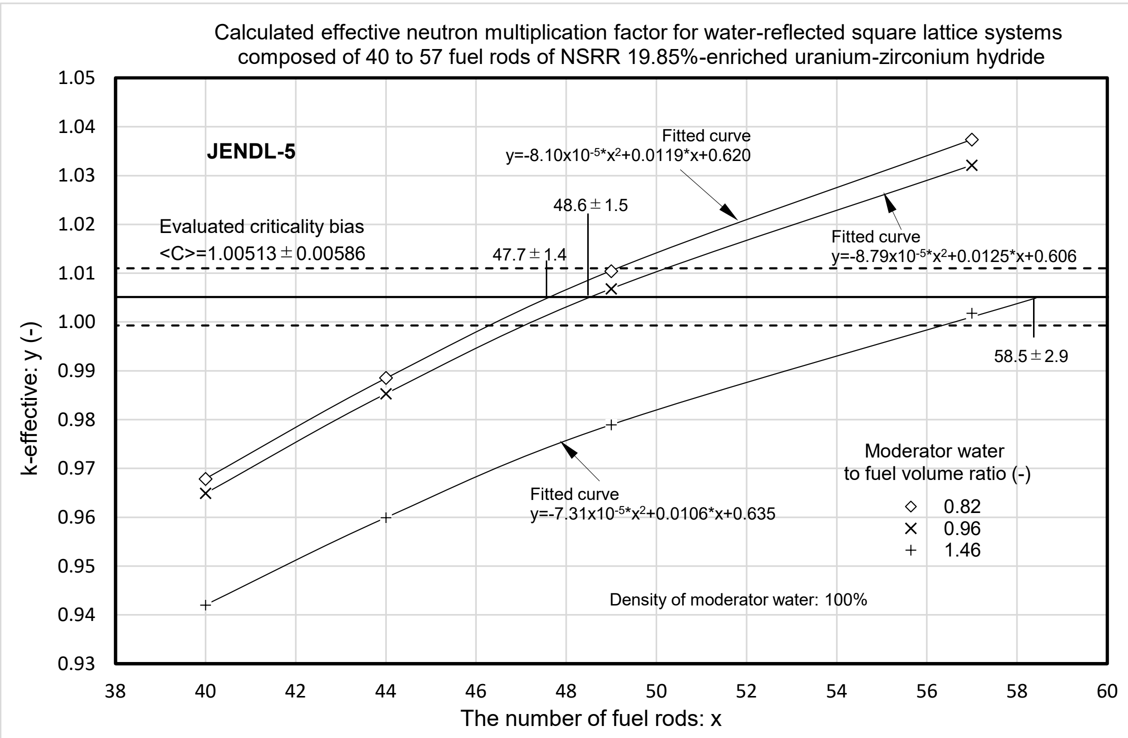


Fig.3.3.1.8(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-5, criticality bias evaluated by 2 benchmark cases.

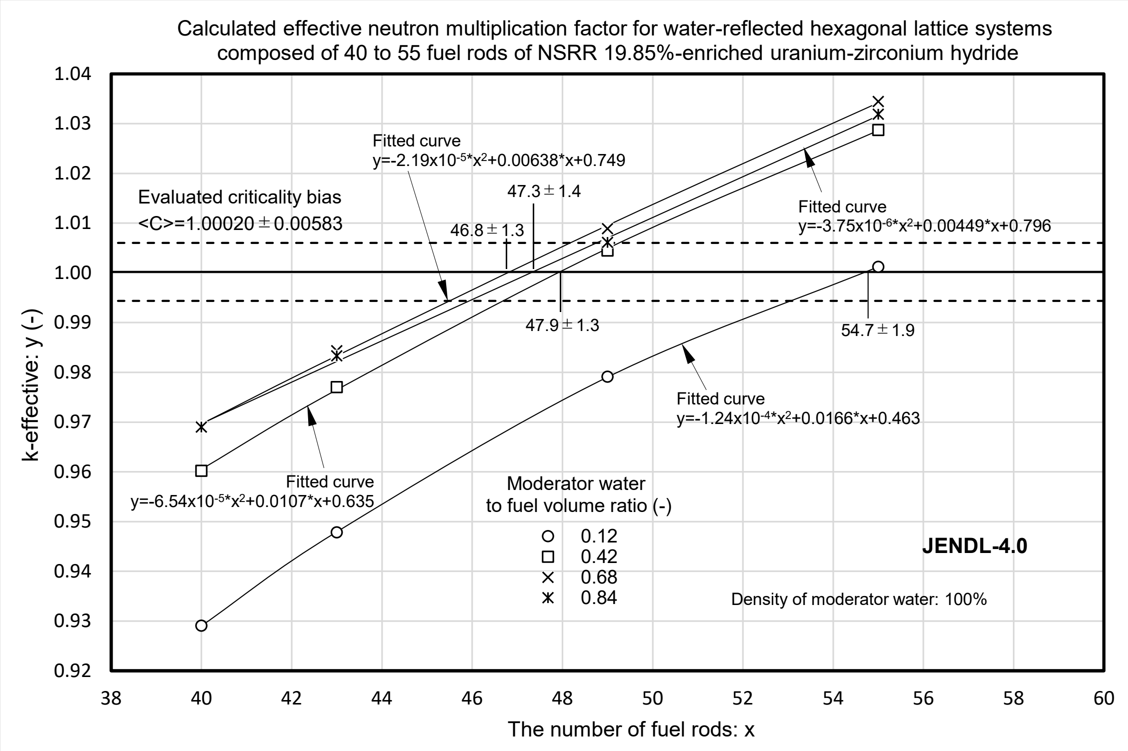


Fig.3.3.1.9 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-4.0, criticality bias evaluated by 2 benchmark cases.

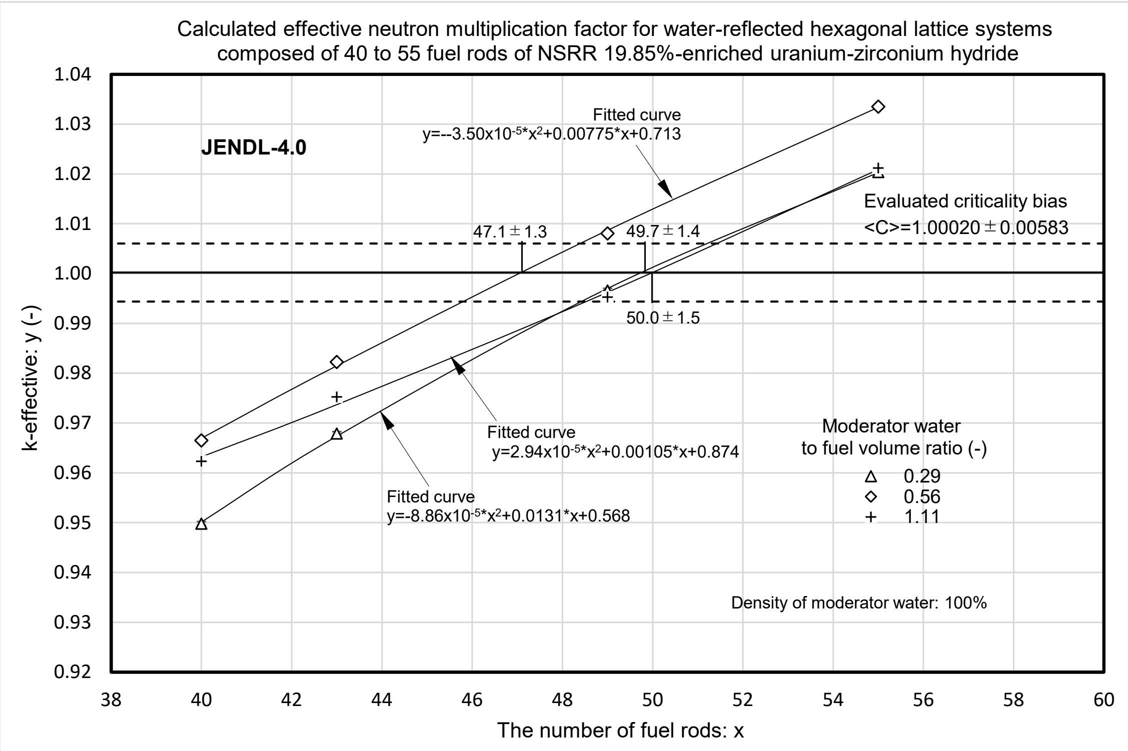


Fig.3.3.1.9(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-4.0, criticality bias evaluated by 2 benchmark cases.

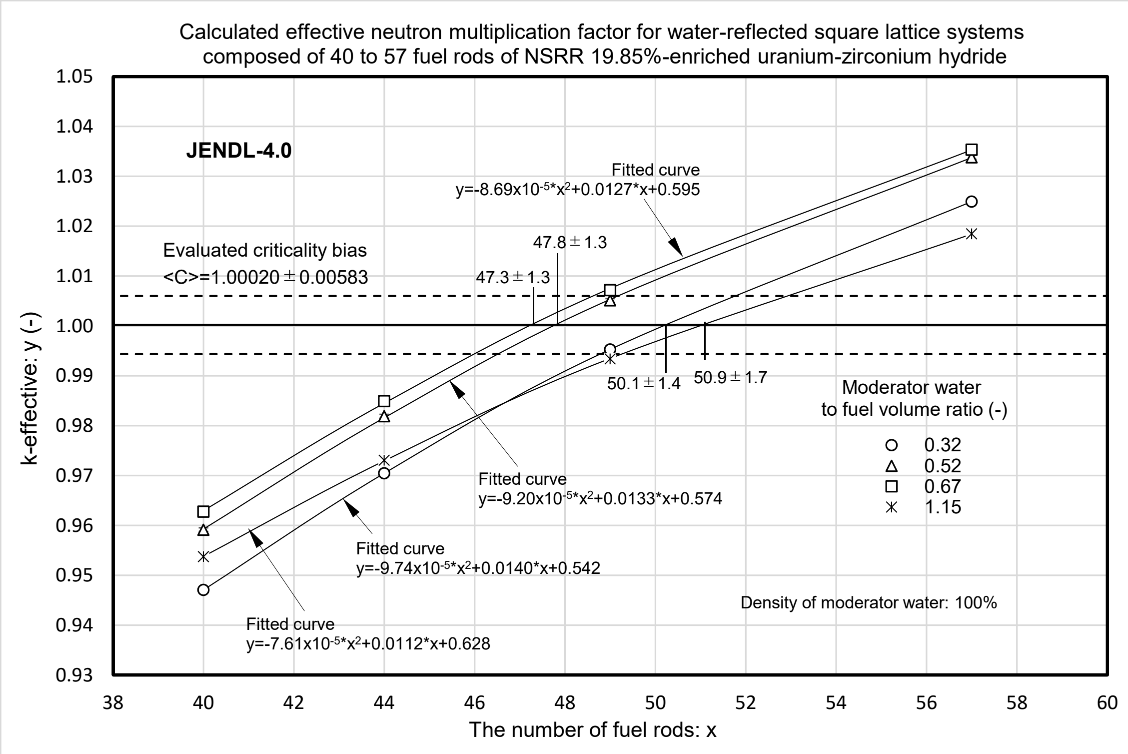


Fig.3.3.1.10 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-4.0, criticality bias evaluated by 2 benchmark cases.

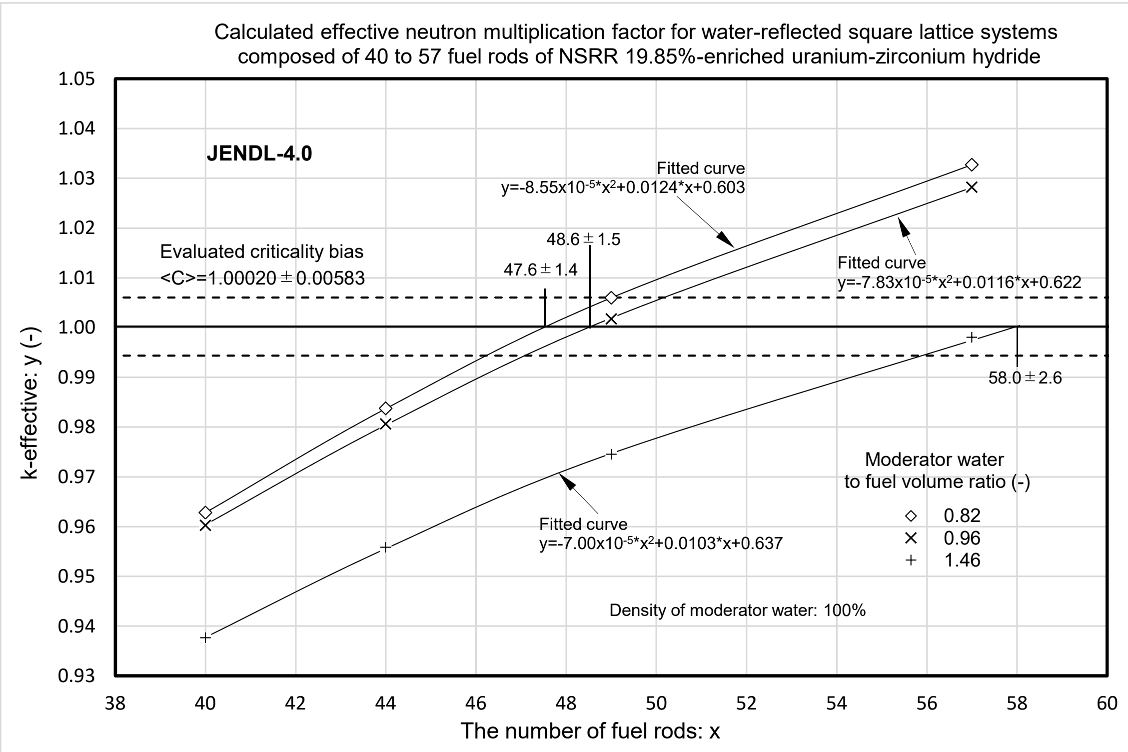


Fig.3.3.1.10(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-4.0, criticality bias evaluated by 2 benchmark cases.

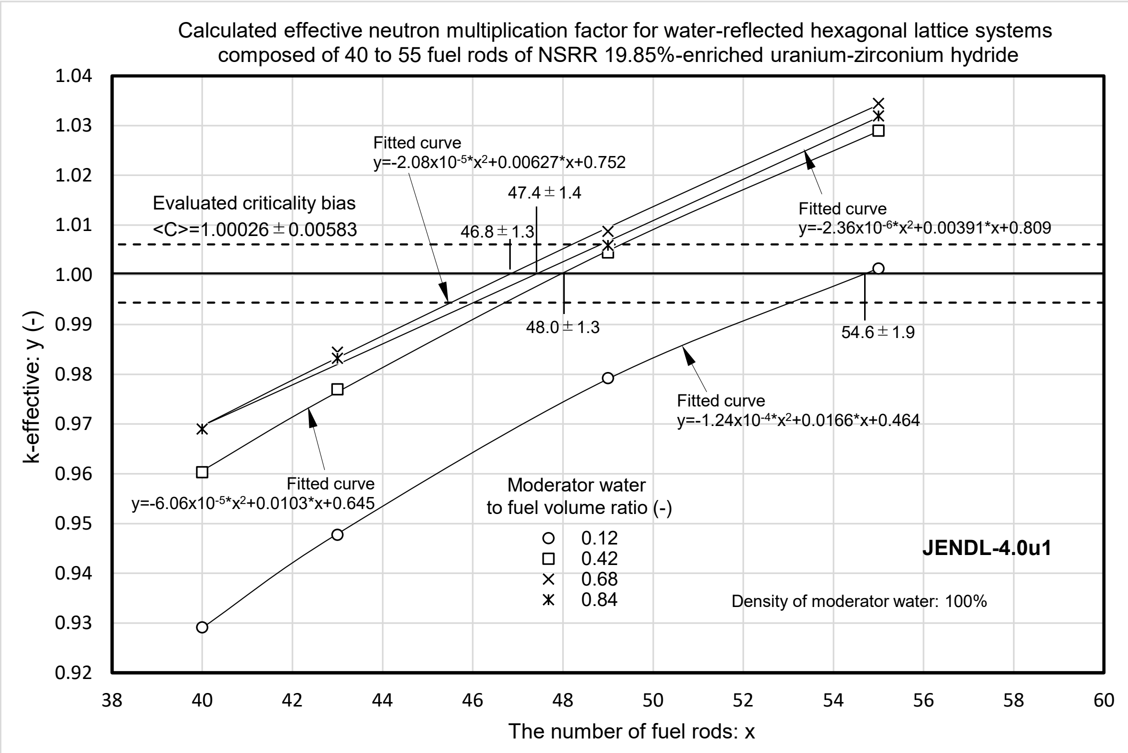


Fig.3.3.1.11 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-4.0u1, criticality bias evaluated by 2 benchmark cases.

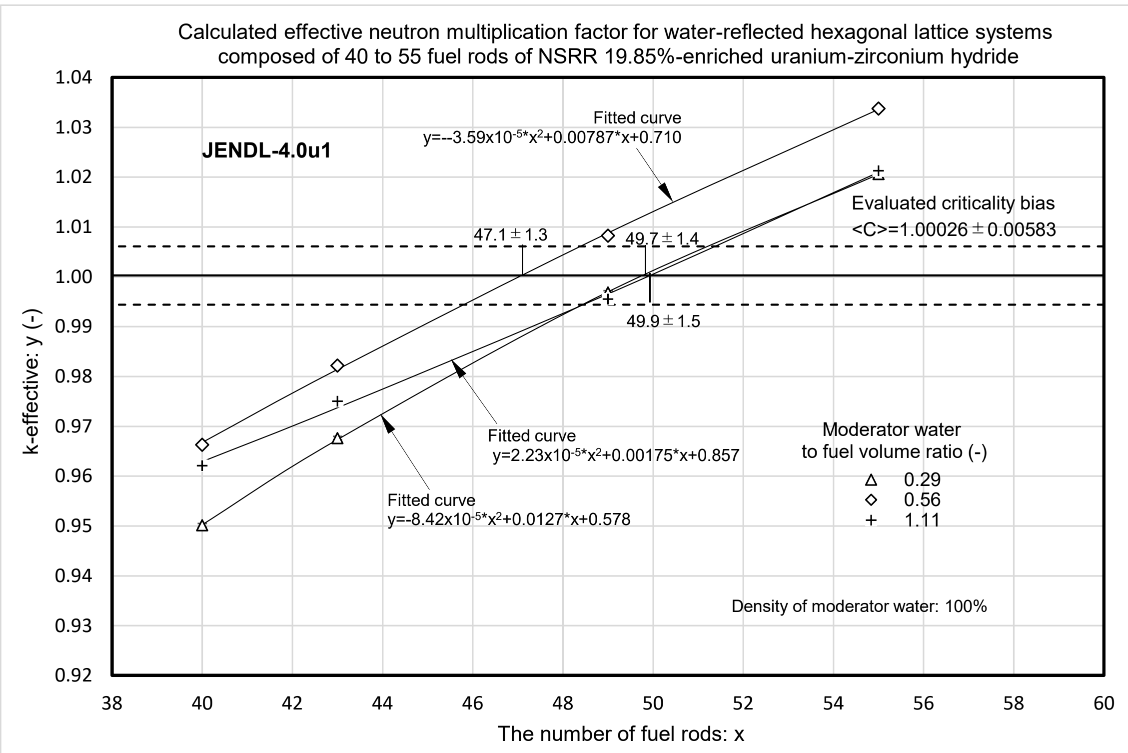


Fig.3.3.1.11(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected hexagonal lattice systems, using JENDL-4.0u1, criticality bias evaluated by 2 benchmark cases.

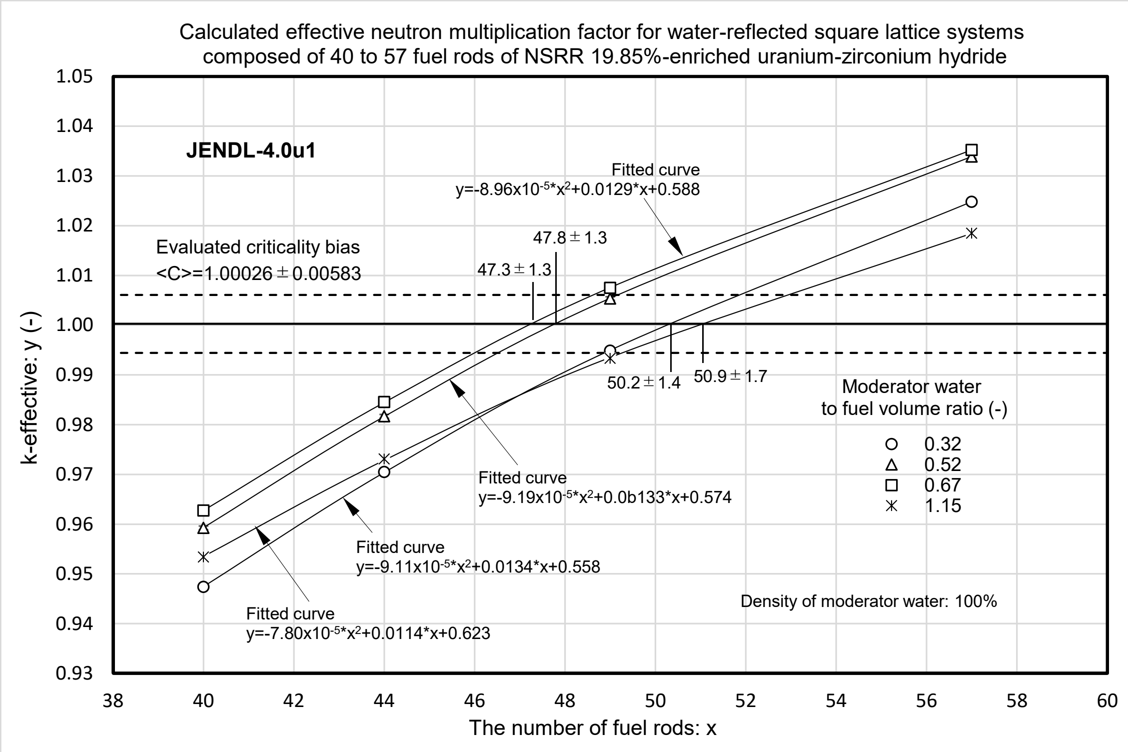


Fig.3.3.1.12 Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-4.0u1, criticality bias evaluated by 2 benchmark cases.

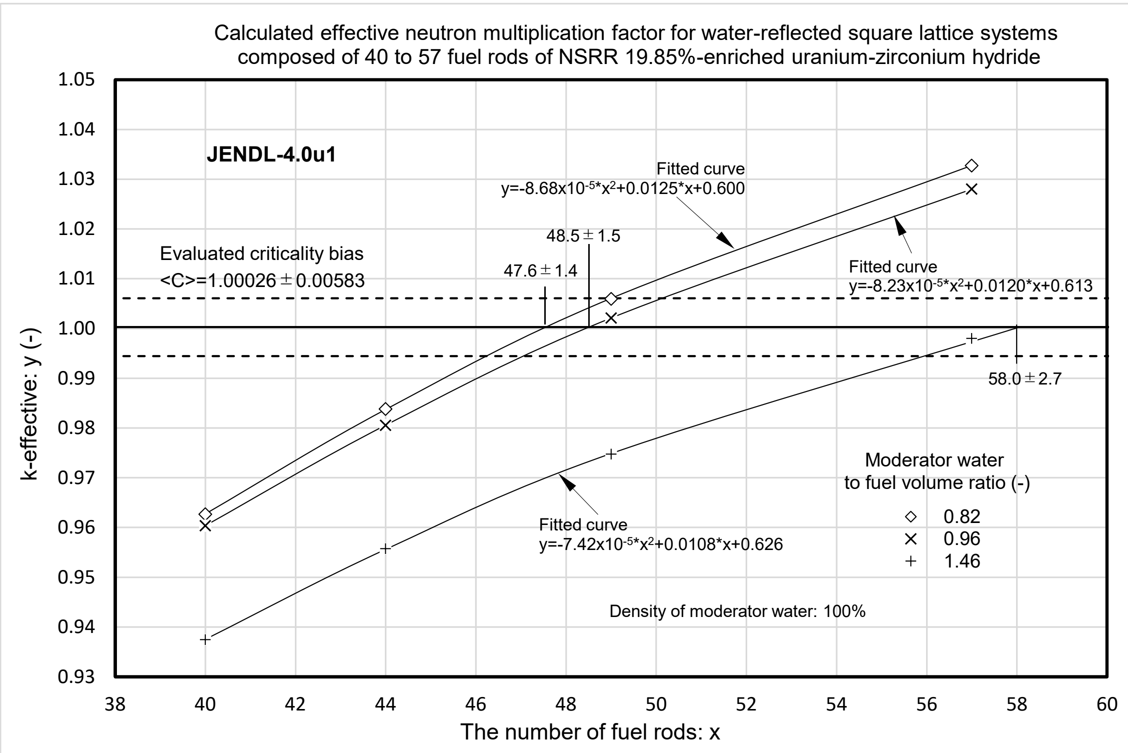


Fig.3.3.1.12(contd.) Relation between effective neutron multiplication factor and the number of fuel rods for water-reflected square lattice systems, using JENDL-4.0u1, criticality bias evaluated by 2 benchmark cases.

Tables 3.3.1.1 and 3.3.1.2 summarize the most probable values of the critical number of fuel rods for the finite hexagonal and square lattices, respectively. It is confirmed that the difference in the critical number of fuel rods among the libraries is within three times its σ whilst the averaged difference in k_{eff} between the JENDL-5 and JENDL-4.0 libraries is larger than three times its σ, as presented in Appendix-4. The criticality biases were evaluated using the NSRR detailed benchmark models, of which VR is 0.42, as explained in Appendix-6. This value of VR is the vicinity of the VR making k_{eff} maximum in the finite lattice systems subjected here. Hence, it is considered that the difference in the criticality bias among the libraries is almost same as the difference in k_{eff} of the finite lattice systems used for the evaluation of the critical number of fuel rods. For this reason, it is considered that significant difference is not likely to occur in the critical number of fuel rods among the libraries.

In addition, it is seen that the differences in the critical number of fuel rods between two sorts of criticality biases are quite small, but their errors are enlarged if the criticality bias evaluated by 2 benchmark cases is adopted.

Table 3.3.1.1 Critical number of fuel rods for water-reflected hexagonal lattice systems, density of the moderator water: 100 %, using two sorts of criticality biases evaluated by 37 and 2 benchmark cases.

VR	Critical number of fuel rods ± 3σ					
	JENDL-5		JENDL-4.0		JENDL-4.0u1	
	37 cases*1	2 cases*2	37 cases*1	2 cases*2	37 cases*1	2 cases*2
0.12	54.0 ± 0.4	54.1 ± 1.8	54.7 ± 0.5	54.7 ± 1.9	54.7 ± 0.5	54.6 ± 1.9
0.29	49.5 ± 0.3	49.5 ± 1.4	49.8 ± 0.3	49.7 ± 1.4	49.8 ± 0.3	49.7 ± 1.4
0.42	47.9 ± 0.3	47.9 ± 1.3	48.0 ± 0.3	47.9 ± 1.3	48.0 ± 0.3	48.0 ± 1.3
0.56	46.9 ± 0.3	47.0 ± 1.3	47.1 ± 0.3	47.1 ± 1.3	47.1 ± 0.3	47.1 ± 1.3
0.68	46.9 ± 0.3	46.9 ± 1.4	46.9 ± 0.3	46.8 ± 1.3	46.9 ± 0.3	46.8 ± 1.3
0.84	47.4 ± 0.4	47.5 ± 1.4	47.4 ± 0.4	47.3 ± 1.4	47.5 ± 0.4	47.4 ± 1.4
1.11	50.1 ± 0.4	50.2 ± 1.5	50.0 ± 0.4	50.0 ± 1.5	50.0 ± 0.4	49.9 ± 1.5

*1 Using criticality bias evaluated by 37 benchmark cases shown in Appendix-6.
*2 Using criticality bias evaluated by 2 benchmark cases shown in Appendix-6.

Table 3.3.1.2 Critical number of fuel rods for water-reflected square lattice systems, density of the moderator water: 100 %, using two sorts of criticality biases evaluated by 37 and 2 benchmark cases.

VR	Critical number of fuel rods ± 3σ					
	JENDL-5		JENDL-4.0		JENDL-4.0u1	
	37 cases*1	2 cases*2	37 cases*1	2 cases*2	37 cases*1	2 cases*2
0.30	49.9 ± 0.3	50.0 ± 1.4	50.2 ± 0.3	50.1 ± 1.4	50.3 ± 0.3	50.2 ± 1.4
0.49	47.7 ± 0.3	47.7 ± 1.3	47.9 ± 0.3	47.8 ± 1.3	47.9 ± 0.3	47.8 ± 1.3
0.64	47.2 ± 0.3	47.3 ± 1.3	47.4 ± 0.3	47.3 ± 1.3	47.3 ± 0.3	47.3 ± 1.3
0.79	47.6 ± 0.3	47.7 ± 1.4	47.6 ± 0.3	47.6 ± 1.4	47.6 ± 0.3	47.6 ± 1.4
0.92	48.5 ± 0.4	48.6 ± 1.5	48.6 ± 0.4	48.6 ± 1.5	48.6 ± 0.4	48.5 ± 1.5
1.10	50.9 ± 0.4	51.0 ± 1.7	50.9 ± 0.4	50.9 ± 1.7	50.9 ± 0.4	50.9 ± 1.7
1.40	58.4 ± 0.7	58.5 ± 2.9	58.1 ± 0.7	58.0 ± 2.6	58.1 ± 0.7	58.0 ± 2.7

*1 Using criticality bias evaluated by 37 benchmark cases shown in Appendix-6.
*2 Using criticality bias evaluated by 2 benchmark cases shown in Appendix-6.

Using the data listed in Tables 3.3.1.1 and 3.3.1.2, the values of the critical number of fuel rod were fitted to the fourth-degree polynomials of VR by the least square technique. The polynomial represents a convex downward curve as VR increases so that the minimum critical number of fuel rods was evaluated by the VR value making the first-order derivation of the polynomial zero.

Figure 3.3.1.13 shows the fitted fourth-degree polynomial, and the minimum critical number of fuel rods based on the criticality bias evaluated by 37 benchmark cases using the JENDL-5 library. As seen in Fig.3.3.1.13, the probable values of the minimum critical number of fuel rods of the finite hexagonal and square lattices were evaluated to be 46.8 ± 0.2 and 47.2 ± 0.2, respectively. It is also confirmed that the minimum critical number of fuel rods of the square lattices is slightly larger than that of the hexagonal lattice. It is considered that the fuel cell region of the finite lattices composed of the small number of fuel rods is difficult to make near cylindrical shapes which bring the smallest horizontal geometrical buckling. For this reason, it is considered that the difference in the minimum critical number of fuel rods occurs between the hexagonal and square lattices*5.

*5 There were not significant differences in the probable values of the minimum critical number of low-enriched uranium dioxide fuel rods, which were evaluated to be 170 to 190 fuel rods in the former evaluation [3)], between the hexagonal and square lattices.

Figures 3.3.1.14(1) and 3.3.1.14(2) show the differences in the minimum critical number of fuel rods among the libraries. It is also seen that the differences among the libraries are quite small.

Similarly, the results of the minimum critical number of fuel rods based on the criticality bias evaluated by 2 benchmark cases are shown in Figs. 3.3.1.15(1) and 3.3.1.15(2).

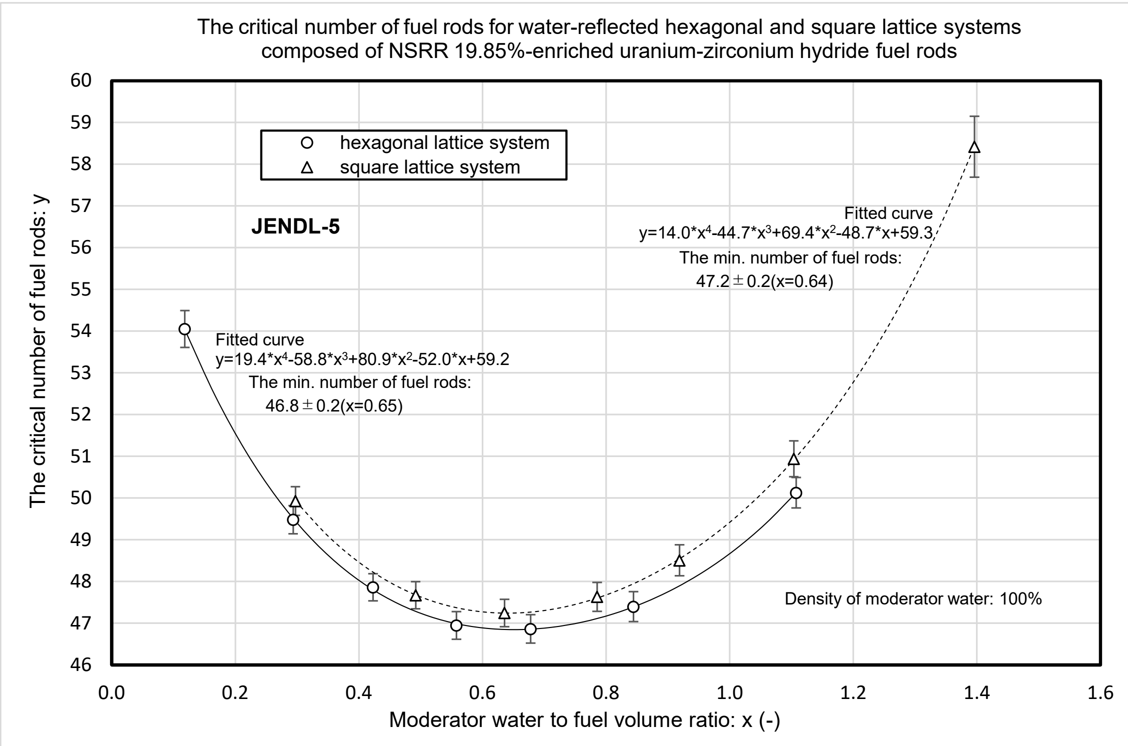


Fig.3.3.1.13 Critical number of fuel rods as function of moderator water to fuel volume ratio for water-reflected hexagonal and square lattice systems, using JENDL-5, criticality bias evaluated by 37 benchmark cases.

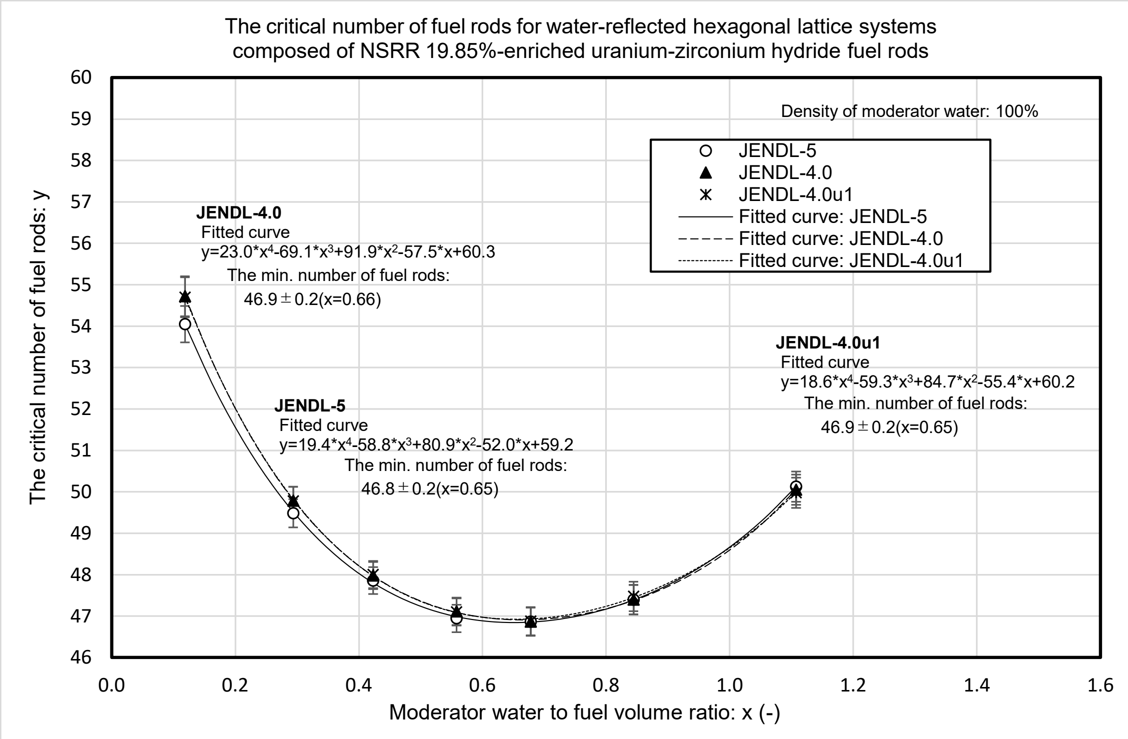


Fig.3.3.1.14(1) Comparison of critical number of fuel rods as function of moderator water to fuel volume ratio for water-reflected hexagonal lattice systems among JENDL libraries, criticality bias evaluated by 37 benchmark cases.

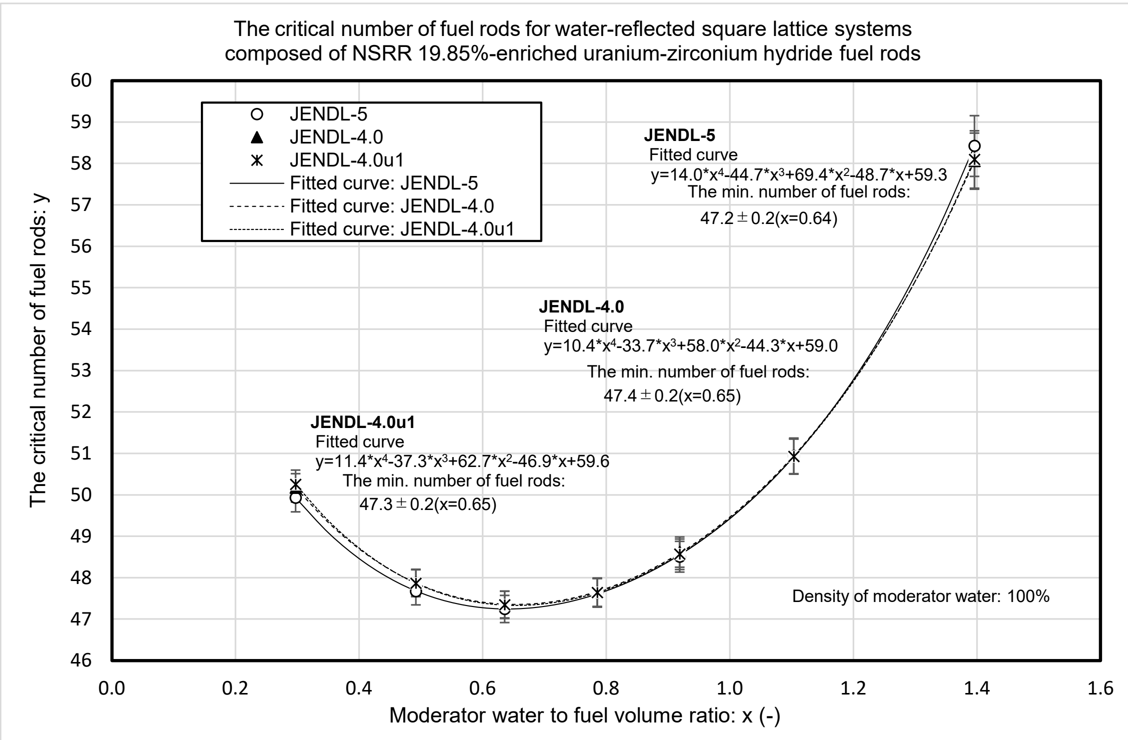


Fig.3.3.1.14(2) Comparison of critical number of fuel rods as function of moderator water to fuel volume ratio for water-reflected square lattice systems among JENDL libraries, criticality bias evaluated by 37 benchmark cases.

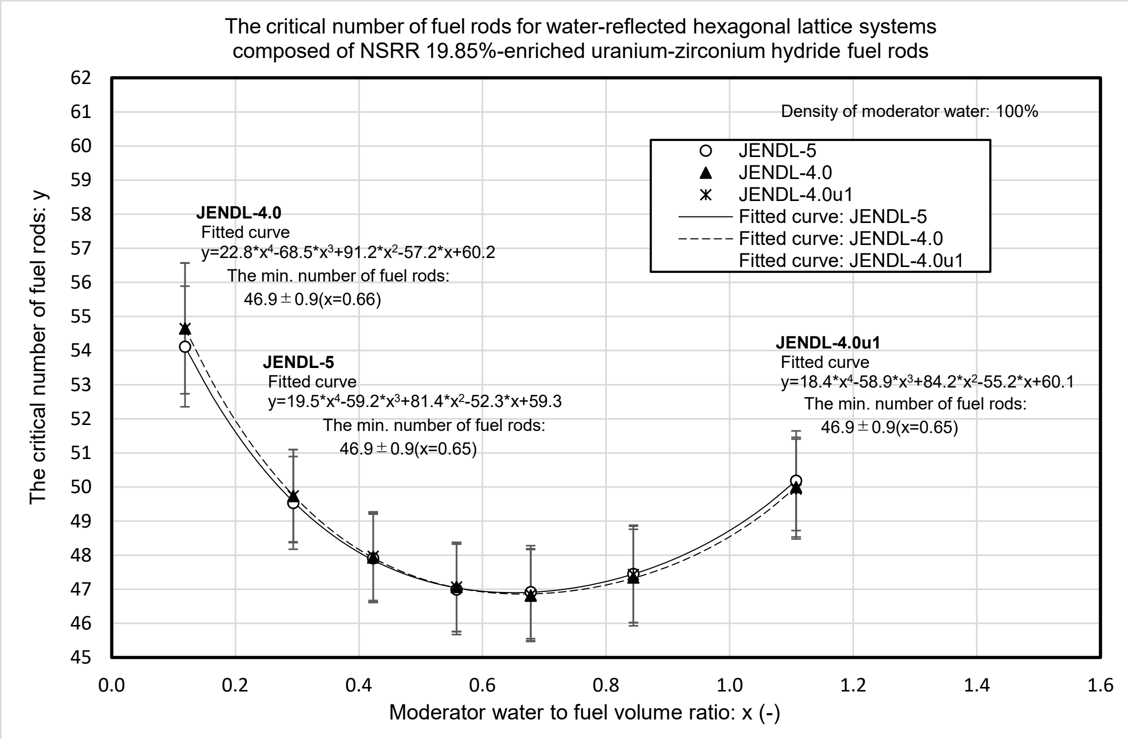


Fig.3.3.1.15(1) Comparison of critical number of fuel rods as function of moderator water to fuel volume ratio for water-reflected hexagonal lattice systems among JENDL libraries, criticality bias evaluated by 2 benchmark cases.

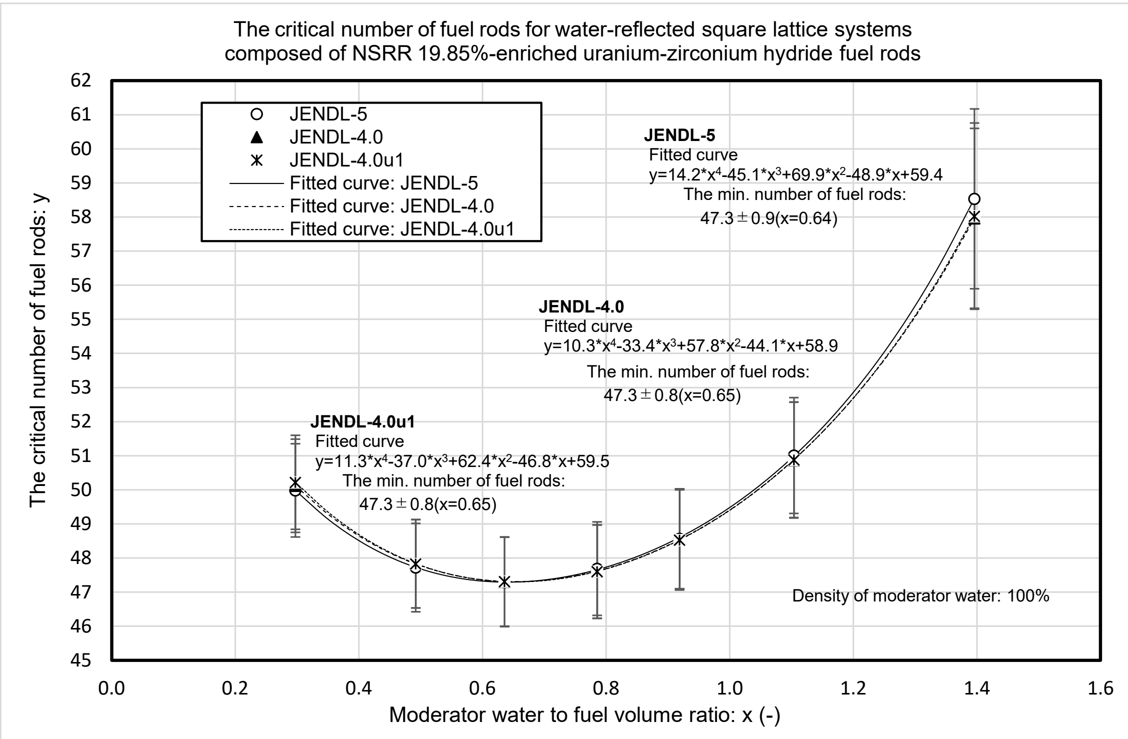


Fig.3.3.1.15(2) Comparison of critical number of fuel rods as function of moderator water to fuel volume ratio for water-reflected square lattice systems among JENDL libraries, criticality bias evaluated by 2 benchmark cases.

Table 3.3.1.3 summarizes the most probable values of the minimum critical number of fuel rods for the finite hexagonal and square lattices. In the former evaluation[3)] based on the simplified model of the NSRR fuel rod by using the MVP version 2 code with the JENDL-4.0 library, the values of the minimum critical number of fuel rods of the finite hexagonal and square lattices were evaluated to be 43.9 ± 0.2 and 44.7 ± 0.2. As listed in Table 3.3.1.3, the values of the minimum critical number of fuel rods in the present re-evaluation are larger than those in the former evaluation. It is considered that this is due to the neglection of the molybdenum disc, the top/bottom plugs, which behave as neutron ,absorbers, and the impurities in the former evaluation, as mentioned in Sec.2.1 and Sec.2.4, and about 1.2 % smaller uranium mass inventory of the present detailed fuel rod model than that of the simplified model.

Table 3.3.1.3 Minimum critical number of fuel rods for water-reflected hexagonal and square lattice systems, density of the moderator water: 100 %, using two sorts of criticality biases evaluated by 37 and 2 benchmark cases.

Lattice	Minimum critical number of fuel rods ± 3σ					
	JENDL-5		JENDL-4.0		JENDL-4.0u1	
	37 cases*1	2 cases*2	37 cases*1	2 cases*2	37 cases*1	2 cases*2
hexagonal	46.8 ± 0.2	46.9 ± 0.9	46.9 ± 0.2	46.9 ± 0.9	46.9 ± 0.2	46.9 ± 0.9
square	47.2 ± 0.2	47.3 ± 0.8	47.4 ± 0.2	47.3 ± 0.8	47.3 ± 0.2	47.3 ± 0.9

*1 Using criticality bias evaluated by 37 benchmark cases shown in Appendix-6.
*2 Using criticality bias evaluated by 2 benchmark cases shown in Appendix-6.

Table 3.3.1.4 summarizes the most probable values of the mass of uranium-235 corresponding to the minimum critical number of fuel rods for the finite hexagonal and square lattices. In the Japanese nuclear criticality safety handbook[12)], no data on uranium-zirconium hydride is presented. For reference, the estimated lower limit of the minimum critical mass of heterogeneous UO_2-H_2O systems of which uranium-235 enrichment is 20 % is obtained to be 0.912 kg[*6] of uranium-235 using the handbook. As listed in Table 3.3.1.4, the values of the critical mass of uranium-235 in the present re-evaluation are more than two and a half times the above value from the handbook.

*6 The mass of uranium-235 is obtained by using the estimated lower limit of the minimum critical mass, 4.56 kgU of 20 % enriched uranium in heterogeneous UO_2-H_2O systems, listed in Table 5.10 of the Japanese nuclear criticality safety handbook [12)].

Table 3.3.1.4 Mass of uranium-235 corresponding to the minimum critical number of fuel rods for water-reflected hexagonal and square lattice systems, density of the moderator water: 100 %, using two sorts of criticality biases evaluated by 37 and 2 benchmark cases.

Lattice	Critical mass of uranium-235 (kg) ± 3σ					
	JENDL-5		JENDL-4.0		JENDL-4.0u1	
	37 cases*1	2 cases*2	37 cases*1	2 cases*2	37 cases*1	2 cases*2
hexagonal	2.43 ± 0.01	2.43 ± 0.05	2.43 ± 0.01	2.43 ± 0.05	2.43 ± 0.01	2.43 ± 0.05
square	2.45 ± 0.01	2.45 ± 0.04	2.46 ± 0.01	2.45 ± 0.04	2.45 ± 0.01	2.45 ± 0.05

*1 Using criticality bias evaluated by 37 benchmark cases shown in Appendix-6.
*2 Using criticality bias evaluated by 2 benchmark cases shown in Appendix-6.

3.3.2 Criticality under no moderator water condition

The relations between k_{eff} and the number of fuel rods using the JENDL-5, JENDL-4.0 and JENDL-4.0u1 libraries are shown in Figs.3.3.2.1, 3.3.2.2 and 3.3.2.3, respectively. The relations were represented as third-degree polynomials by the least square technique. Figures 3.3.2.1 to 3.3.2.3 also show the most probable critical number of fuel rods determined by an intersecting point of the third-degree polynomial and the criticality bias evaluated by 37 benchmark cases shown in Appendix-6.

Similarly, the relations between k_{eff} and the number of fuel rods using the JENDL-5, JENDL-4.0 and JENDL-4.0u1 libraries, together with the criticality bias evaluated by 2 benchmark cases shown in Appendix-6 are shown in Figs.3.3.2.4, 3.3.2.5 and 3.3.2.6, respectively.

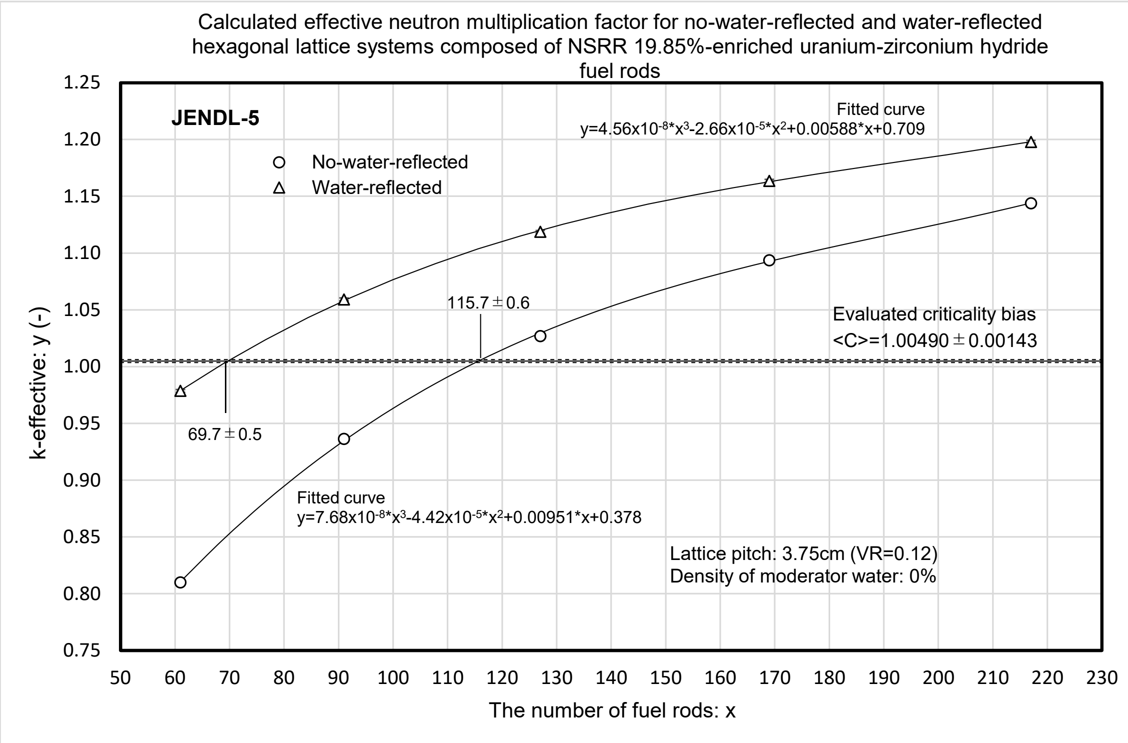


Fig.3.3.2.1 Relation between effective neutron multiplication factor and the number of fuel rods for hexagonal lattice systems under no moderator water condition, using JENDL-5, criticality bias evaluated by 37 benchmark cases.

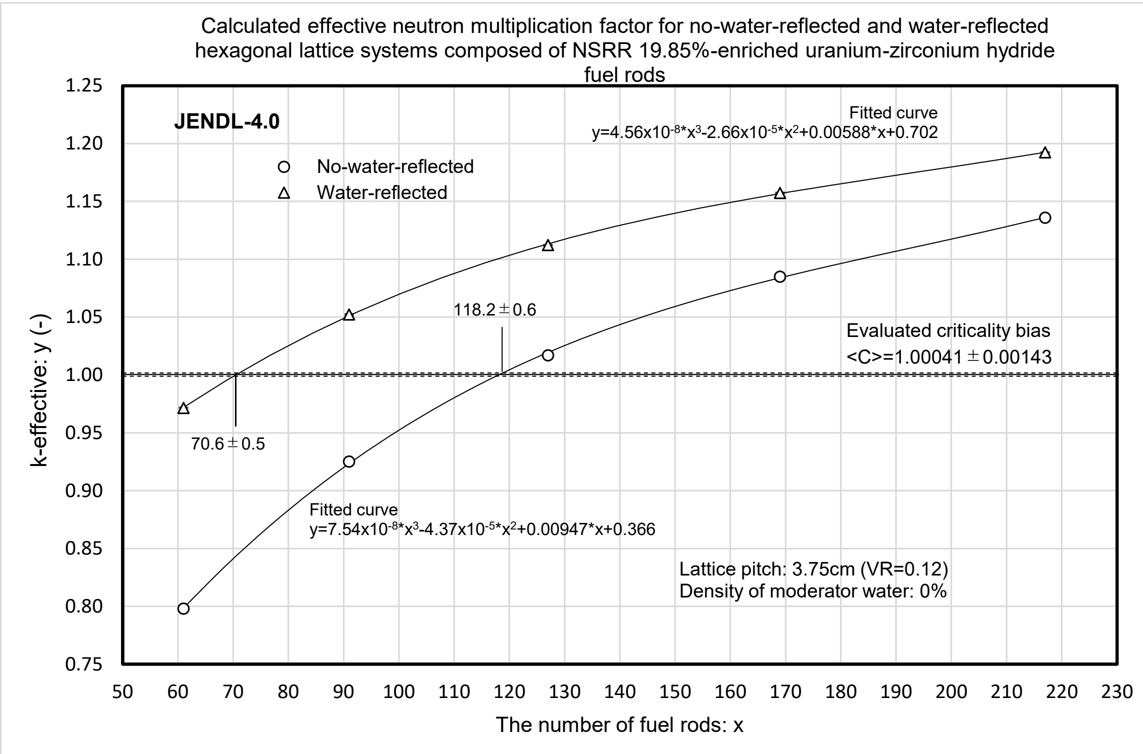


Fig.3.3.2.2 Relation between effective neutron multiplication factor and the number of fuel rods for hexagonal lattice systems under no moderator water condition, using JENDL-4.0, criticality bias evaluated by 37 benchmark cases.

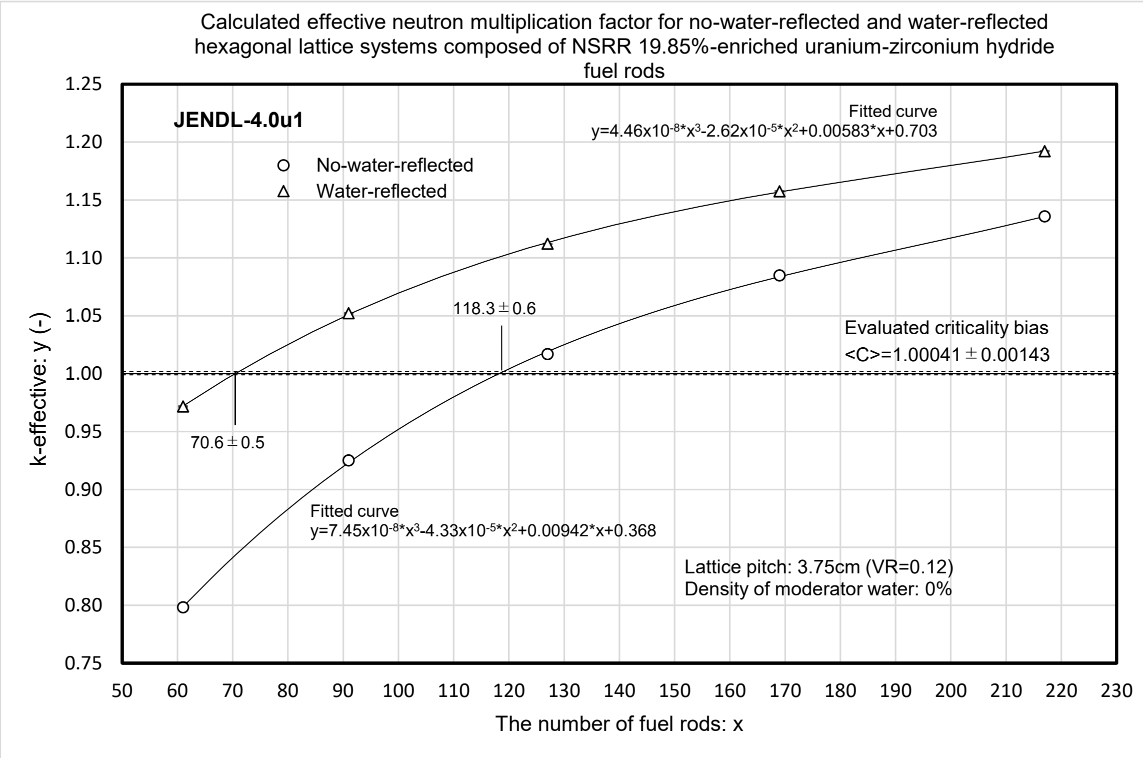


Fig.3.3.2.3 Relation between effective neutron multiplication factor and the number of fuel rods for hexagonal lattice systems under no moderator water condition, using JENDL-4.0u1, criticality bias evaluated by 37 benchmark cases.

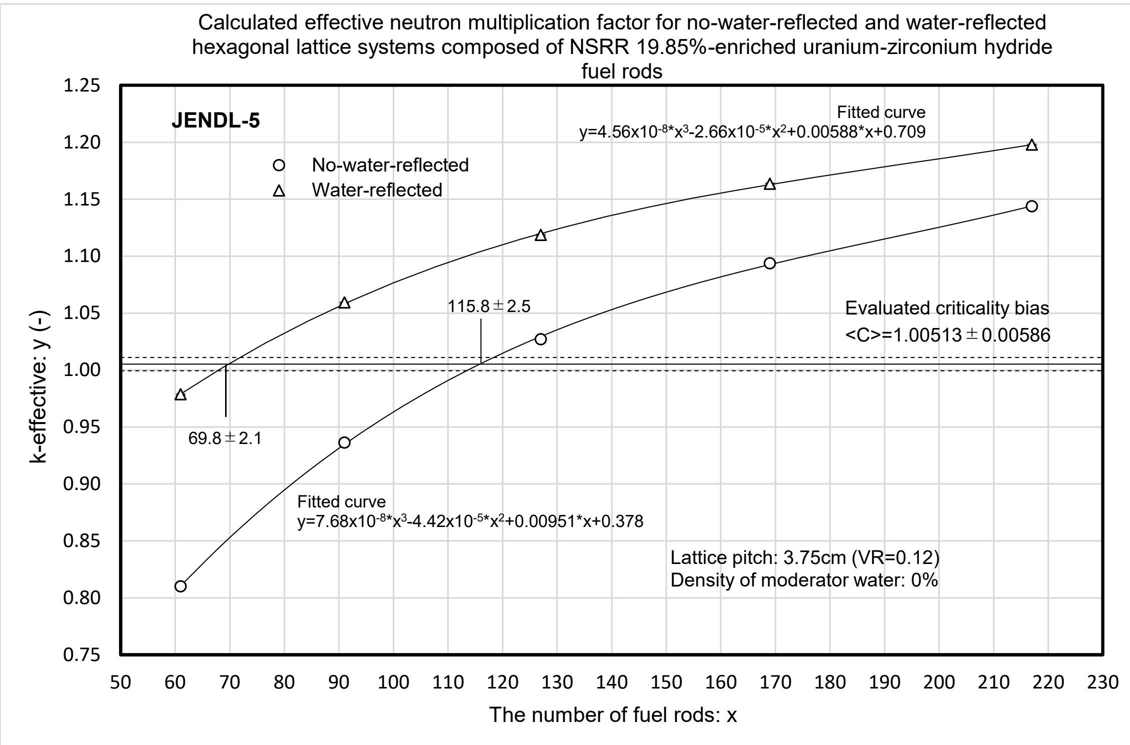


Fig.3.3.2.4 Relation between effective neutron multiplication factor and the number of fuel rods for hexagonal lattice systems under no moderator water condition, using JENDL-5, criticality bias evaluated by 2 benchmark cases.

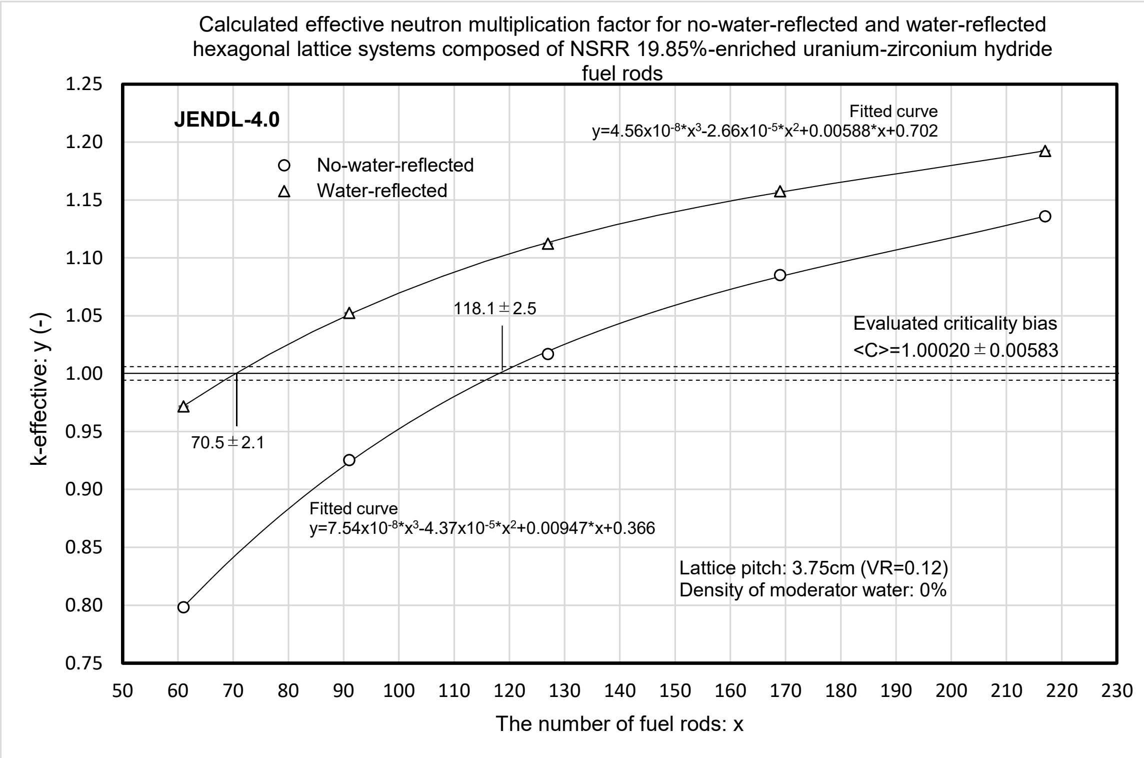


Fig.3.3.2.5 Relation between effective neutron multiplication factor and the number of fuel rods for hexagonal lattice systems under no moderator water condition, using JENDL-4.0, criticality bias evaluated by 2 benchmark cases.

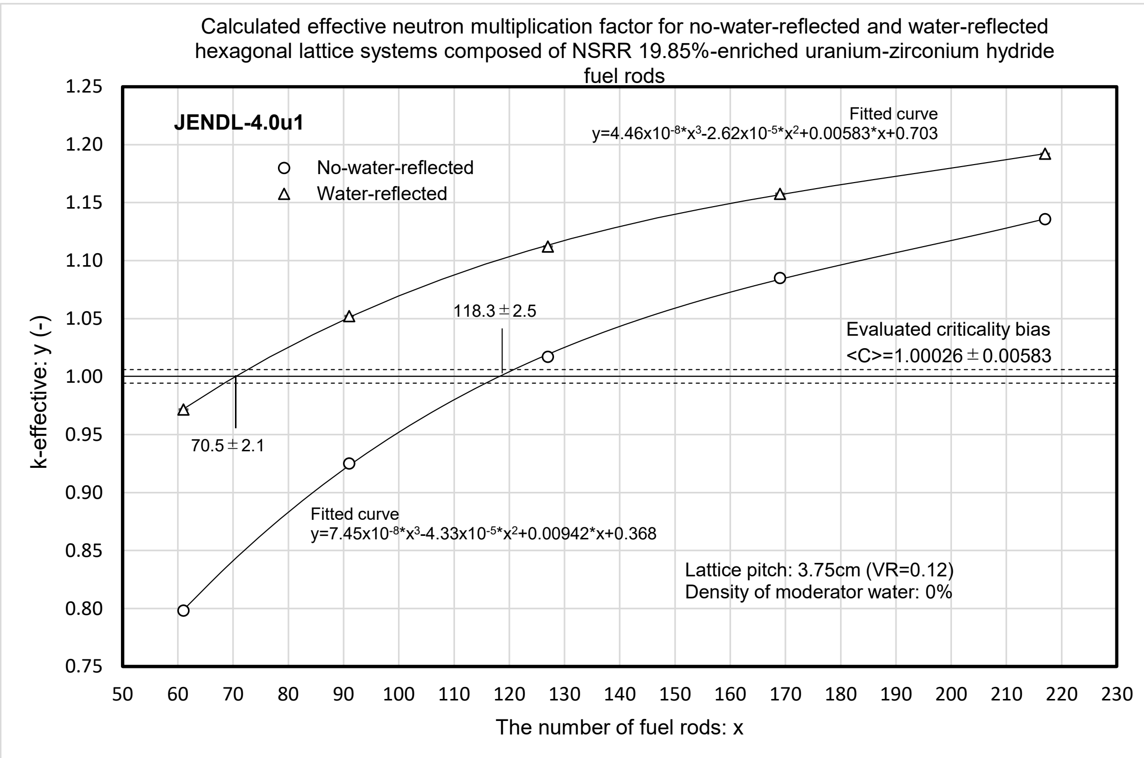


Fig.3.3.2.6 Relation between effective neutron multiplication factor and the number of fuel rods for hexagonal lattice systems under no moderator water condition, using JENDL-4.0u1, criticality bias evaluated by 2 benchmark cases.

Table 3.3.2.1 summarizes the most probable values of the critical number of fuel rods for the finite hexagonal lattices under no moderator water condition. It is clarified that the criticality is possible to be attained with the number of fuel rods smaller than 120 even if the water as reflector and moderator does not exist. The evaluated critical number of fuel rods is smaller than 149 fuel rods loaded in the standard core of NSRR. This is the distinctive property of the TRIGA fuel rod, in which the zirconium hydride moderator and graphite reflector are involved, to be noted from safety point of view.

As listed in Table 3.3.2.1, it is also confirmed under no-water-reflected condition that the values of the critical number of fuel rods using the JENDL-5 library are smaller than those using the JENDL-4.0 and JENDL-4.0u1 libraries whilst the differences in the critical number of fuel rods among the libraries are within three times their σ's under the water-reflected condition. As presented in Appendix-4, it is confirmed that the difference in k_{eff} of the hexagonal lattice systems containing no moderator water under the water-reflected condition between the JENDL-5 and JENDL-4.0 libraries is about 0.7 % at the vicinity of 70 fuel rods. Under the no-water-reflected condition, however, the difference is beyond 1.0 % for the smaller number of fuel rods than 120. The differences in the criticality biases between the JENDL-5 and JENDL-4.0 libraries are in the range of 0.4 to 0.5 %, as shown in Appendix-6, hence it is considered that the difference in the critical number of fuel rods is enlarged between the JENDL-5 and JENDL-4.0 libraries under the no-water-reflected condition.

From the results on the benchmark analyses for the other TRIGA reactors[13), it had been confirmed that data of thermal neutron scattering law (TSL) largely affect the difference in k_{eff} between the JENDL-5 and JENDL-4.0 libraries. It is considered that the different dominant factor for the difference in k_{eff} whether the reflector water is in presence or not is possibly due to the TSL data. The re-evaluation on the TSL data in the JENDL-5 library is on-going based on the molecular dynamics simulation[14).

In the former evaluation[3) based on the simplified model of the NSRR fuel rod by using the MVP version 2 code with the JENDL-4.0 library, the values of the critical number of fuel rods under the water-reflected and no-water-reflected conditions were evaluated to be 66.9 ± 0.3 and 116.1 ± 0.4. As listed in Table 3.3.2.1, the values of the critical number of fuel rods using the JENDL-4.0 library in the present re-evaluation are larger than those in the former evaluation. This is considered to be the same reason as mentioned in Sec.3.3.1.

Table 3.3.2.1 Critical number of fuel rods for hexagonal lattice systems under no moderator water condition, using two sorts of criticality biases evaluated by 37 and 2 benchmark cases.

Reflector water	Critical number of fuel rods ± 3σ					
	JENDL-5		JENDL-4.0		JENDL-4.0u1	
	37 cases*1	2 cases*2	37 cases*1	2 cases*2	37 cases*1	2 cases*2
presence	69.7 ± 0.5	69.8 ± 2.1	70.6 ± 0.5	70.5 ± 2.1	70.6 ± 0.5	70.5 ± 2.1
none	115.7 ± 0.6	115.8 ± 2.5	118.2 ± 0.6	118.1 ± 2.5	118.3 ± 0.6	118.3 ± 2.5

*1 Using criticality bias evaluated by 37 benchmark cases shown in Appendix-6.
*2 Using criticality bias evaluated by 2 benchmark cases shown in Appendix-6.

Table 3.3.2.2 summarizes the most probable values of the mass of uranium-235 corresponding to the minimum critical number of fuel rods for the finite hexagonal lattices under no moderator water condition.

Table 3.3.2.2 Mass of uranium-235 corresponding to the critical number of fuel rods for hexagonal lattice systems under no moderator water condition, using two sorts of criticality biases evaluated by 37 and 2 benchmark cases.

Reflector water	Critical mass of uranium-235 (kg) ± 3σ					
	JENDL-5		JENDL-4.0		JENDL-4.0u1	
	37 cases*1	2 cases*2	37 cases*1	2 cases*2	37 cases*1	2 cases*2
presence	3.61 ± 0.03	3.62 ± 0.11	3.66 ± 0.03	3.65 ± 0.11	3.66 ± 0.03	3.65 ± 0.11
none	6.00 ± 0.03	6.00 ± 0.13	6.13 ± 0.03	6.12 ± 0.13	6.13 ± 0.03	6.13 ± 0.13

*1 Using criticality bias evaluated by 37 benchmark cases shown in Appendix-6.
*2 Using criticality bias evaluated by 2 benchmark cases shown in Appendix-6.

7. Summary

The criticality characteristics for infinite and finite lattice systems were re-evaluated with the use of the detailed models of the NSRR fuel rods for the purpose of understandings of criticality risks of the TRIGA fuel rods and review of criticality safety measures for handling them. The MVP version 3 code was used with the latest JENDL library, JENDL-5, for the re-evaluation. For comparison, the previous versions of the JENDL libraries, JENDL-4.0 and JENDL-4.0u1 were also used in the part of the re-evaluation. The critical number of fuel rods was re-evaluated from the results of those criticality characteristics.

Using the JENDL-5 library, the minimum critical number of fuel rods in the presence of the water as moderator and reflector was re-evaluated with the criticality bias obtained by 37 benchmark cases of the NSRR detailed models, as,

46.8 ± 0.2 for the finite hexagonal lattice systems, and

47.2 ± 0.2 for the finite square lattice systems.

It was also found that the differences in the re-evaluated minimum critical number of fuel rods among the JENDL libraries were quite small.

Moreover, the critical number of fuel rods with no moderator water was also re-evaluated as the important property in terms of nuclear criticality safety since the zirconium hydride moderator and the axial graphite reflector are equipped with the TRIGA fuel rods. The results based on the above-mentioned criticality bias were obtained using the JENDL-5 library as,

69.7 ± 0.5 for the water-reflected finite hexagonal lattice systems, and

115.7 ± 0.6 for the no-water-reflected finite hexagonal lattice systems.

It was confirmed that the criticality was attainable using a smaller number of fuel rods than 149 fuel rods loaded in the NSRR standard core even though no water as moderator and reflector existed. It was also found under no-water-reflected condition that the critical number of fuel rods using the JENDL-5 library was smaller than that using the JENDL-4.0 and JENDL-4.0u1 libraries. This is because the differences in k_{eff} between the JENDL-5 and JENDL-4.0 or JENDL-4.0u1 library under the no-water-reflected condition are larger than those in the criticality biases between the libraries.

At an off-reactor dry storage for the fuel rods in NSRR, subcriticality is adequately ensured by the combination of mass and geometry controls, i.e., six fuel rods are stored in a flat container, and sufficient distance between the containers is maintained structurally. On the other hand, in the transitional situation of fuel transfer to/from in-reactor-pool storages or transport casks, mass controls may be only measures to prevent accidental criticality. The results shown in this report are considered to be useful to understand criticality risks of the TRIGA fuel rods and examine safety measures by the mass control only. All re-evaluated values in this report are the most probable ones for nuclear criticality so that proper margins should be considered to apply the results shown here to the safety measures.

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Appendix-1 Numerical Data Tables of Infinite Lattice Systems

(1) Infinite hexagonal lattice system

The results of numerical data calculated using the JENDL-5 library for the infinite hexagonal lattice systems are listed in Tables A.1.1(1) to A.1.1(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.1.1(1) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-5, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51257 ± 0.00015	1.52642 ± 0.00084	0.99043 ± 0.00001	1.51180 ± 0.00083
4.00	0.29	1.50315 ± 0.00014	1.54163 ± 0.00085	0.97463 ± 0.00002	1.50252 ± 0.00082
4.175	0.42	1.49283 ± 0.00015	1.55152 ± 0.00085	0.96179 ± 0.00002	1.49223 ± 0.00081
4.35	0.56	1.47945 ± 0.00015	1.56058 ± 0.00092	0.94766 ± 0.00003	1.47889 ± 0.00086
4.50	0.68	1.46555 ± 0.00015	1.56753 ± 0.00092	0.93462 ± 0.00004	1.46505 ± 0.00084
4.70	0.84	1.44408 ± 0.00015	1.57565 ± 0.00087	0.91618 ± 0.00005	1.44358 ± 0.00078
5.00	1.11	1.40627 ± 0.00015	1.58587 ± 0.00088	0.88650 ± 0.00007	1.40588 ± 0.00076
5.50	1.58	1.33219 ± 0.00018	1.59843 ± 0.00100	0.83319 ± 0.00011	1.33179 ± 0.00080
6.00	2.10	1.25000 ± 0.00020	1.60748 ± 0.00107	0.77744 ± 0.00014	1.24971 ± 0.00079
6.50	2.67	1.16434 ± 0.00022	1.61384 ± 0.00101	0.72131 ± 0.00017	1.16408 ± 0.00069
7.00	3.28	1.07888 ± 0.00024	1.61847 ± 0.00108	0.66644 ± 0.00022	1.07861 ± 0.00067

Table A.1.1(2) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-5, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51303 ± 0.00015	1.52529 ± 0.00089	0.99151 ± 0.00001	1.51233 ± 0.00088
4.00	0.29	1.50499 ± 0.00015	1.53891 ± 0.00095	0.97753 ± 0.00002	1.50433 ± 0.00093
4.175	0.42	1.49659 ± 0.00015	1.54841 ± 0.00085	0.96617 ± 0.00002	1.49602 ± 0.00081
4.35	0.56	1.48549 ± 0.00016	1.55708 ± 0.00086	0.95366 ± 0.00003	1.48493 ± 0.00081
4.50	0.68	1.47384 ± 0.00015	1.56378 ± 0.00086	0.94213 ± 0.00004	1.47329 ± 0.00080
4.70	0.84	1.45541 ± 0.00015	1.57172 ± 0.00092	0.92569 ± 0.00005	1.45493 ± 0.00084
5.00	1.11	1.42265 ± 0.00015	1.58177 ± 0.00087	0.89913 ± 0.00006	1.42222 ± 0.00076
5.50	1.58	1.35768 ± 0.00016	1.59478 ± 0.00094	0.85108 ± 0.00010	1.35729 ± 0.00077
6.00	2.10	1.28378 ± 0.00018	1.60424 ± 0.00100	0.80005 ± 0.00013	1.28347 ± 0.00077
6.50	2.67	1.20542 ± 0.00021	1.61110 ± 0.00095	0.74800 ± 0.00016	1.20511 ± 0.00068
7.00	3.28	1.12562 ± 0.00022	1.61619 ± 0.00102	0.69630 ± 0.00019	1.12535 ± 0.00067

Table A.1.1(3) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-5. density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51353 ± 0.00015	1.52411 ± 0.00084	0.99256 ± 0.00001	1.51277 ± 0.00083
4.00	0.29	1.50681 ± 0.00015	1.53627 ± 0.00084	0.98035 ± 0.00001	1.50609 ± 0.00082
4.175	0.42	1.50001 ± 0.00015	1.54504 ± 0.00090	0.97045 ± 0.00002	1.49938 ± 0.00087
4.35	0.56	1.49086 ± 0.00016	1.55299 ± 0.00086	0.95956 ± 0.00003	1.49018 ± 0.00081
4.50	0.68	1.48135 ± 0.00015	1.55957 ± 0.00091	0.94948 ± 0.00003	1.48078 ± 0.00086
4.70	0.84	1.46612 ± 0.00015	1.56737 ± 0.00087	0.93508 ± 0.00004	1.46561 ± 0.00079
5.00	1.11	1.43856 ± 0.00015	1.57731 ± 0.00087	0.91172 ± 0.00006	1.43806 ± 0.00077
5.50	1.58	1.38262 ± 0.00016	1.59054 ± 0.00088	0.86900 ± 0.00008	1.38218 ± 0.00074
6.00	2.10	1.31754 ± 0.00017	1.60041 ± 0.00089	0.82303 ± 0.00011	1.31719 ± 0.00070
6.50	2.67	1.24704 ± 0.00019	1.60772 ± 0.00095	0.77547 ± 0.00014	1.24675 ± 0.00070
7.00	3.28	1.17406 ± 0.00021	1.61334 ± 0.00101	0.72757 ± 0.00017	1.17381 ± 0.00069

Table A.1.1(4) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-5, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51429 ± 0.00015	1.52172 ± 0.00089	0.99459 ± 0.00000	1.51349 ± 0.00088
4.00	0.29	1.50983 ± 0.00015	1.53091 ± 0.00089	0.98580 ± 0.00001	1.50916 ± 0.00088
4.175	0.42	1.50573 ± 0.00015	1.53785 ± 0.00084	0.97871 ± 0.00001	1.50511 ± 0.00082
4.35	0.56	1.50031 ± 0.00015	1.54454 ± 0.00085	0.97091 ± 0.00002	1.49961 ± 0.00081
4.50	0.68	1.49454 ± 0.00015	1.55021 ± 0.00085	0.96370 ± 0.00002	1.49393 ± 0.00081
4.70	0.84	1.48512 ± 0.00015	1.55714 ± 0.00088	0.95336 ± 0.00003	1.48452 ± 0.00082
5.00	1.11	1.46755 ± 0.00015	1.56662 ± 0.00092	0.93642 ± 0.00004	1.46701 ± 0.00085
5.50	1.58	1.43000 ± 0.00015	1.57983 ± 0.00093	0.90485 ± 0.00006	1.42952 ± 0.00082
6.00	2.10	1.38401 ± 0.00016	1.59027 ± 0.00094	0.87004 ± 0.00008	1.38359 ± 0.00079
6.50	2.67	1.33176 ± 0.00018	1.59857 ± 0.00090	0.83287 ± 0.00011	1.33140 ± 0.00072
7.00	3.28	1.27520 ± 0.00019	1.60521 ± 0.00095	0.79420 ± 0.00013	1.27486 ± 0.00072

Table A.1.1(5) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-5, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51493 ± 0.00016	1.51958 ± 0.00078	0.99652 ± 0.00000	1.51429 ± 0.00077
4.00	0.29	1.51233 ± 0.00015	1.52544 ± 0.00084	0.99094 ± 0.00001	1.51162 ± 0.00083
4.175	0.42	1.51027 ± 0.00014	1.53021 ± 0.00084	0.98650 ± 0.00001	1.50955 ± 0.00082
4.35	0.56	1.50753 ± 0.00016	1.53505 ± 0.00085	0.98163 ± 0.00001	1.50686 ± 0.00083
4.50	0.68	1.50479 ± 0.00015	1.53929 ± 0.00084	0.97714 ± 0.00002	1.50410 ± 0.00082
4.70	0.84	1.50016 ± 0.00014	1.54481 ± 0.00085	0.97068 ± 0.00002	1.49951 ± 0.00082
5.00	1.11	1.49134 ± 0.00015	1.55274 ± 0.00080	0.96005 ± 0.00003	1.49071 ± 0.00076
5.50	1.58	1.47134 ± 0.00015	1.56484 ± 0.00086	0.93993 ± 0.00004	1.47083 ± 0.00079
6.00	2.10	1.44528 ± 0.00015	1.57521 ± 0.00087	0.91717 ± 0.00005	1.44473 ± 0.00078
6.50	2.67	1.41363 ± 0.00015	1.58400 ± 0.00088	0.89216 ± 0.00006	1.41318 ± 0.00076
7.00	3.28	1.37752 ± 0.00016	1.59156 ± 0.00094	0.86530 ± 0.00009	1.37717 ± 0.00078

Table A.1.1(6) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-5, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51580 ± 0.00016	1.51765 ± 0.00088	0.99833 ± 0.00000	1.51510 ± 0.00088
4.00	0.29	1.51439 ± 0.00015	1.52021 ± 0.00083	0.99571 ± 0.00000	1.51369 ± 0.00083
4.175	0.42	1.51350 ± 0.00016	1.52236 ± 0.00083	0.99367 ± 0.00000	1.51273 ± 0.00082
4.35	0.56	1.51262 ± 0.00015	1.52492 ± 0.00084	0.99147 ± 0.00001	1.51192 ± 0.00083
4.50	0.68	1.51174 ± 0.00015	1.52713 ± 0.00084	0.98945 ± 0.00001	1.51102 ± 0.00083
4.70	0.84	1.51029 ± 0.00015	1.53020 ± 0.00084	0.98655 ± 0.00001	1.50962 ± 0.00082
5.00	1.11	1.50780 ± 0.00015	1.53512 ± 0.00090	0.98180 ± 0.00001	1.50719 ± 0.00088
5.50	1.58	1.50183 ± 0.00015	1.54324 ± 0.00085	0.97276 ± 0.00002	1.50121 ± 0.00082
6.00	2.10	1.49349 ± 0.00015	1.55139 ± 0.00085	0.96234 ± 0.00003	1.49297 ± 0.00081
6.50	2.67	1.48234 ± 0.00016	1.55877 ± 0.00086	0.95059 ± 0.00003	1.48175 ± 0.00080
7.00	3.28	1.46866 ± 0.00016	1.56593 ± 0.00086	0.93754 ± 0.00004	1.46811 ± 0.00080

Table A.1.1(7) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-5, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51688 ± 0.00016	1.51616 ± 0.00088	1.00000 ± 0.00000	1.51616 ± 0.00088
4.00	0.29	1.51670 ± 0.00016	1.51597 ± 0.00083	1.00000 ± 0.00000	1.51597 ± 0.00083
4.175	0.42	1.51676 ± 0.00015	1.51600 ± 0.00083	1.00000 ± 0.00000	1.51600 ± 0.00083
4.35	0.56	1.51688 ± 0.00015	1.51606 ± 0.00083	1.00000 ± 0.00000	1.51606 ± 0.00083
4.50	0.68	1.51684 ± 0.00016	1.51605 ± 0.00083	1.00000 ± 0.00000	1.51605 ± 0.00083
4.70	0.84	1.51677 ± 0.00015	1.51602 ± 0.00083	1.00000 ± 0.00000	1.51602 ± 0.00083
5.00	1.11	1.51689 ± 0.00015	1.51603 ± 0.00088	1.00000 ± 0.00000	1.51603 ± 0.00088
5.50	1.58	1.51676 ± 0.00016	1.51595 ± 0.00083	1.00000 ± 0.00000	1.51595 ± 0.00083
6.00	2.10	1.51689 ± 0.00015	1.51613 ± 0.00088	1.00000 ± 0.00000	1.51613 ± 0.00088
6.50	2.67	1.51675 ± 0.00015	1.51598 ± 0.00083	1.00000 ± 0.00000	1.51598 ± 0.00083
7.00	3.28	1.51681 ± 0.00015	1.51601 ± 0.00083	1.00000 ± 0.00000	1.51601 ± 0.00083

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the infinite hexagonal lattice systems are also listed in Tables A.1.2(1) to A.1.2(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.1.2(1) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-4.0, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51412 ± 0.00015	1.52794 ± 0.00083	0.99044 ± 0.00001	1.51333 ± 0.00082
4.00	0.29	1.50455 ± 0.00015	1.54291 ± 0.00085	0.97470 ± 0.00002	1.50387 ± 0.00082
4.175	0.42	1.49434 ± 0.00015	1.55288 ± 0.00086	0.96187 ± 0.00003	1.49367 ± 0.00081
4.35	0.56	1.48078 ± 0.00014	1.56187 ± 0.00092	0.94772 ± 0.00004	1.48022 ± 0.00085
4.50	0.68	1.46687 ± 0.00015	1.56886 ± 0.00086	0.93465 ± 0.00004	1.46634 ± 0.00079
4.70	0.84	1.44499 ± 0.00015	1.57681 ± 0.00087	0.91607 ± 0.00005	1.44446 ± 0.00078
5.00	1.11	1.40656 ± 0.00015	1.58691 ± 0.00088	0.88606 ± 0.00007	1.40610 ± 0.00075
5.50	1.58	1.33116 ± 0.00017	1.59935 ± 0.00094	0.83205 ± 0.00011	1.33074 ± 0.00075
6.00	2.10	1.24717 ± 0.00018	1.60828 ± 0.00095	0.77527 ± 0.00014	1.24685 ± 0.00070
6.50	2.67	1.15983 ± 0.00022	1.61458 ± 0.00101	0.71816 ± 0.00018	1.15953 ± 0.00069
7.00	3.28	1.07259 ± 0.00024	1.61911 ± 0.00114	0.66231 ± 0.00022	1.07236 ± 0.00070

Table A.1.2(2) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-4.0, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51809 ± 0.00015	1.51727 ± 0.00088	1.00000 ± 0.00000	1.51727 ± 0.00088
4.00	0.29	1.51799 ± 0.00016	1.51716 ± 0.00084	1.00000 ± 0.00000	1.51716 ± 0.00084
4.175	0.42	1.51805 ± 0.00015	1.51718 ± 0.00083	1.00000 ± 0.00000	1.51718 ± 0.00083
4.35	0.56	1.51806 ± 0.00015	1.51732 ± 0.00088	1.00000 ± 0.00000	1.51732 ± 0.00088
4.50	0.68	1.51819 ± 0.00016	1.51738 ± 0.00084	1.00000 ± 0.00000	1.51738 ± 0.00084
4.70	0.84	1.51818 ± 0.00015	1.51737 ± 0.00083	1.00000 ± 0.00000	1.51737 ± 0.00083
5.00	1.11	1.51814 ± 0.00015	1.51734 ± 0.00088	1.00000 ± 0.00000	1.51734 ± 0.00088
5.50	1.58	1.51812 ± 0.00015	1.51731 ± 0.00083	1.00000 ± 0.00000	1.51731 ± 0.00083
6.00	2.10	1.51810 ± 0.00015	1.51725 ± 0.00083	1.00000 ± 0.00000	1.51725 ± 0.00083
6.50	2.67	1.51819 ± 0.00016	1.51733 ± 0.00083	1.00000 ± 0.00000	1.51733 ± 0.00083
7.00	3.28	1.51804 ± 0.00015	1.51719 ± 0.00078	1.00000 ± 0.00000	1.51719 ± 0.00078

Table A.1.2(3) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-4.0u1, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51404 ± 0.00015	1.52790 ± 0.00084	0.99044 ± 0.00001	1.51330 ± 0.00083
4.00	0.29	1.50463 ± 0.00015	1.54297 ± 0.00085	0.97471 ± 0.00002	1.50394 ± 0.00082
4.175	0.42	1.49442 ± 0.00015	1.55295 ± 0.00091	0.96187 ± 0.00003	1.49374 ± 0.00087
4.35	0.56	1.48081 ± 0.00015	1.56181 ± 0.00092	0.94772 ± 0.00004	1.48015 ± 0.00085
4.50	0.68	1.46682 ± 0.00016	1.56873 ± 0.00092	0.93468 ± 0.00005	1.46626 ± 0.00084
4.70	0.84	1.44511 ± 0.00015	1.57693 ± 0.00087	0.91607 ± 0.00005	1.44457 ± 0.00078
5.00	1.11	1.40661 ± 0.00016	1.58693 ± 0.00093	0.88609 ± 0.00007	1.40616 ± 0.00080
5.50	1.58	1.33107 ± 0.00017	1.59933 ± 0.00094	0.83199 ± 0.00010	1.33063 ± 0.00075
6.00	2.10	1.24726 ± 0.00019	1.60828 ± 0.00101	0.77534 ± 0.00014	1.24697 ± 0.00074
6.50	2.67	1.15990 ± 0.00021	1.61459 ± 0.00101	0.71822 ± 0.00018	1.15963 ± 0.00069
7.00	3.28	1.07259 ± 0.00025	1.61890 ± 0.00108	0.66238 ± 0.00021	1.07233 ± 0.00067

Table A.1.2(4) Infinite neutron multiplication factor and ratio of reactions for infinite hexagonal lattice systems, using JENDL-4.0u1, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.12	1.51804 ± 0.00015	1.51725 ± 0.00083	1.00000 ± 0.00000	1.51725 ± 0.00083
4.00	0.29	1.51799 ± 0.00015	1.51718 ± 0.00083	1.00000 ± 0.00000	1.51718 ± 0.00083
4.175	0.42	1.51808 ± 0.00016	1.51715 ± 0.00088	1.00000 ± 0.00000	1.51715 ± 0.00088
4.35	0.56	1.51812 ± 0.00015	1.51733 ± 0.00088	1.00000 ± 0.00000	1.51733 ± 0.00088
4.50	0.68	1.51819 ± 0.00016	1.51733 ± 0.00083	1.00000 ± 0.00000	1.51733 ± 0.00083
4.70	0.84	1.51818 ± 0.00015	1.51742 ± 0.00078	1.00000 ± 0.00000	1.51742 ± 0.00078
5.00	1.11	1.51808 ± 0.00015	1.51724 ± 0.00083	1.00000 ± 0.00000	1.51724 ± 0.00083
5.50	1.58	1.51814 ± 0.00015	1.51726 ± 0.00083	1.00000 ± 0.00000	1.51726 ± 0.00083
6.00	2.10	1.51825 ± 0.00015	1.51747 ± 0.00083	1.00000 ± 0.00000	1.51747 ± 0.00083
6.50	2.67	1.51822 ± 0.00015	1.51740 ± 0.00083	1.00000 ± 0.00000	1.51740 ± 0.00083
7.00	3.28	1.51809 ± 0.00016	1.51725 ± 0.00088	1.00000 ± 0.00000	1.51725 ± 0.00088

(2) Infinite square lattice system

The results of numerical data calculated using the JENDL-5 library for the infinite square lattice systems are listed in Tables A.1.3(1) to A.1.3(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.1.3(1) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-5, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.49845 ± 0.00016	1.54522 ± 0.00091	0.96932 ± 0.00002	1.49782 ± 0.00087
4.00	0.52	1.47942 ± 0.00015	1.55864 ± 0.00086	0.94879 ± 0.00004	1.47882 ± 0.00080
4.175	0.67	1.46215 ± 0.00014	1.56715 ± 0.00092	0.93268 ± 0.00004	1.46166 ± 0.00084
4.35	0.82	1.44213 ± 0.00015	1.57480 ± 0.00092	0.91545 ± 0.00006	1.44164 ± 0.00083
4.50	0.96	1.42262 ± 0.00015	1.58043 ± 0.00093	0.89984 ± 0.00007	1.42214 ± 0.00081
4.70	1.15	1.39413 ± 0.00017	1.58723 ± 0.00099	0.87812 ± 0.00008	1.39377 ± 0.00084
5.00	1.46	1.34677 ± 0.00017	1.59549 ± 0.00100	0.84386 ± 0.00011	1.34638 ± 0.00081
5.50	2.01	1.25996 ± 0.00019	1.60580 ± 0.00095	0.78442 ± 0.00014	1.25963 ± 0.00071
6.00	2.61	1.16848 ± 0.00021	1.61287 ± 0.00101	0.72430 ± 0.00017	1.16821 ± 0.00069
6.50	3.26	1.07721 ± 0.00022	1.61809 ± 0.00108	0.66561 ± 0.00021	1.07701 ± 0.00067
7.00	3.96	0.98885 ± 0.00026	1.62154 ± 0.00114	0.60968 ± 0.00026	0.98862 ± 0.00065

Table A.1.3(2) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-5, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.50169 ± 0.00016	1.54250 ± 0.00090	0.97310 ± 0.00002	1.50100 ± 0.00087
4.00	0.52	1.48564 ± 0.00016	1.55512 ± 0.00086	0.95490 ± 0.00003	1.48499 ± 0.00081
4.175	0.67	1.47118 ± 0.00015	1.56344 ± 0.00086	0.94062 ± 0.00004	1.47060 ± 0.00080
4.35	0.82	1.45407 ± 0.00016	1.57087 ± 0.00086	0.92529 ± 0.00005	1.45351 ± 0.00078
4.50	0.96	1.43718 ± 0.00016	1.57639 ± 0.00087	0.91134 ± 0.00006	1.43663 ± 0.00077
4.70	1.15	1.41262 ± 0.00015	1.58337 ± 0.00093	0.89188 ± 0.00007	1.41217 ± 0.00081
5.00	1.46	1.37105 ± 0.00016	1.59175 ± 0.00094	0.86106 ± 0.00009	1.37059 ± 0.00078
5.50	2.01	1.29310 ± 0.00018	1.60242 ± 0.00089	0.80674 ± 0.00012	1.29274 ± 0.00069
6.00	2.61	1.20939 ± 0.00020	1.61018 ± 0.00101	0.75091 ± 0.00015	1.20910 ± 0.00072
6.50	3.26	1.12410 ± 0.00022	1.61583 ± 0.00107	0.69549 ± 0.00019	1.12379 ± 0.00070
7.00	3.96	1.04013 ± 0.00023	1.61974 ± 0.00102	0.64198 ± 0.00021	1.03984 ± 0.00061

Table A.1.3(3) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-5, density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.50445 ± 0.00016	1.53963 ± 0.00085	0.97673 ± 0.00002	1.50379 ± 0.00082
4.00	0.52	1.49145 ± 0.00015	1.55154 ± 0.00086	0.96087 ± 0.00003	1.49083 ± 0.00081
4.175	0.67	1.47947 ± 0.00015	1.55946 ± 0.00086	0.94838 ± 0.00004	1.47897 ± 0.00080
4.35	0.82	1.46515 ± 0.00016	1.56650 ± 0.00092	0.93493 ± 0.00005	1.46457 ± 0.00084
4.50	0.96	1.45115 ± 0.00015	1.57215 ± 0.00087	0.92272 ± 0.00005	1.45066 ± 0.00078
4.70	1.15	1.43017 ± 0.00015	1.57885 ± 0.00087	0.90552 ± 0.00006	1.42967 ± 0.00077
5.00	1.46	1.39445 ± 0.00016	1.58749 ± 0.00087	0.87813 ± 0.00008	1.39402 ± 0.00074
5.50	2.01	1.32619 ± 0.00017	1.59868 ± 0.00094	0.82934 ± 0.00011	1.32584 ± 0.00075
6.00	2.61	1.25105 ± 0.00020	1.60690 ± 0.00095	0.77837 ± 0.00014	1.25075 ± 0.00070
6.50	3.26	1.17298 ± 0.00019	1.61299 ± 0.00101	0.72706 ± 0.00016	1.17275 ± 0.00069
7.00	3.96	1.09428 ± 0.00022	1.61754 ± 0.00108	0.67640 ± 0.00020	1.09411 ± 0.00068

Table A.1.3(4) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-5, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.50910 ± 0.00016	1.53367 ± 0.00084	0.98355 ± 0.00001	1.50844 ± 0.00082
4.00	0.52	1.50108 ± 0.00014	1.54338 ± 0.00085	0.97221 ± 0.00002	1.50049 ± 0.00082
4.175	0.67	1.49387 ± 0.00016	1.55015 ± 0.00091	0.96328 ± 0.00003	1.49323 ± 0.00087
4.35	0.82	1.48508 ± 0.00015	1.55665 ± 0.00086	0.95361 ± 0.00003	1.48443 ± 0.00081
4.50	0.96	1.47604 ± 0.00015	1.56172 ± 0.00086	0.94476 ± 0.00004	1.47545 ± 0.00080
4.70	1.15	1.46251 ± 0.00014	1.56826 ± 0.00081	0.93223 ± 0.00004	1.46198 ± 0.00074
5.00	1.46	1.43850 ± 0.00015	1.57673 ± 0.00087	0.91201 ± 0.00006	1.43800 ± 0.00078
5.50	2.01	1.39073 ± 0.00016	1.58856 ± 0.00094	0.87519 ± 0.00008	1.39028 ± 0.00079
6.00	2.61	1.33520 ± 0.00017	1.59772 ± 0.00100	0.83546 ± 0.00011	1.33483 ± 0.00080
6.50	3.26	1.27465 ± 0.00019	1.60488 ± 0.00095	0.79405 ± 0.00013	1.27436 ± 0.00072
7.00	3.96	1.21107 ± 0.00019	1.61045 ± 0.00101	0.75184 ± 0.00015	1.21079 ± 0.00072

Table A.1.3(5) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-5, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.51234 ± 0.00015	1.52720 ± 0.00084	0.98975 ± 0.00001	1.51154 ± 0.00083
4.00	0.52	1.50826 ± 0.00014	1.53413 ± 0.00084	0.98266 ± 0.00001	1.50753 ± 0.00082
4.175	0.67	1.50474 ± 0.00015	1.53926 ± 0.00090	0.97710 ± 0.00002	1.50401 ± 0.00087
4.35	0.82	1.50042 ± 0.00014	1.54455 ± 0.00085	0.97106 ± 0.00002	1.49985 ± 0.00082
4.50	0.96	1.49607 ± 0.00014	1.54888 ± 0.00085	0.96553 ± 0.00002	1.49550 ± 0.00082
4.70	1.15	1.48905 ± 0.00015	1.55428 ± 0.00086	0.95763 ± 0.00003	1.48842 ± 0.00081
5.00	1.46	1.47636 ± 0.00015	1.56207 ± 0.00086	0.94478 ± 0.00004	1.47581 ± 0.00080
5.50	2.01	1.44943 ± 0.00015	1.57350 ± 0.00087	0.92084 ± 0.00005	1.44894 ± 0.00078
6.00	2.61	1.41602 ± 0.00016	1.58308 ± 0.00088	0.89419 ± 0.00007	1.41557 ± 0.00076
6.50	3.26	1.37738 ± 0.00016	1.59113 ± 0.00094	0.86541 ± 0.00009	1.37698 ± 0.00078
7.00	3.96	1.33460 ± 0.00017	1.59795 ± 0.00090	0.83497 ± 0.00010	1.33425 ± 0.00072

Table A.1.3(6) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-5, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.51462 ± 0.00015	1.52105 ± 0.00083	0.99527 ± 0.00000	1.51386 ± 0.00083
4.00	0.52	1.51295 ± 0.00016	1.52431 ± 0.00089	0.99204 ± 0.00001	1.51217 ± 0.00088
4.175	0.67	1.51181 ± 0.00015	1.52704 ± 0.00084	0.98953 ± 0.00001	1.51106 ± 0.00083
4.35	0.82	1.51051 ± 0.00015	1.52994 ± 0.00084	0.98683 ± 0.00001	1.50979 ± 0.00083
4.50	0.96	1.50927 ± 0.00016	1.53254 ± 0.00084	0.98436 ± 0.00001	1.50857 ± 0.00082
4.70	1.15	1.50724 ± 0.00015	1.53604 ± 0.00084	0.98083 ± 0.00001	1.50660 ± 0.00082
5.00	1.46	1.50350 ± 0.00016	1.54128 ± 0.00090	0.97507 ± 0.00002	1.50285 ± 0.00087
5.50	2.01	1.49494 ± 0.00015	1.54983 ± 0.00085	0.96416 ± 0.00003	1.49429 ± 0.00081
6.00	2.61	1.48350 ± 0.00015	1.55810 ± 0.00086	0.95173 ± 0.00003	1.48288 ± 0.00081
6.50	3.26	1.46888 ± 0.00015	1.56573 ± 0.00081	0.93777 ± 0.00004	1.46830 ± 0.00075
7.00	3.96	1.45126 ± 0.00015	1.57273 ± 0.00087	0.92246 ± 0.00005	1.45077 ± 0.00078

Table A.1.3(7) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-5, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.51685 ± 0.00015	1.51608 ± 0.00088	1.00000 ± 0.00000	1.51608 ± 0.00088
4.00	0.52	1.51687 ± 0.00015	1.51608 ± 0.00083	1.00000 ± 0.00000	1.51608 ± 0.00083
4.175	0.67	1.51681 ± 0.00016	1.51606 ± 0.00083	1.00000 ± 0.00000	1.51606 ± 0.00083
4.35	0.82	1.51680 ± 0.00015	1.51599 ± 0.00088	1.00000 ± 0.00000	1.51599 ± 0.00088
4.50	0.96	1.51678 ± 0.00016	1.51596 ± 0.00088	1.00000 ± 0.00000	1.51596 ± 0.00088
4.70	1.15	1.51669 ± 0.00015	1.51583 ± 0.00083	1.00000 ± 0.00000	1.51583 ± 0.00083
5.00	1.46	1.51666 ± 0.00016	1.51587 ± 0.00083	1.00000 ± 0.00000	1.51587 ± 0.00083
5.50	2.01	1.51687 ± 0.00015	1.51606 ± 0.00088	1.00000 ± 0.00000	1.51606 ± 0.00088
6.00	2.61	1.51683 ± 0.00016	1.51603 ± 0.00089	1.00000 ± 0.00000	1.51603 ± 0.00089
6.50	3.26	1.51678 ± 0.00015	1.51595 ± 0.00094	1.00000 ± 0.00000	1.51595 ± 0.00094
7.00	3.96	1.51675 ± 0.00015	1.51593 ± 0.00088	1.00000 ± 0.00000	1.51593 ± 0.00088

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the infinite square lattice systems are also listed in Tables A.1.4(1) to A.1.4(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.1.4(1) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-4.0, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.49983 ± 0.00015	1.54657 ± 0.00091	0.96930 ± 0.00002	1.49909 ± 0.00087
4.00	0.52	1.48053 ± 0.00015	1.56001 ± 0.00086	0.94868 ± 0.00004	1.47994 ± 0.00080
4.175	0.67	1.46322 ± 0.00015	1.56846 ± 0.00092	0.93253 ± 0.00005	1.46263 ± 0.00084
4.35	0.82	1.44263 ± 0.00015	1.57591 ± 0.00092	0.91511 ± 0.00006	1.44214 ± 0.00083
4.50	0.96	1.42293 ± 0.00015	1.58160 ± 0.00093	0.89938 ± 0.00007	1.42245 ± 0.00081
4.70	1.15	1.39382 ± 0.00017	1.58817 ± 0.00094	0.87734 ± 0.00009	1.39337 ± 0.00080
5.00	1.46	1.34585 ± 0.00017	1.59642 ± 0.00094	0.84276 ± 0.00010	1.34540 ± 0.00076
5.50	2.01	1.25712 ± 0.00018	1.60659 ± 0.00100	0.78228 ± 0.00014	1.25680 ± 0.00075
6.00	2.61	1.16374 ± 0.00021	1.61358 ± 0.00101	0.72106 ± 0.00018	1.16349 ± 0.00069
6.50	3.26	1.07070 ± 0.00021	1.61863 ± 0.00113	0.66136 ± 0.00022	1.07050 ± 0.00070
7.00	3.96	0.98081 ± 0.00025	1.62198 ± 0.00114	0.60458 ± 0.00025	0.98062 ± 0.00064

Table A.1.4(2) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-4.0, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.51828 ± 0.00016	1.51748 ± 0.00084	1.00000 ± 0.00000	1.51748 ± 0.00084
4.00	0.52	1.51810 ± 0.00015	1.51730 ± 0.00083	1.00000 ± 0.00000	1.51730 ± 0.00083
4.175	0.67	1.51816 ± 0.00015	1.51733 ± 0.00083	1.00000 ± 0.00000	1.51733 ± 0.00083
4.35	0.82	1.51810 ± 0.00016	1.51730 ± 0.00083	1.00000 ± 0.00000	1.51730 ± 0.00083
4.50	0.96	1.51807 ± 0.00015	1.51721 ± 0.00083	1.00000 ± 0.00000	1.51721 ± 0.00083
4.70	1.15	1.51810 ± 0.00015	1.51729 ± 0.00083	1.00000 ± 0.00000	1.51729 ± 0.00083
5.00	1.46	1.51814 ± 0.00016	1.51725 ± 0.00083	1.00000 ± 0.00000	1.51725 ± 0.00083
5.50	2.01	1.51816 ± 0.00015	1.51736 ± 0.00083	1.00000 ± 0.00000	1.51736 ± 0.00083
6.00	2.61	1.51821 ± 0.00016	1.51737 ± 0.00084	1.00000 ± 0.00000	1.51737 ± 0.00084
6.50	3.26	1.51808 ± 0.00015	1.51730 ± 0.00083	1.00000 ± 0.00000	1.51730 ± 0.00083
7.00	3.96	1.51812 ± 0.00015	1.51733 ± 0.00088	1.00000 ± 0.00000	1.51733 ± 0.00088

Table A.1.4(3) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-4.0u1, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.49978 ± 0.00015	1.54653 ± 0.00085	0.96931 ± 0.00002	1.49907 ± 0.00082
4.00	0.52	1.48057 ± 0.00015	1.55993 ± 0.00086	0.94869 ± 0.00004	1.47989 ± 0.00080
4.175	0.67	1.46321 ± 0.00015	1.56849 ± 0.00092	0.93251 ± 0.00005	1.46263 ± 0.00084
4.35	0.82	1.44267 ± 0.00015	1.57593 ± 0.00087	0.91511 ± 0.00006	1.44215 ± 0.00078
4.50	0.96	1.42294 ± 0.00016	1.58159 ± 0.00093	0.89938 ± 0.00007	1.42245 ± 0.00081
4.70	1.15	1.39392 ± 0.00015	1.58810 ± 0.00088	0.87741 ± 0.00007	1.39341 ± 0.00074
5.00	1.46	1.34579 ± 0.00017	1.59643 ± 0.00094	0.84275 ± 0.00010	1.34539 ± 0.00076
5.50	2.01	1.25716 ± 0.00020	1.60655 ± 0.00101	0.78233 ± 0.00015	1.25686 ± 0.00075
6.00	2.61	1.16378 ± 0.00020	1.61351 ± 0.00107	0.72108 ± 0.00018	1.16346 ± 0.00073
6.50	3.26	1.07058 ± 0.00022	1.61858 ± 0.00108	0.66131 ± 0.00022	1.07038 ± 0.00067
7.00	3.96	0.98072 ± 0.00024	1.62197 ± 0.00108	0.60448 ± 0.00024	0.98045 ± 0.00061

Table A.1.4(4) Infinite neutron multiplication factor and ratio of reactions for infinite square lattice systems, using JENDL-4.0u1, density of moderator water: 0 %

Lattice pitch (cm)	Volume ratio	k-infinity ± 3σ	Ratio (1): $\nu F/A_{RD}$ ± 3σ	Ratio (2): $A_{RD}/(A_{RD}+A_{WA})$ ± 3σ	Ratio (3)=(1)*(2): $\nu F/(A_{RD}+A_{WA})$ ± 3σ
3.75	0.32	1.51816 ± 0.00015	1.51735 ± 0.00088	1.00000 ± 0.00000	1.51735 ± 0.00088
4.00	0.52	1.51804 ± 0.00016	1.51722 ± 0.00078	1.00000 ± 0.00000	1.51722 ± 0.00078
4.175	0.67	1.51810 ± 0.00015	1.51727 ± 0.00089	1.00000 ± 0.00000	1.51727 ± 0.00089
4.35	0.82	1.51804 ± 0.00015	1.51721 ± 0.00083	1.00000 ± 0.00000	1.51721 ± 0.00083
4.50	0.96	1.51809 ± 0.00016	1.51736 ± 0.00083	1.00000 ± 0.00000	1.51736 ± 0.00083
4.70	1.15	1.51806 ± 0.00015	1.51721 ± 0.00083	1.00000 ± 0.00000	1.51721 ± 0.00083
5.00	1.46	1.51814 ± 0.00015	1.51733 ± 0.00083	1.00000 ± 0.00000	1.51733 ± 0.00083
5.50	2.01	1.51829 ± 0.00015	1.51739 ± 0.00083	1.00000 ± 0.00000	1.51739 ± 0.00083
6.00	2.61	1.51809 ± 0.00016	1.51730 ± 0.00089	1.00000 ± 0.00000	1.51730 ± 0.00089
6.50	3.26	1.51809 ± 0.00016	1.51727 ± 0.00083	1.00000 ± 0.00000	1.51727 ± 0.00083
7.00	3.96	1.51811 ± 0.00015	1.51732 ± 0.00084	1.00000 ± 0.00000	1.51732 ± 0.00084

Appendix-2 Numerical Data Tables of Finite Lattice Systems for Search on Minimum Critical Number of Fuel Rods

(1) Finite hexagonal lattice system composed of 55 fuel rods

The results of numerical data calculated using the JENDL-5 library for the finite hexagonal lattice systems composed of 55 fuel rods are listed in Tables A.2.1(1) to A.2.1(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.2.1(1) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 55 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	1.00792 ± 0.00039	1.52030 ± 0.00118	0.66472 ± 0.00035	1.01058 ± 0.00077	1.00770 ± 0.00077
4.00	0.29	1.02634 ± 0.00041	1.50757 ± 0.00116	0.68241 ± 0.00034	1.02878 ± 0.00079	1.02610 ± 0.00078
4.175	0.42	1.03472 ± 0.00036	1.49591 ± 0.00110	0.69335 ± 0.00031	1.03718 ± 0.00075	1.03463 ± 0.00075
4.35	0.56	1.03836 ± 0.00037	1.48130 ± 0.00114	0.70252 ± 0.00031	1.04064 ± 0.00079	1.03821 ± 0.00078
4.50	0.68	1.03907 ± 0.00037	1.46663 ± 0.00108	0.70983 ± 0.00031	1.04106 ± 0.00076	1.03875 ± 0.00076
4.70	0.84	1.03622 ± 0.00038	1.44422 ± 0.00111	0.71876 ± 0.00031	1.03804 ± 0.00079	1.03588 ± 0.00079
5.00	1.11	1.02539 ± 0.00035	1.40596 ± 0.00097	0.73050 ± 0.00029	1.02706 ± 0.00071	1.02511 ± 0.00071
5.50	1.58	0.99287 ± 0.00036	1.33202 ± 0.00096	0.74653 ± 0.00029	0.99440 ± 0.00072	0.99276 ± 0.00072
6.00	2.10	0.94839 ± 0.00035	1.25036 ± 0.00098	0.75948 ± 0.00029	0.94962 ± 0.00074	0.94825 ± 0.00074
6.50	2.67	0.89673 ± 0.00032	1.16574 ± 0.00087	0.77004 ± 0.00028	0.89766 ± 0.00067	0.89653 ± 0.00067
7.00	3.28	0.84162 ± 0.00032	1.08171 ± 0.00084	0.77883 ± 0.00029	0.84246 ± 0.00066	0.84152 ± 0.00066

Table A.2.1(2) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 55 fuel rods, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	1.00342 ± 0.00039	1.52104 ± 0.00118	0.66138 ± 0.00035	1.00598 ± 0.00077	1.00309 ± 0.00077
4.00	0.29	1.01777 ± 0.00039	1.51040 ± 0.00112	0.67545 ± 0.00033	1.02020 ± 0.00075	1.01748 ± 0.00074
4.175	0.42	1.02418 ± 0.00040	1.50029 ± 0.00115	0.68414 ± 0.00033	1.02642 ± 0.00078	1.02383 ± 0.00078
4.35	0.56	1.02742 ± 0.00040	1.48778 ± 0.00115	0.69205 ± 0.00034	1.02962 ± 0.00079	1.02713 ± 0.00079
4.50	0.68	1.02785 ± 0.00037	1.47531 ± 0.00108	0.69815 ± 0.00032	1.02999 ± 0.00075	1.02762 ± 0.00075
4.70	0.84	1.02536 ± 0.00040	1.45595 ± 0.00111	0.70553 ± 0.00033	1.02722 ± 0.00078	1.02498 ± 0.00078
5.00	1.11	1.01650 ± 0.00038	1.42267 ± 0.00109	0.71583 ± 0.00031	1.01839 ± 0.00077	1.01635 ± 0.00077
5.50	1.58	0.98904 ± 0.00035	1.35732 ± 0.00103	0.72976 ± 0.00030	0.99052 ± 0.00075	0.98877 ± 0.00075
6.00	2.10	0.95083 ± 0.00034	1.28389 ± 0.00097	0.74152 ± 0.00028	0.95203 ± 0.00071	0.95055 ± 0.00071
6.50	2.67	0.90529 ± 0.00033	1.20643 ± 0.00090	0.75133 ± 0.00028	0.90642 ± 0.00068	0.90517 ± 0.00068
7.00	3.28	0.85550 ± 0.00033	1.12771 ± 0.00088	0.75938 ± 0.00027	0.85636 ± 0.00066	0.85531 ± 0.00066

Table A.2.1(3) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 55 fuel rods, density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.99897 ± 0.00040	1.52195 ± 0.00123	0.65806 ± 0.00036	1.00153 ± 0.00080	0.99863 ± 0.00079
4.00	0.29	1.00888 ± 0.00039	1.51282 ± 0.00112	0.66861 ± 0.00034	1.01149 ± 0.00074	1.00874 ± 0.00074
4.175	0.42	1.01306 ± 0.00037	1.50448 ± 0.00111	0.67492 ± 0.00032	1.01540 ± 0.00074	1.01275 ± 0.00074
4.35	0.56	1.01474 ± 0.00040	1.49416 ± 0.00115	0.68069 ± 0.00034	1.01707 ± 0.00077	1.01452 ± 0.00077
4.50	0.68	1.01489 ± 0.00040	1.48358 ± 0.00109	0.68557 ± 0.00034	1.01710 ± 0.00075	1.01466 ± 0.00075
4.70	0.84	1.01289 ± 0.00038	1.46750 ± 0.00109	0.69174 ± 0.00033	1.01513 ± 0.00075	1.01281 ± 0.00074
5.00	1.11	1.00463 ± 0.00037	1.43886 ± 0.00105	0.69952 ± 0.00031	1.00651 ± 0.00073	1.00439 ± 0.00072
5.50	1.58	0.98153 ± 0.00034	1.38223 ± 0.00096	0.71131 ± 0.00029	0.98319 ± 0.00068	0.98134 ± 0.00068
6.00	2.10	0.94899 ± 0.00033	1.31753 ± 0.00100	0.72133 ± 0.00029	0.95037 ± 0.00071	0.94877 ± 0.00071
6.50	2.67	0.90925 ± 0.00035	1.24762 ± 0.00094	0.72978 ± 0.00031	0.91049 ± 0.00069	0.90912 ± 0.00069
7.00	3.28	0.86543 ± 0.00035	1.17557 ± 0.00092	0.73706 ± 0.00030	0.86646 ± 0.00068	0.86529 ± 0.00068

Table A.2.1(4) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 55 fuel rods, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.98947 ± 0.00039	1.52368 ± 0.00118	0.65106 ± 0.00034	0.99201 ± 0.00075	0.98908 ± 0.00075
4.00	0.29	0.98895 ± 0.00038	1.51771 ± 0.00117	0.65326 ± 0.00033	0.99145 ± 0.00075	0.98864 ± 0.00074
4.175	0.42	0.98780 ± 0.00038	1.51222 ± 0.00117	0.65485 ± 0.00035	0.99028 ± 0.00075	0.98756 ± 0.00075
4.35	0.56	0.98583 ± 0.00037	1.50558 ± 0.00116	0.65631 ± 0.00034	0.98812 ± 0.00075	0.98549 ± 0.00075
4.50	0.68	0.98395 ± 0.00037	1.49898 ± 0.00111	0.65795 ± 0.00035	0.98626 ± 0.00073	0.98369 ± 0.00072
4.70	0.84	0.97978 ± 0.00039	1.48833 ± 0.00114	0.65982 ± 0.00033	0.98204 ± 0.00074	0.97956 ± 0.00074
5.00	1.11	0.97133 ± 0.00036	1.46932 ± 0.00108	0.66242 ± 0.00032	0.97330 ± 0.00070	0.97098 ± 0.00070
5.50	1.58	0.95270 ± 0.00037	1.43037 ± 0.00109	0.66742 ± 0.00032	0.95466 ± 0.00072	0.95258 ± 0.00071
6.00	2.10	0.92833 ± 0.00035	1.38378 ± 0.00101	0.67202 ± 0.00032	0.92993 ± 0.00067	0.92807 ± 0.00067
6.50	2.67	0.89935 ± 0.00037	1.33154 ± 0.00101	0.67665 ± 0.00033	0.90099 ± 0.00068	0.89935 ± 0.00068
7.00	3.28	0.86704 ± 0.00035	1.27532 ± 0.00096	0.68085 ± 0.00032	0.86830 ± 0.00065	0.86686 ± 0.00065

Table A.2.1(5) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 55 fuel rods, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.97952 ± 0.00038	1.52521 ± 0.00118	0.64405 ± 0.00035	0.98232 ± 0.00074	0.97936 ± 0.00074
4.00	0.29	0.96706 ± 0.00040	1.52221 ± 0.00118	0.63699 ± 0.00036	0.96964 ± 0.00074	0.96676 ± 0.00074
4.175	0.42	0.95849 ± 0.00039	1.51934 ± 0.00129	0.63256 ± 0.00037	0.96108 ± 0.00079	0.95828 ± 0.00079
4.35	0.56	0.95092 ± 0.00038	1.51601 ± 0.00123	0.62882 ± 0.00037	0.95330 ± 0.00075	0.95056 ± 0.00075
4.50	0.68	0.94431 ± 0.00038	1.51250 ± 0.00117	0.62598 ± 0.00035	0.94679 ± 0.00071	0.94412 ± 0.00071
4.70	0.84	0.93565 ± 0.00038	1.50680 ± 0.00116	0.62256 ± 0.00034	0.93807 ± 0.00070	0.93545 ± 0.00070
5.00	1.11	0.92287 ± 0.00038	1.49645 ± 0.00115	0.61818 ± 0.00036	0.92507 ± 0.00070	0.92258 ± 0.00070
5.50	1.58	0.90160 ± 0.00037	1.47447 ± 0.00119	0.61289 ± 0.00035	0.90369 ± 0.00070	0.90140 ± 0.00070
6.00	2.10	0.87894 ± 0.00036	1.44644 ± 0.00117	0.60893 ± 0.00036	0.88077 ± 0.00069	0.87867 ± 0.00069
6.50	2.67	0.85567 ± 0.00037	1.41383 ± 0.00113	0.60646 ± 0.00034	0.85744 ± 0.00066	0.85552 ± 0.00066
7.00	3.28	0.83175 ± 0.00036	1.37723 ± 0.00110	0.60513 ± 0.00036	0.83340 ± 0.00065	0.83164 ± 0.00065

Table A.2.1(6) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 55 fuel rods, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.96911 ± 0.00039	1.52701 ± 0.00124	0.63639 ± 0.00036	0.97177 ± 0.00077	0.96879 ± 0.00077
4.00	0.29	0.94269 ± 0.00036	1.52648 ± 0.00119	0.61924 ± 0.00034	0.94526 ± 0.00071	0.94233 ± 0.00071
4.175	0.42	0.92575 ± 0.00040	1.52616 ± 0.00129	0.60828 ± 0.00038	0.92832 ± 0.00076	0.92544 ± 0.00076
4.35	0.56	0.90949 ± 0.00038	1.52544 ± 0.00118	0.59786 ± 0.00036	0.91199 ± 0.00069	0.90916 ± 0.00069
4.50	0.68	0.89678 ± 0.00040	1.52455 ± 0.00123	0.58991 ± 0.00038	0.89934 ± 0.00071	0.89656 ± 0.00071
4.70	0.84	0.88060 ± 0.00037	1.52310 ± 0.00129	0.57981 ± 0.00037	0.88311 ± 0.00071	0.88039 ± 0.00071
5.00	1.11	0.85814 ± 0.00039	1.52012 ± 0.00134	0.56609 ± 0.00039	0.86053 ± 0.00072	0.85790 ± 0.00072
5.50	1.58	0.82527 ± 0.00037	1.51292 ± 0.00134	0.54697 ± 0.00040	0.82752 ± 0.00069	0.82506 ± 0.00069
6.00	2.10	0.79564 ± 0.00035	1.50243 ± 0.00128	0.53094 ± 0.00040	0.79770 ± 0.00064	0.79539 ± 0.00064
6.50	2.67	0.76869 ± 0.00037	1.48907 ± 0.00132	0.51750 ± 0.00040	0.77059 ± 0.00064	0.76843 ± 0.00064
7.00	3.28	0.74406 ± 0.00038	1.47349 ± 0.00129	0.50619 ± 0.00042	0.74587 ± 0.00062	0.74386 ± 0.00062

Table A.2.1(7) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 55 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.95859 ± 0.00037	1.52902 ± 0.00118	0.62868 ± 0.00034	0.96127 ± 0.00072	0.95827 ± 0.00072
4.00	0.29	0.91707 ± 0.00040	1.53162 ± 0.00119	0.60053 ± 0.00037	0.91979 ± 0.00070	0.91682 ± 0.00070
4.175	0.42	0.88954 ± 0.00037	1.53352 ± 0.00130	0.58169 ± 0.00038	0.89204 ± 0.00072	0.88910 ± 0.00072
4.35	0.56	0.86409 ± 0.00039	1.53544 ± 0.00130	0.56452 ± 0.00039	0.86678 ± 0.00070	0.86387 ± 0.00070
4.50	0.68	0.84382 ± 0.00037	1.53710 ± 0.00130	0.55077 ± 0.00039	0.84658 ± 0.00069	0.84371 ± 0.00068
4.70	0.84	0.81883 ± 0.00039	1.53925 ± 0.00136	0.53365 ± 0.00040	0.82141 ± 0.00069	0.81859 ± 0.00068
5.00	1.11	0.78460 ± 0.00035	1.54217 ± 0.00131	0.51050 ± 0.00039	0.78728 ± 0.00063	0.78455 ± 0.00062
5.50	1.58	0.73511 ± 0.00037	1.54689 ± 0.00153	0.47673 ± 0.00045	0.73745 ± 0.00068	0.73485 ± 0.00067
6.00	2.10	0.69259 ± 0.00036	1.55156 ± 0.00149	0.44789 ± 0.00045	0.69493 ± 0.00061	0.69248 ± 0.00061
6.50	2.67	0.65573 ± 0.00034	1.55591 ± 0.00150	0.42284 ± 0.00046	0.65791 ± 0.00058	0.65559 ± 0.00058
7.00	3.28	0.62297 ± 0.00036	1.56003 ± 0.00161	0.40064 ± 0.00050	0.62502 ± 0.00059	0.62283 ± 0.00058

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the finite hexagonal lattice systems composed of 55 fuel rods are listed in Tables A.2.2(1) to A.2.2(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.2.2(1) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0, 55 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	1.00122 ± 0.00036	1.52182 ± 0.00112	0.65962 ± 0.00031	1.00382 ± 0.00072	1.00094 ± 0.00072
4.00	0.29	1.02041 ± 0.00039	1.50910 ± 0.00111	0.67777 ± 0.00033	1.02283 ± 0.00075	1.02013 ± 0.00075
4.175	0.42	1.02871 ± 0.00037	1.49725 ± 0.00115	0.68861 ± 0.00031	1.03102 ± 0.00078	1.02845 ± 0.00078
4.35	0.56	1.03354 ± 0.00039	1.48247 ± 0.00114	0.69863 ± 0.00033	1.03569 ± 0.00079	1.03326 ± 0.00079
4.50	0.68	1.03442 ± 0.00039	1.46774 ± 0.00108	0.70620 ± 0.00032	1.03651 ± 0.00076	1.03418 ± 0.00075
4.70	0.84	1.03187 ± 0.00038	1.44502 ± 0.00110	0.71541 ± 0.00032	1.03378 ± 0.00079	1.03158 ± 0.00079
5.00	1.11	1.02122 ± 0.00037	1.40605 ± 0.00107	0.72761 ± 0.00030	1.02306 ± 0.00077	1.02107 ± 0.00077
5.50	1.58	0.98896 ± 0.00034	1.33078 ± 0.00092	0.74425 ± 0.00029	0.99044 ± 0.00069	0.98878 ± 0.00068
6.00	2.10	0.94415 ± 0.00035	1.24764 ± 0.00094	0.75765 ± 0.00029	0.94528 ± 0.00071	0.94389 ± 0.00071
6.50	2.67	0.89155 ± 0.00035	1.16127 ± 0.00090	0.76861 ± 0.00028	0.89257 ± 0.00069	0.89141 ± 0.00069
7.00	3.28	0.83557 ± 0.00033	1.07522 ± 0.00087	0.77794 ± 0.00028	0.83646 ± 0.00068	0.83550 ± 0.00067

Table A.2.2(2) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0, 55 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.95127 ± 0.00038	1.53038 ± 0.00119	0.62341 ± 0.00036	0.95405 ± 0.00072	0.95105 ± 0.00072
4.00	0.29	0.90975 ± 0.00038	1.53272 ± 0.00119	0.59528 ± 0.00037	0.91240 ± 0.00069	0.90942 ± 0.00069
4.175	0.42	0.88283 ± 0.00037	1.53502 ± 0.00125	0.57691 ± 0.00038	0.88557 ± 0.00069	0.88263 ± 0.00069
4.35	0.56	0.85749 ± 0.00036	1.53689 ± 0.00130	0.55960 ± 0.00037	0.86004 ± 0.00069	0.85714 ± 0.00069
4.50	0.68	0.83718 ± 0.00037	1.53857 ± 0.00131	0.54583 ± 0.00039	0.83980 ± 0.00068	0.83693 ± 0.00067
4.70	0.84	0.81252 ± 0.00037	1.54051 ± 0.00137	0.52919 ± 0.00040	0.81523 ± 0.00068	0.81240 ± 0.00067
5.00	1.11	0.77849 ± 0.00039	1.54355 ± 0.00142	0.50596 ± 0.00042	0.78097 ± 0.00067	0.77823 ± 0.00067
5.50	1.58	0.72928 ± 0.00039	1.54833 ± 0.00143	0.47254 ± 0.00045	0.73166 ± 0.00063	0.72906 ± 0.00063
6.00	2.10	0.68693 ± 0.00037	1.55272 ± 0.00149	0.44388 ± 0.00047	0.68922 ± 0.00061	0.68676 ± 0.00061
6.50	2.67	0.64993 ± 0.00035	1.55695 ± 0.00149	0.41884 ± 0.00048	0.65212 ± 0.00058	0.64979 ± 0.00058
7.00	3.28	0.61776 ± 0.00034	1.56109 ± 0.00168	0.39709 ± 0.00051	0.61989 ± 0.00060	0.61769 ± 0.00060

Table A.2.2(3) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0u1, 55 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	1.00127 ± 0.00038	1.52177 ± 0.00112	0.65971 ± 0.00034	1.00393 ± 0.00073	1.00105 ± 0.00073
4.00	0.29	1.02065 ± 0.00040	1.50929 ± 0.00127	0.67787 ± 0.00035	1.02310 ± 0.00084	1.02041 ± 0.00084
4.175	0.42	1.02896 ± 0.00038	1.49729 ± 0.00110	0.68875 ± 0.00032	1.03125 ± 0.00075	1.02868 ± 0.00075
4.35	0.56	1.03375 ± 0.00038	1.48255 ± 0.00109	0.69872 ± 0.00032	1.03589 ± 0.00075	1.03345 ± 0.00075
4.50	0.68	1.03442 ± 0.00038	1.46772 ± 0.00102	0.70615 ± 0.00033	1.03643 ± 0.00073	1.03410 ± 0.00073
4.70	0.84	1.03194 ± 0.00040	1.44512 ± 0.00111	0.71536 ± 0.00032	1.03377 ± 0.00079	1.03159 ± 0.00079
5.00	1.11	1.02127 ± 0.00037	1.40612 ± 0.00102	0.72757 ± 0.00031	1.02305 ± 0.00075	1.02106 ± 0.00075
5.50	1.58	0.98913 ± 0.00033	1.33084 ± 0.00096	0.74439 ± 0.00028	0.99066 ± 0.00071	0.98900 ± 0.00071
6.00	2.10	0.94417 ± 0.00034	1.24753 ± 0.00094	0.75782 ± 0.00029	0.94540 ± 0.00071	0.94401 ± 0.00071
6.50	2.67	0.89163 ± 0.00033	1.16125 ± 0.00087	0.76863 ± 0.00027	0.89257 ± 0.00066	0.89141 ± 0.00066
7.00	3.28	0.83559 ± 0.00033	1.07524 ± 0.00083	0.77788 ± 0.00028	0.83641 ± 0.00065	0.83545 ± 0.00065

Table A.2.2(4) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0u1, 55 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.95147 ± 0.00039	1.53041 ± 0.00124	0.62344 ± 0.00036	0.95412 ± 0.00075	0.95112 ± 0.00075
4.00	0.29	0.90972 ± 0.00040	1.53296 ± 0.00135	0.59515 ± 0.00039	0.91234 ± 0.00077	0.90934 ± 0.00077
4.175	0.42	0.88291 ± 0.00038	1.53508 ± 0.00124	0.57697 ± 0.00037	0.88570 ± 0.00069	0.88275 ± 0.00069
4.35	0.56	0.85742 ± 0.00038	1.53685 ± 0.00125	0.55966 ± 0.00038	0.86012 ± 0.00067	0.85721 ± 0.00067
4.50	0.68	0.83763 ± 0.00038	1.53865 ± 0.00136	0.54610 ± 0.00040	0.84026 ± 0.00071	0.83739 ± 0.00070
4.70	0.84	0.81249 ± 0.00038	1.54041 ± 0.00137	0.52911 ± 0.00042	0.81505 ± 0.00069	0.81224 ± 0.00068
5.00	1.11	0.77832 ± 0.00038	1.54348 ± 0.00137	0.50589 ± 0.00043	0.78082 ± 0.00065	0.77809 ± 0.00065
5.50	1.58	0.72928 ± 0.00038	1.54822 ± 0.00149	0.47261 ± 0.00044	0.73170 ± 0.00065	0.72910 ± 0.00065
6.00	2.10	0.68699 ± 0.00035	1.55273 ± 0.00150	0.44389 ± 0.00046	0.68924 ± 0.00061	0.68679 ± 0.00061
6.50	2.67	0.65003 ± 0.00036	1.55707 ± 0.00155	0.41891 ± 0.00049	0.65227 ± 0.00060	0.64994 ± 0.00059
7.00	3.28	0.61771 ± 0.00032	1.56110 ± 0.00151	0.39703 ± 0.00047	0.61980 ± 0.00054	0.61761 ± 0.00054

(2) Finite hexagonal lattice system composed of 49 fuel rods

The results of numerical data calculated using the JENDL-5 library for the finite hexagonal lattice systems composed of 49 fuel rods are listed in Tables A.2.3(1) to A.2.3(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.2.3(1) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.98531 ± 0.00037	1.52565 ± 0.00113	0.64747 ± 0.00033	0.98782 ± 0.00072	0.98505 ± 0.00071
4.00	0.29	1.00256 ± 0.00038	1.51158 ± 0.00117	0.66473 ± 0.00032	1.00480 ± 0.00076	1.00223 ± 0.00075
4.175	0.42	1.00952 ± 0.00038	1.49866 ± 0.00116	0.67502 ± 0.00032	1.01162 ± 0.00076	1.00920 ± 0.00076
4.35	0.56	1.01324 ± 0.00039	1.48332 ± 0.00114	0.68447 ± 0.00033	1.01529 ± 0.00077	1.01300 ± 0.00077
4.50	0.68	1.01338 ± 0.00039	1.46801 ± 0.00118	0.69164 ± 0.00032	1.01533 ± 0.00080	1.01315 ± 0.00080
4.70	0.84	1.01052 ± 0.00040	1.44504 ± 0.00106	0.70055 ± 0.00033	1.01232 ± 0.00074	1.01030 ± 0.00074
5.00	1.11	0.99947 ± 0.00036	1.40600 ± 0.00103	0.71201 ± 0.00030	1.00109 ± 0.00073	0.99927 ± 0.00072
5.50	1.58	0.96815 ± 0.00034	1.33151 ± 0.00096	0.72814 ± 0.00029	0.96953 ± 0.00070	0.96803 ± 0.00070
6.00	2.10	0.92535 ± 0.00034	1.24959 ± 0.00094	0.74144 ± 0.00028	0.92650 ± 0.00069	0.92526 ± 0.00069
6.50	2.67	0.87552 ± 0.00035	1.16498 ± 0.00094	0.75234 ± 0.00030	0.87646 ± 0.00071	0.87544 ± 0.00071
7.00	3.28	0.82248 ± 0.00033	1.08063 ± 0.00084	0.76179 ± 0.00029	0.82321 ± 0.00064	0.82238 ± 0.00064

Table A.2.3(2) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.98158 ± 0.00038	1.52675 ± 0.00119	0.64460 ± 0.00035	0.98414 ± 0.00075	0.98136 ± 0.00075
4.00	0.29	0.99416 ± 0.00037	1.51439 ± 0.00117	0.65801 ± 0.00033	0.99649 ± 0.00075	0.99389 ± 0.00075
4.175	0.42	0.99982 ± 0.00037	1.50338 ± 0.00111	0.66648 ± 0.00032	1.00197 ± 0.00073	0.99951 ± 0.00072
4.35	0.56	1.00265 ± 0.00039	1.49020 ± 0.00115	0.67426 ± 0.00033	1.00479 ± 0.00076	1.00244 ± 0.00076
4.50	0.68	1.00257 ± 0.00034	1.47696 ± 0.00108	0.68011 ± 0.00031	1.00449 ± 0.00072	1.00225 ± 0.00072
4.70	0.84	0.99985 ± 0.00038	1.45695 ± 0.00107	0.68755 ± 0.00033	1.00172 ± 0.00073	0.99963 ± 0.00073
5.00	1.11	0.99064 ± 0.00036	1.42296 ± 0.00103	0.69731 ± 0.00032	0.99224 ± 0.00072	0.99034 ± 0.00072
5.50	1.58	0.96404 ± 0.00036	1.35696 ± 0.00098	0.71148 ± 0.00030	0.96546 ± 0.00070	0.96387 ± 0.00069
6.00	2.10	0.92664 ± 0.00035	1.28323 ± 0.00096	0.72308 ± 0.00030	0.92788 ± 0.00069	0.92654 ± 0.00069
6.50	2.67	0.88285 ± 0.00034	1.20560 ± 0.00095	0.73308 ± 0.00029	0.88380 ± 0.00069	0.88269 ± 0.00069
7.00	3.28	0.83488 ± 0.00033	1.12681 ± 0.00083	0.74162 ± 0.00028	0.83566 ± 0.00062	0.83474 ± 0.00062

Table A.2.3(3) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.97708 ± 0.00038	1.52777 ± 0.00118	0.64117 ± 0.00034	0.97956 ± 0.00074	0.97677 ± 0.00074
4.00	0.29	0.98592 ± 0.00038	1.51734 ± 0.00123	0.65133 ± 0.00033	0.98829 ± 0.00077	0.98568 ± 0.00077
4.175	0.42	0.98938 ± 0.00037	1.50799 ± 0.00116	0.65761 ± 0.00032	0.99167 ± 0.00074	0.98915 ± 0.00074
4.35	0.56	0.99061 ± 0.00035	1.49663 ± 0.00110	0.66334 ± 0.00032	0.99278 ± 0.00072	0.99040 ± 0.00071
4.50	0.68	0.99010 ± 0.00037	1.48562 ± 0.00109	0.66783 ± 0.00031	0.99215 ± 0.00071	0.98986 ± 0.00071
4.70	0.84	0.98732 ± 0.00036	1.46887 ± 0.00108	0.67343 ± 0.00032	0.98919 ± 0.00071	0.98702 ± 0.00071
5.00	1.11	0.97901 ± 0.00036	1.43967 ± 0.00111	0.68129 ± 0.00032	0.98083 ± 0.00074	0.97885 ± 0.00074
5.50	1.58	0.95573 ± 0.00035	1.38211 ± 0.00105	0.69266 ± 0.00031	0.95734 ± 0.00072	0.95564 ± 0.00072
6.00	2.10	0.92368 ± 0.00036	1.31674 ± 0.00099	0.70244 ± 0.00031	0.92493 ± 0.00069	0.92349 ± 0.00069
6.50	2.67	0.88563 ± 0.00035	1.24682 ± 0.00094	0.71114 ± 0.00030	0.88666 ± 0.00066	0.88544 ± 0.00066
7.00	3.28	0.84334 ± 0.00033	1.17476 ± 0.00088	0.71870 ± 0.00031	0.84430 ± 0.00064	0.84328 ± 0.00063

Table A.2.3(4) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.96834 ± 0.00036	1.52968 ± 0.00118	0.63472 ± 0.00034	0.97091 ± 0.00073	0.96809 ± 0.00073
4.00	0.29	0.96727 ± 0.00038	1.52270 ± 0.00123	0.63681 ± 0.00034	0.96967 ± 0.00076	0.96699 ± 0.00076
4.175	0.42	0.96508 ± 0.00038	1.51648 ± 0.00117	0.63786 ± 0.00034	0.96730 ± 0.00073	0.96472 ± 0.00072
4.35	0.56	0.96278 ± 0.00037	1.50929 ± 0.00117	0.63937 ± 0.00033	0.96499 ± 0.00072	0.96250 ± 0.00072
4.50	0.68	0.95996 ± 0.00036	1.50205 ± 0.00115	0.64053 ± 0.00034	0.96211 ± 0.00072	0.95971 ± 0.00072
4.70	0.84	0.95548 ± 0.00036	1.49075 ± 0.00109	0.64239 ± 0.00033	0.95764 ± 0.00069	0.95533 ± 0.00069
5.00	1.11	0.94669 ± 0.00036	1.47098 ± 0.00113	0.64491 ± 0.00034	0.94865 ± 0.00071	0.94652 ± 0.00071
5.50	1.58	0.92714 ± 0.00038	1.43098 ± 0.00109	0.64909 ± 0.00033	0.92883 ± 0.00070	0.92694 ± 0.00069
6.00	2.10	0.90263 ± 0.00035	1.38363 ± 0.00110	0.65348 ± 0.00033	0.90418 ± 0.00070	0.90251 ± 0.00070
6.50	2.67	0.87376 ± 0.00038	1.33084 ± 0.00106	0.65753 ± 0.00033	0.87507 ± 0.00068	0.87362 ± 0.00068
7.00	3.28	0.84241 ± 0.00038	1.27466 ± 0.00105	0.66170 ± 0.00033	0.84345 ± 0.00068	0.84218 ± 0.00068

Table A.2.3(5) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.95890 ± 0.00039	1.53150 ± 0.00119	0.62772 ± 0.00034	0.96136 ± 0.00072	0.95851 ± 0.00072
4.00	0.29	0.94641 ± 0.00037	1.52789 ± 0.00124	0.62107 ± 0.00036	0.94893 ± 0.00074	0.94620 ± 0.00074
4.175	0.42	0.93766 ± 0.00039	1.52462 ± 0.00129	0.61663 ± 0.00037	0.94012 ± 0.00077	0.93747 ± 0.00077
4.35	0.56	0.92964 ± 0.00039	1.52075 ± 0.00123	0.61284 ± 0.00036	0.93197 ± 0.00073	0.92939 ± 0.00073
4.50	0.68	0.92288 ± 0.00038	1.51679 ± 0.00123	0.61004 ± 0.00037	0.92530 ± 0.00073	0.92279 ± 0.00073
4.70	0.84	0.91389 ± 0.00040	1.51070 ± 0.00127	0.60646 ± 0.00036	0.91617 ± 0.00074	0.91375 ± 0.00074
5.00	1.11	0.90032 ± 0.00038	1.49962 ± 0.00132	0.60177 ± 0.00037	0.90243 ± 0.00076	0.90013 ± 0.00076
5.50	1.58	0.87801 ± 0.00038	1.47634 ± 0.00125	0.59600 ± 0.00037	0.87990 ± 0.00071	0.87782 ± 0.00071
6.00	2.10	0.85496 ± 0.00038	1.44765 ± 0.00121	0.59183 ± 0.00038	0.85676 ± 0.00070	0.85487 ± 0.00070
6.50	2.67	0.83109 ± 0.00037	1.41421 ± 0.00123	0.58880 ± 0.00037	0.83268 ± 0.00069	0.83099 ± 0.00069
7.00	3.28	0.80582 ± 0.00035	1.37690 ± 0.00119	0.58631 ± 0.00037	0.80729 ± 0.00067	0.80576 ± 0.00067

Table A.2.3(6) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.94923 ± 0.00038	1.53354 ± 0.00119	0.62062 ± 0.00036	0.95175 ± 0.00072	0.94889 ± 0.00072
4.00	0.29	0.92363 ± 0.00037	1.53294 ± 0.00119	0.60412 ± 0.00036	0.92608 ± 0.00070	0.92329 ± 0.00070
4.175	0.42	0.90733 ± 0.00039	1.53240 ± 0.00130	0.59366 ± 0.00036	0.90973 ± 0.00074	0.90700 ± 0.00073
4.35	0.56	0.89149 ± 0.00039	1.53162 ± 0.00125	0.58372 ± 0.00037	0.89403 ± 0.00070	0.89138 ± 0.00070
4.50	0.68	0.87881 ± 0.00039	1.53060 ± 0.00119	0.57578 ± 0.00038	0.88128 ± 0.00067	0.87868 ± 0.00067
4.70	0.84	0.86293 ± 0.00036	1.52878 ± 0.00135	0.56597 ± 0.00038	0.86524 ± 0.00072	0.86271 ± 0.00072
5.00	1.11	0.84063 ± 0.00039	1.52532 ± 0.00129	0.55244 ± 0.00039	0.84264 ± 0.00068	0.84022 ± 0.00068
5.50	1.58	0.80666 ± 0.00036	1.51716 ± 0.00129	0.53314 ± 0.00037	0.80885 ± 0.00064	0.80662 ± 0.00064
6.00	2.10	0.77644 ± 0.00037	1.50577 ± 0.00127	0.51694 ± 0.00040	0.77839 ± 0.00062	0.77633 ± 0.00062
6.50	2.67	0.74871 ± 0.00038	1.49199 ± 0.00132	0.50300 ± 0.00043	0.75047 ± 0.00063	0.74857 ± 0.00063
7.00	3.28	0.72284 ± 0.00036	1.47546 ± 0.00140	0.49100 ± 0.00042	0.72446 ± 0.00064	0.72272 ± 0.00064

Table A.2.3(7) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.93937 ± 0.00038	1.53587 ± 0.00125	0.61334 ± 0.00037	0.94201 ± 0.00075	0.93912 ± 0.00074
4.00	0.29	0.89996 ± 0.00038	1.53866 ± 0.00125	0.58648 ± 0.00037	0.90239 ± 0.00070	0.89957 ± 0.00070
4.175	0.42	0.87390 ± 0.00039	1.54110 ± 0.00137	0.56873 ± 0.00038	0.87647 ± 0.00073	0.87369 ± 0.00073
4.35	0.56	0.84982 ± 0.00040	1.54311 ± 0.00136	0.55245 ± 0.00041	0.85249 ± 0.00072	0.84975 ± 0.00072
4.50	0.68	0.83040 ± 0.00039	1.54450 ± 0.00136	0.53921 ± 0.00041	0.83281 ± 0.00070	0.83014 ± 0.00070
4.70	0.84	0.80595 ± 0.00038	1.54664 ± 0.00142	0.52271 ± 0.00041	0.80845 ± 0.00070	0.80583 ± 0.00069
5.00	1.11	0.77324 ± 0.00037	1.54985 ± 0.00132	0.50044 ± 0.00043	0.77560 ± 0.00063	0.77309 ± 0.00063
5.50	1.58	0.72491 ± 0.00038	1.55452 ± 0.00149	0.46762 ± 0.00045	0.72692 ± 0.00065	0.72458 ± 0.00064
6.00	2.10	0.68299 ± 0.00037	1.55925 ± 0.00150	0.43935 ± 0.00046	0.68506 ± 0.00061	0.68287 ± 0.00060
6.50	2.67	0.64633 ± 0.00038	1.56342 ± 0.00150	0.41454 ± 0.00048	0.64810 ± 0.00057	0.64605 ± 0.00057
7.00	3.28	0.61343 ± 0.00036	1.56745 ± 0.00168	0.39248 ± 0.00050	0.61520 ± 0.00059	0.61329 ± 0.00059

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the finite hexagonal lattice systems composed of

49 fuel rods are listed in Tables A.2.4(1) to A.2.4(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.2.4(1) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0, 49 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.97912 ± 0.00037	1.52720 ± 0.00118	0.64283 ± 0.00034	0.98173 ± 0.00074	0.97895 ± 0.00074
4.00	0.29	0.99663 ± 0.00038	1.51293 ± 0.00112	0.66025 ± 0.00033	0.99891 ± 0.00073	0.99632 ± 0.00072
4.175	0.42	1.00450 ± 0.00039	1.49992 ± 0.00116	0.67100 ± 0.00034	1.00645 ± 0.00077	1.00402 ± 0.00076
4.35	0.56	1.00810 ± 0.00040	1.48444 ± 0.00114	0.68046 ± 0.00034	1.01010 ± 0.00077	1.00779 ± 0.00077
4.50	0.68	1.00886 ± 0.00039	1.46912 ± 0.00118	0.68812 ± 0.00032	1.01093 ± 0.00080	1.00874 ± 0.00079
4.70	0.84	1.00610 ± 0.00038	1.44593 ± 0.00111	0.69703 ± 0.00032	1.00786 ± 0.00076	1.00581 ± 0.00076
5.00	1.11	0.99529 ± 0.00036	1.40616 ± 0.00107	0.70899 ± 0.00031	0.99695 ± 0.00075	0.99511 ± 0.00075
5.50	1.58	0.96407 ± 0.00035	1.33020 ± 0.00101	0.72579 ± 0.00030	0.96544 ± 0.00073	0.96392 ± 0.00073
6.00	2.10	0.92093 ± 0.00036	1.24677 ± 0.00094	0.73947 ± 0.00029	0.92194 ± 0.00069	0.92068 ± 0.00069
6.50	2.67	0.87046 ± 0.00034	1.16042 ± 0.00091	0.75091 ± 0.00030	0.87138 ± 0.00068	0.87035 ± 0.00068
7.00	3.28	0.81630 ± 0.00033	1.07440 ± 0.00083	0.76038 ± 0.00028	0.81696 ± 0.00063	0.81611 ± 0.00063

Table A.2.4(2) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0, 49 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.93238 ± 0.00039	1.53717 ± 0.00125	0.60826 ± 0.00037	0.93500 ± 0.00074	0.93212 ± 0.00073
4.00	0.29	0.89328 ± 0.00038	1.54016 ± 0.00125	0.58161 ± 0.00037	0.89576 ± 0.00070	0.89292 ± 0.00070
4.175	0.42	0.86749 ± 0.00040	1.54217 ± 0.00137	0.56416 ± 0.00040	0.87003 ± 0.00073	0.86724 ± 0.00073
4.35	0.56	0.84343 ± 0.00039	1.54441 ± 0.00137	0.54774 ± 0.00040	0.84594 ± 0.00071	0.84320 ± 0.00071
4.50	0.68	0.82416 ± 0.00037	1.54619 ± 0.00131	0.53463 ± 0.00038	0.82665 ± 0.00066	0.82396 ± 0.00066
4.70	0.84	0.80000 ± 0.00037	1.54810 ± 0.00131	0.51834 ± 0.00041	0.80244 ± 0.00065	0.79981 ± 0.00065
5.00	1.11	0.76736 ± 0.00039	1.55120 ± 0.00138	0.49622 ± 0.00043	0.76973 ± 0.00065	0.76722 ± 0.00064
5.50	1.58	0.71921 ± 0.00036	1.55594 ± 0.00143	0.46369 ± 0.00044	0.72148 ± 0.00062	0.71912 ± 0.00062
6.00	2.10	0.67739 ± 0.00035	1.56034 ± 0.00150	0.43545 ± 0.00046	0.67945 ± 0.00060	0.67724 ± 0.00060
6.50	2.67	0.64057 ± 0.00036	1.56452 ± 0.00156	0.41069 ± 0.00048	0.64253 ± 0.00058	0.64048 ± 0.00058
7.00	3.28	0.60804 ± 0.00034	1.56837 ± 0.00163	0.38879 ± 0.00051	0.60978 ± 0.00057	0.60786 ± 0.00057

Table A.2.4(3) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0u1, 49 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.97920 ± 0.00036	1.52715 ± 0.00119	0.64286 ± 0.00033	0.98175 ± 0.00074	0.97898 ± 0.00074
4.00	0.29	0.99685 ± 0.00037	1.51296 ± 0.00117	0.66036 ± 0.00032	0.99910 ± 0.00075	0.99651 ± 0.00075
4.175	0.42	1.00448 ± 0.00037	1.50012 ± 0.00121	0.67109 ± 0.00032	1.00672 ± 0.00079	1.00427 ± 0.00079
4.35	0.56	1.00824 ± 0.00040	1.48449 ± 0.00114	0.68059 ± 0.00033	1.01032 ± 0.00077	1.00802 ± 0.00076
4.50	0.68	1.00873 ± 0.00037	1.46913 ± 0.00118	0.68793 ± 0.00032	1.01066 ± 0.00080	1.00846 ± 0.00079
4.70	0.84	1.00590 ± 0.00037	1.44580 ± 0.00106	0.69705 ± 0.00032	1.00780 ± 0.00073	1.00574 ± 0.00073
5.00	1.11	0.99553 ± 0.00037	1.40617 ± 0.00107	0.70903 ± 0.00031	0.99702 ± 0.00075	0.99519 ± 0.00075
5.50	1.58	0.96431 ± 0.00033	1.33022 ± 0.00096	0.72592 ± 0.00029	0.96564 ± 0.00069	0.96411 ± 0.00069
6.00	2.10	0.92077 ± 0.00034	1.24667 ± 0.00094	0.73945 ± 0.00029	0.92185 ± 0.00069	0.92060 ± 0.00069
6.50	2.67	0.87028 ± 0.00034	1.16030 ± 0.00090	0.75078 ± 0.00029	0.87113 ± 0.00068	0.87010 ± 0.00068
7.00	3.28	0.81658 ± 0.00035	1.07451 ± 0.00087	0.76068 ± 0.00029	0.81736 ± 0.00066	0.81651 ± 0.00066

Table A.2.4(4) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0u1, 49 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.93202 ± 0.00038	1.53709 ± 0.00125	0.60805 ± 0.00036	0.93462 ± 0.00073	0.93173 ± 0.00073
4.00	0.29	0.89311 ± 0.00037	1.54020 ± 0.00125	0.58155 ± 0.00037	0.89571 ± 0.00070	0.89287 ± 0.00070
4.175	0.42	0.86750 ± 0.00038	1.54233 ± 0.00130	0.56418 ± 0.00038	0.87016 ± 0.00070	0.86737 ± 0.00070
4.35	0.56	0.84324 ± 0.00039	1.54422 ± 0.00131	0.54763 ± 0.00041	0.84566 ± 0.00069	0.84293 ± 0.00069
4.50	0.68	0.82389 ± 0.00039	1.54595 ± 0.00132	0.53459 ± 0.00041	0.82644 ± 0.00067	0.82375 ± 0.00067
4.70	0.84	0.79998 ± 0.00041	1.54817 ± 0.00139	0.51830 ± 0.00043	0.80241 ± 0.00068	0.79981 ± 0.00068
5.00	1.11	0.76704 ± 0.00036	1.55106 ± 0.00137	0.49601 ± 0.00042	0.76934 ± 0.00064	0.76682 ± 0.00064
5.50	1.58	0.71903 ± 0.00036	1.55580 ± 0.00133	0.46352 ± 0.00043	0.72115 ± 0.00058	0.71879 ± 0.00058
6.00	2.10	0.67757 ± 0.00037	1.56056 ± 0.00156	0.43555 ± 0.00049	0.67970 ± 0.00063	0.67749 ± 0.00062
6.50	2.67	0.64082 ± 0.00035	1.56440 ± 0.00162	0.41080 ± 0.00050	0.64266 ± 0.00061	0.64061 ± 0.00060
7.00	3.28	0.60786 ± 0.00035	1.56840 ± 0.00157	0.38866 ± 0.00050	0.60957 ± 0.00056	0.60764 ± 0.00055

(3) Finite hexagonal lattice system composed of 43 fuel rods

The results of numerical data calculated using the JENDL-5 library for the finite hexagonal lattice systems composed of 43 fuel rods are listed in Tables A.2.5(1) to A.2.5(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.2.5(1) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 43 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.95404 ± 0.00038	1.52397 ± 0.00118	0.62747 ± 0.00036	0.95625 ± 0.00073	0.95375 ± 0.00072
4.00	0.29	0.97368 ± 0.00037	1.51003 ± 0.00122	0.64611 ± 0.00035	0.97565 ± 0.00077	0.97333 ± 0.00077
4.175	0.42	0.98239 ± 0.00039	1.49747 ± 0.00116	0.65722 ± 0.00033	0.98417 ± 0.00074	0.98198 ± 0.00074
4.35	0.56	0.98761 ± 0.00036	1.48237 ± 0.00109	0.66741 ± 0.00031	0.98934 ± 0.00071	0.98728 ± 0.00071
4.50	0.68	0.98894 ± 0.00038	1.46719 ± 0.00108	0.67522 ± 0.00034	0.99067 ± 0.00073	0.98871 ± 0.00072
4.70	0.84	0.98799 ± 0.00036	1.44460 ± 0.00110	0.68507 ± 0.00033	0.98965 ± 0.00075	0.98782 ± 0.00075
5.00	1.11	0.97930 ± 0.00037	1.40576 ± 0.00107	0.69771 ± 0.00033	0.98081 ± 0.00074	0.97917 ± 0.00074
5.50	1.58	0.95168 ± 0.00035	1.33137 ± 0.00096	0.71573 ± 0.00030	0.95290 ± 0.00069	0.95156 ± 0.00069
6.00	2.10	0.91179 ± 0.00036	1.24990 ± 0.00098	0.73028 ± 0.00031	0.91278 ± 0.00072	0.91167 ± 0.00071
6.50	2.67	0.86421 ± 0.00034	1.16532 ± 0.00095	0.74231 ± 0.00030	0.86503 ± 0.00070	0.86413 ± 0.00070
7.00	3.28	0.81306 ± 0.00035	1.08121 ± 0.00087	0.75249 ± 0.00029	0.81360 ± 0.00066	0.81286 ± 0.00066

Table A.2.5(2) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 43 fuel rods, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.94995 ± 0.00036	1.52499 ± 0.00124	0.62439 ± 0.00035	0.95220 ± 0.00075	0.94968 ± 0.00075
4.00	0.29	0.96492 ± 0.00039	1.51292 ± 0.00122	0.63918 ± 0.00034	0.96703 ± 0.00076	0.96468 ± 0.00075
4.175	0.42	0.97184 ± 0.00038	1.50215 ± 0.00116	0.64826 ± 0.00034	0.97378 ± 0.00074	0.97156 ± 0.00074
4.35	0.56	0.97615 ± 0.00039	1.48909 ± 0.00120	0.65677 ± 0.00033	0.97799 ± 0.00076	0.97589 ± 0.00076
4.50	0.68	0.97730 ± 0.00037	1.47613 ± 0.00114	0.66330 ± 0.00033	0.97912 ± 0.00074	0.97712 ± 0.00074
4.70	0.84	0.97649 ± 0.00035	1.45651 ± 0.00112	0.67161 ± 0.00031	0.97820 ± 0.00073	0.97632 ± 0.00073
5.00	1.11	0.96950 ± 0.00033	1.42268 ± 0.00099	0.68255 ± 0.00030	0.97106 ± 0.00067	0.96936 ± 0.00067
5.50	1.58	0.94608 ± 0.00035	1.35685 ± 0.00103	0.69821 ± 0.00033	0.94736 ± 0.00072	0.94594 ± 0.00072
6.00	2.10	0.91168 ± 0.00036	1.28341 ± 0.00092	0.71110 ± 0.00032	0.91264 ± 0.00066	0.91145 ± 0.00066
6.50	2.67	0.87023 ± 0.00033	1.20594 ± 0.00090	0.72242 ± 0.00030	0.87120 ± 0.00065	0.87022 ± 0.00065
7.00	3.28	0.82449 ± 0.00033	1.12743 ± 0.00088	0.73194 ± 0.00029	0.82521 ± 0.00064	0.82439 ± 0.00064

Table A.2.5(3) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 43 fuel rods, density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.94535 ± 0.00036	1.52582 ± 0.00124	0.62106 ± 0.00036	0.94763 ± 0.00074	0.94511 ± 0.00074
4.00	0.29	0.95600 ± 0.00040	1.51580 ± 0.00128	0.63211 ± 0.00037	0.95816 ± 0.00079	0.95578 ± 0.00078
4.175	0.42	0.96079 ± 0.00039	1.50664 ± 0.00121	0.63907 ± 0.00035	0.96284 ± 0.00076	0.96059 ± 0.00075
4.35	0.56	0.96318 ± 0.00038	1.49569 ± 0.00121	0.64538 ± 0.00035	0.96529 ± 0.00076	0.96314 ± 0.00076
4.50	0.68	0.96403 ± 0.00037	1.48478 ± 0.00114	0.65050 ± 0.00032	0.96586 ± 0.00072	0.96380 ± 0.00072
4.70	0.84	0.96268 ± 0.00038	1.46801 ± 0.00113	0.65698 ± 0.00033	0.96446 ± 0.00073	0.96252 ± 0.00073
5.00	1.11	0.95653 ± 0.00038	1.43911 ± 0.00105	0.66572 ± 0.00033	0.95804 ± 0.00070	0.95628 ± 0.00069
5.50	1.58	0.93675 ± 0.00034	1.38205 ± 0.00101	0.67878 ± 0.00031	0.93811 ± 0.00067	0.93660 ± 0.00067
6.00	2.10	0.90759 ± 0.00034	1.31691 ± 0.00099	0.69009 ± 0.00031	0.90879 ± 0.00068	0.90752 ± 0.00068
6.50	2.67	0.87178 ± 0.00034	1.24723 ± 0.00098	0.69969 ± 0.00030	0.87267 ± 0.00068	0.87161 ± 0.00067
7.00	3.28	0.83164 ± 0.00036	1.17512 ± 0.00096	0.70826 ± 0.00032	0.83229 ± 0.00068	0.83139 ± 0.00067

Table A.2.5(4) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 43 fuel rods, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.93604 ± 0.00037	1.52776 ± 0.00119	0.61425 ± 0.00035	0.93843 ± 0.00071	0.93588 ± 0.00070
4.00	0.29	0.93605 ± 0.00037	1.52100 ± 0.00123	0.61682 ± 0.00034	0.93818 ± 0.00073	0.93577 ± 0.00073
4.175	0.42	0.93581 ± 0.00037	1.51495 ± 0.00117	0.61900 ± 0.00034	0.93776 ± 0.00070	0.93544 ± 0.00070
4.35	0.56	0.93425 ± 0.00036	1.50809 ± 0.00122	0.62083 ± 0.00034	0.93628 ± 0.00073	0.93405 ± 0.00073
4.50	0.68	0.93241 ± 0.00038	1.50081 ± 0.00116	0.62255 ± 0.00035	0.93432 ± 0.00070	0.93217 ± 0.00070
4.70	0.84	0.92878 ± 0.00037	1.48975 ± 0.00115	0.62471 ± 0.00034	0.93066 ± 0.00070	0.92861 ± 0.00069
5.00	1.11	0.92188 ± 0.00037	1.47030 ± 0.00118	0.62808 ± 0.00036	0.92346 ± 0.00072	0.92157 ± 0.00072
5.50	1.58	0.90539 ± 0.00036	1.43052 ± 0.00115	0.63392 ± 0.00032	0.90684 ± 0.00070	0.90517 ± 0.00070
6.00	2.10	0.88305 ± 0.00035	1.38357 ± 0.00111	0.63916 ± 0.00035	0.88432 ± 0.00070	0.88287 ± 0.00069
6.50	2.67	0.85694 ± 0.00035	1.33104 ± 0.00106	0.64473 ± 0.00034	0.85816 ± 0.00067	0.85691 ± 0.00067
7.00	3.28	0.82736 ± 0.00035	1.27481 ± 0.00105	0.64968 ± 0.00033	0.82822 ± 0.00067	0.82712 ± 0.00067

Table A.2.5(5) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 43 fuel rods, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.92641 ± 0.00040	1.52955 ± 0.00130	0.60722 ± 0.00036	0.92877 ± 0.00075	0.92621 ± 0.00075
4.00	0.29	0.91470 ± 0.00039	1.52602 ± 0.00119	0.60079 ± 0.00037	0.91682 ± 0.00070	0.91437 ± 0.00069
4.175	0.42	0.90698 ± 0.00038	1.52282 ± 0.00123	0.59705 ± 0.00037	0.90920 ± 0.00071	0.90684 ± 0.00071
4.35	0.56	0.89974 ± 0.00038	1.51912 ± 0.00118	0.59366 ± 0.00036	0.90184 ± 0.00068	0.89955 ± 0.00068
4.50	0.68	0.89370 ± 0.00040	1.51523 ± 0.00133	0.59111 ± 0.00037	0.89567 ± 0.00075	0.89344 ± 0.00075
4.70	0.84	0.88522 ± 0.00038	1.50925 ± 0.00123	0.58768 ± 0.00038	0.88695 ± 0.00070	0.88481 ± 0.00069
5.00	1.11	0.87333 ± 0.00036	1.49839 ± 0.00126	0.58403 ± 0.00038	0.87510 ± 0.00071	0.87309 ± 0.00071
5.50	1.58	0.85315 ± 0.00039	1.47541 ± 0.00119	0.57931 ± 0.00037	0.85473 ± 0.00067	0.85291 ± 0.00066
6.00	2.10	0.83264 ± 0.00037	1.44697 ± 0.00121	0.57641 ± 0.00037	0.83404 ± 0.00067	0.83242 ± 0.00067
6.50	2.67	0.81064 ± 0.00035	1.41377 ± 0.00113	0.57438 ± 0.00037	0.81204 ± 0.00063	0.81060 ± 0.00063
7.00	3.28	0.78790 ± 0.00035	1.37674 ± 0.00115	0.57313 ± 0.00037	0.78904 ± 0.00063	0.78776 ± 0.00063

Table A.2.5(6) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 43 fuel rods, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.91635 ± 0.00039	1.53158 ± 0.00125	0.59983 ± 0.00038	0.91868 ± 0.00072	0.91610 ± 0.00072
4.00	0.29	0.89122 ± 0.00038	1.53100 ± 0.00125	0.58363 ± 0.00037	0.89353 ± 0.00070	0.89104 ± 0.00070
4.175	0.42	0.87509 ± 0.00038	1.53033 ± 0.00135	0.57315 ± 0.00039	0.87710 ± 0.00074	0.87468 ± 0.00074
4.35	0.56	0.86024 ± 0.00039	1.52973 ± 0.00130	0.56371 ± 0.00039	0.86232 ± 0.00070	0.85997 ± 0.00070
4.50	0.68	0.84806 ± 0.00039	1.52875 ± 0.00130	0.55608 ± 0.00039	0.85011 ± 0.00069	0.84783 ± 0.00069
4.70	0.84	0.83257 ± 0.00039	1.52701 ± 0.00129	0.54650 ± 0.00040	0.83452 ± 0.00068	0.83230 ± 0.00067
5.00	1.11	0.81131 ± 0.00038	1.52362 ± 0.00129	0.53376 ± 0.00041	0.81325 ± 0.00066	0.81115 ± 0.00066
5.50	1.58	0.77973 ± 0.00037	1.51562 ± 0.00134	0.51570 ± 0.00043	0.78160 ± 0.00066	0.77969 ± 0.00066
6.00	2.10	0.75171 ± 0.00037	1.50467 ± 0.00133	0.50073 ± 0.00043	0.75343 ± 0.00063	0.75168 ± 0.00063
6.50	2.67	0.72606 ± 0.00036	1.49077 ± 0.00137	0.48799 ± 0.00045	0.72748 ± 0.00063	0.72589 ± 0.00063
7.00	3.28	0.70227 ± 0.00035	1.47460 ± 0.00135	0.47711 ± 0.00043	0.70355 ± 0.00060	0.70210 ± 0.00060

Table A.2.5(7) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 43 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.90619 ± 0.00039	1.53386 ± 0.00130	0.59229 ± 0.00036	0.90850 ± 0.00073	0.90590 ± 0.00073
4.00	0.29	0.86687 ± 0.00040	1.53667 ± 0.00136	0.56559 ± 0.00040	0.86913 ± 0.00073	0.86662 ± 0.00073
4.175	0.42	0.84105 ± 0.00040	1.53891 ± 0.00131	0.54798 ± 0.00041	0.84329 ± 0.00069	0.84083 ± 0.00069
4.35	0.56	0.81733 ± 0.00037	1.54102 ± 0.00131	0.53182 ± 0.00040	0.81955 ± 0.00066	0.81715 ± 0.00066
4.50	0.68	0.79817 ± 0.00037	1.54269 ± 0.00142	0.51874 ± 0.00042	0.80026 ± 0.00069	0.79792 ± 0.00069
4.70	0.84	0.77492 ± 0.00039	1.54453 ± 0.00137	0.50299 ± 0.00042	0.77688 ± 0.00065	0.77462 ± 0.00064
5.00	1.11	0.74269 ± 0.00035	1.54748 ± 0.00142	0.48116 ± 0.00042	0.74458 ± 0.00063	0.74242 ± 0.00063
5.50	1.58	0.69687 ± 0.00036	1.55252 ± 0.00143	0.44998 ± 0.00046	0.69860 ± 0.00060	0.69661 ± 0.00060
6.00	2.10	0.65734 ± 0.00037	1.55700 ± 0.00156	0.42325 ± 0.00048	0.65899 ± 0.00060	0.65717 ± 0.00060
6.50	2.67	0.62243 ± 0.00036	1.56128 ± 0.00156	0.39964 ± 0.00052	0.62395 ± 0.00058	0.62226 ± 0.00057
7.00	3.28	0.59185 ± 0.00033	1.56541 ± 0.00163	0.37904 ± 0.00051	0.59335 ± 0.00055	0.59179 ± 0.00055

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the finite hexagonal lattice systems composed of

43 fuel rods are listed in Tables A.2.6(1) to A.2.6(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.2.6(1) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0, 43 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.94783 ± 0.00037	1.52550 ± 0.00118	0.62277 ± 0.00035	0.95003 ± 0.00072	0.94751 ± 0.00071
4.00	0.29	0.96790 ± 0.00038	1.51159 ± 0.00117	0.64175 ± 0.00035	0.97006 ± 0.00074	0.96773 ± 0.00073
4.175	0.42	0.97704 ± 0.00037	1.49898 ± 0.00116	0.65308 ± 0.00032	0.97895 ± 0.00073	0.97674 ± 0.00073
4.35	0.56	0.98228 ± 0.00038	1.48350 ± 0.00114	0.66344 ± 0.00033	0.98422 ± 0.00074	0.98213 ± 0.00074
4.50	0.68	0.98435 ± 0.00039	1.46830 ± 0.00112	0.67156 ± 0.00033	0.98605 ± 0.00074	0.98407 ± 0.00074
4.70	0.84	0.98335 ± 0.00035	1.44530 ± 0.00106	0.68152 ± 0.00031	0.98499 ± 0.00071	0.98314 ± 0.00071
5.00	1.11	0.97524 ± 0.00037	1.40576 ± 0.00107	0.69479 ± 0.00031	0.97671 ± 0.00074	0.97505 ± 0.00073
5.50	1.58	0.94765 ± 0.00035	1.33031 ± 0.00095	0.71319 ± 0.00030	0.94877 ± 0.00068	0.94740 ± 0.00068
6.00	2.10	0.90733 ± 0.00034	1.24696 ± 0.00089	0.72842 ± 0.00030	0.90830 ± 0.00065	0.90718 ± 0.00065
6.50	2.67	0.85906 ± 0.00033	1.16079 ± 0.00090	0.74074 ± 0.00029	0.85984 ± 0.00067	0.85892 ± 0.00067
7.00	3.28	0.80727 ± 0.00034	1.07495 ± 0.00083	0.75146 ± 0.00028	0.80778 ± 0.00062	0.80703 ± 0.00062

Table A.2.6(2) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0, 43 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.89895 ± 0.00039	1.53532 ± 0.00131	0.58688 ± 0.00037	0.90104 ± 0.00073	0.89845 ± 0.00073
4.00	0.29	0.85977 ± 0.00038	1.53811 ± 0.00125	0.56042 ± 0.00041	0.86198 ± 0.00069	0.85945 ± 0.00068
4.175	0.42	0.83427 ± 0.00039	1.54024 ± 0.00136	0.54315 ± 0.00040	0.83658 ± 0.00070	0.83411 ± 0.00070
4.35	0.56	0.81049 ± 0.00036	1.54224 ± 0.00127	0.52691 ± 0.00040	0.81262 ± 0.00063	0.81021 ± 0.00063
4.50	0.68	0.79184 ± 0.00036	1.54396 ± 0.00137	0.51423 ± 0.00042	0.79396 ± 0.00067	0.79161 ± 0.00066
4.70	0.84	0.76877 ± 0.00038	1.54590 ± 0.00137	0.49867 ± 0.00042	0.77089 ± 0.00064	0.76860 ± 0.00064
5.00	1.11	0.73701 ± 0.00037	1.54892 ± 0.00143	0.47710 ± 0.00043	0.73899 ± 0.00063	0.73682 ± 0.00063
5.50	1.58	0.69103 ± 0.00039	1.55379 ± 0.00149	0.44596 ± 0.00047	0.69293 ± 0.00062	0.69093 ± 0.00061
6.00	2.10	0.65162 ± 0.00035	1.55837 ± 0.00156	0.41925 ± 0.00048	0.65335 ± 0.00059	0.65151 ± 0.00059
6.50	2.67	0.61700 ± 0.00035	1.56249 ± 0.00162	0.39593 ± 0.00049	0.61864 ± 0.00058	0.61694 ± 0.00058
7.00	3.28	0.58657 ± 0.00034	1.56637 ± 0.00179	0.37547 ± 0.00052	0.58812 ± 0.00060	0.58656 ± 0.00059

Table A.2.6(3) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0u1, 43 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.94770 ± 0.00038	1.52543 ± 0.00124	0.62265 ± 0.00035	0.94980 ± 0.00074	0.94729 ± 0.00074
4.00	0.29	0.96762 ± 0.00039	1.51165 ± 0.00122	0.64144 ± 0.00035	0.96963 ± 0.00077	0.96728 ± 0.00076
4.175	0.42	0.97696 ± 0.00038	1.49890 ± 0.00116	0.65316 ± 0.00033	0.97901 ± 0.00074	0.97679 ± 0.00073
4.35	0.56	0.98219 ± 0.00038	1.48358 ± 0.00114	0.66330 ± 0.00032	0.98406 ± 0.00074	0.98197 ± 0.00074
4.50	0.68	0.98443 ± 0.00036	1.46833 ± 0.00108	0.67162 ± 0.00032	0.98616 ± 0.00071	0.98417 ± 0.00071
4.70	0.84	0.98319 ± 0.00037	1.44529 ± 0.00111	0.68134 ± 0.00032	0.98474 ± 0.00074	0.98288 ± 0.00074
5.00	1.11	0.97504 ± 0.00034	1.40598 ± 0.00102	0.69453 ± 0.00029	0.97649 ± 0.00069	0.97483 ± 0.00069
5.50	1.58	0.94753 ± 0.00036	1.33029 ± 0.00096	0.71311 ± 0.00031	0.94865 ± 0.00069	0.94726 ± 0.00068
6.00	2.10	0.90729 ± 0.00035	1.24700 ± 0.00094	0.72830 ± 0.00030	0.90819 ± 0.00068	0.90706 ± 0.00068
6.50	2.67	0.85924 ± 0.00036	1.16078 ± 0.00090	0.74089 ± 0.00030	0.86001 ± 0.00067	0.85910 ± 0.00067
7.00	3.28	0.80716 ± 0.00033	1.07491 ± 0.00084	0.75149 ± 0.00029	0.80778 ± 0.00063	0.80703 ± 0.00063

Table A.2.6(4) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0u1, 43 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.89893 ± 0.00038	1.53521 ± 0.00124	0.58706 ± 0.00037	0.90126 ± 0.00070	0.89866 ± 0.00070
4.00	0.29	0.85968 ± 0.00039	1.53815 ± 0.00130	0.56034 ± 0.00039	0.86189 ± 0.00070	0.85936 ± 0.00070
4.175	0.42	0.83455 ± 0.00041	1.54035 ± 0.00136	0.54331 ± 0.00040	0.83689 ± 0.00070	0.83443 ± 0.00070
4.35	0.56	0.81081 ± 0.00037	1.54222 ± 0.00137	0.52715 ± 0.00040	0.81297 ± 0.00068	0.81056 ± 0.00067
4.50	0.68	0.79172 ± 0.00039	1.54374 ± 0.00136	0.51420 ± 0.00043	0.79380 ± 0.00067	0.79145 ± 0.00067
4.70	0.84	0.76855 ± 0.00038	1.54585 ± 0.00137	0.49851 ± 0.00041	0.77062 ± 0.00064	0.76834 ± 0.00064
5.00	1.11	0.73696 ± 0.00037	1.54891 ± 0.00137	0.47708 ± 0.00045	0.73896 ± 0.00062	0.73679 ± 0.00062
5.50	1.58	0.69090 ± 0.00038	1.55366 ± 0.00155	0.44579 ± 0.00046	0.69260 ± 0.00063	0.69060 ± 0.00063
6.00	2.10	0.65173 ± 0.00037	1.55829 ± 0.00161	0.41933 ± 0.00051	0.65343 ± 0.00062	0.65159 ± 0.00062
6.50	2.67	0.61705 ± 0.00034	1.56254 ± 0.00167	0.39593 ± 0.00051	0.61865 ± 0.00060	0.61695 ± 0.00060
7.00	3.28	0.58641 ± 0.00037	1.56629 ± 0.00157	0.37523 ± 0.00051	0.58772 ± 0.00054	0.58615 ± 0.00053

(4) Finite hexagonal lattice system composed of 40 fuel rods

The results of numerical data calculated using the JENDL-5 library for the finite hexagonal lattice systems composed of 40 fuel rods are listed in Tables A.2.7(1) to A.2.7(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.2.7(1) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.93584 ± 0.00040	1.52315 ± 0.00123	0.61582 ± 0.00036	0.93799 ± 0.00074	0.93561 ± 0.00073
4.00	0.29	0.95616 ± 0.00040	1.50935 ± 0.00133	0.63477 ± 0.00037	0.95810 ± 0.00081	0.95590 ± 0.00081
4.175	0.42	0.96571 ± 0.00037	1.49681 ± 0.00115	0.64638 ± 0.00033	0.96751 ± 0.00073	0.96543 ± 0.00072
4.35	0.56	0.97183 ± 0.00036	1.48174 ± 0.00109	0.65707 ± 0.00031	0.97361 ± 0.00070	0.97166 ± 0.00070
4.50	0.68	0.97403 ± 0.00038	1.46679 ± 0.00118	0.66521 ± 0.00033	0.97572 ± 0.00076	0.97386 ± 0.00076
4.70	0.84	0.97378 ± 0.00037	1.44439 ± 0.00111	0.67524 ± 0.00033	0.97530 ± 0.00074	0.97357 ± 0.00074
5.00	1.11	0.96653 ± 0.00035	1.40559 ± 0.00102	0.68866 ± 0.00032	0.96797 ± 0.00070	0.96642 ± 0.00070
5.50	1.58	0.94075 ± 0.00036	1.33145 ± 0.00096	0.70736 ± 0.00031	0.94182 ± 0.00068	0.94055 ± 0.00068
6.00	2.10	0.90200 ± 0.00035	1.25002 ± 0.00094	0.72237 ± 0.00030	0.90297 ± 0.00068	0.90194 ± 0.00068
6.50	2.67	0.85643 ± 0.00035	1.16563 ± 0.00088	0.73539 ± 0.00030	0.85720 ± 0.00065	0.85635 ± 0.00064
7.00	3.28	0.80628 ± 0.00033	1.08143 ± 0.00083	0.74598 ± 0.00029	0.80673 ± 0.00062	0.80604 ± 0.00062

Table A.2.7(2) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.93128 ± 0.00037	1.52417 ± 0.00118	0.61241 ± 0.00037	0.93342 ± 0.00071	0.93102 ± 0.00071
4.00	0.29	0.94774 ± 0.00039	1.51232 ± 0.00122	0.62800 ± 0.00036	0.94973 ± 0.00075	0.94751 ± 0.00075
4.175	0.42	0.95527 ± 0.00038	1.50159 ± 0.00121	0.63730 ± 0.00035	0.95697 ± 0.00075	0.95486 ± 0.00075
4.35	0.56	0.96001 ± 0.00037	1.48868 ± 0.00115	0.64609 ± 0.00034	0.96182 ± 0.00073	0.95982 ± 0.00072
4.50	0.68	0.96182 ± 0.00038	1.47565 ± 0.00109	0.65291 ± 0.00034	0.96347 ± 0.00070	0.96156 ± 0.00070
4.70	0.84	0.96150 ± 0.00038	1.45622 ± 0.00111	0.66137 ± 0.00033	0.96310 ± 0.00072	0.96133 ± 0.00072
5.00	1.11	0.95587 ± 0.00037	1.42255 ± 0.00104	0.67300 ± 0.00032	0.95738 ± 0.00069	0.95577 ± 0.00069
5.50	1.58	0.93418 ± 0.00037	1.35683 ± 0.00108	0.68937 ± 0.00032	0.93536 ± 0.00073	0.93402 ± 0.00073
6.00	2.10	0.90162 ± 0.00035	1.28346 ± 0.00097	0.70331 ± 0.00030	0.90267 ± 0.00068	0.90156 ± 0.00067
6.50	2.67	0.86162 ± 0.00035	1.20613 ± 0.00099	0.71510 ± 0.00029	0.86250 ± 0.00069	0.86158 ± 0.00069
7.00	3.28	0.81718 ± 0.00035	1.12767 ± 0.00092	0.72513 ± 0.00030	0.81770 ± 0.00066	0.81694 ± 0.00066

Table A.2.7(3) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.92693 ± 0.00037	1.52494 ± 0.00113	0.60924 ± 0.00035	0.92906 ± 0.00067	0.92667 ± 0.00067
4.00	0.29	0.93789 ± 0.00041	1.51494 ± 0.00128	0.62045 ± 0.00036	0.93995 ± 0.00077	0.93769 ± 0.00076
4.175	0.42	0.94347 ± 0.00038	1.50609 ± 0.00116	0.62769 ± 0.00035	0.94536 ± 0.00072	0.94321 ± 0.00071
4.35	0.56	0.94687 ± 0.00039	1.49488 ± 0.00120	0.63465 ± 0.00036	0.94873 ± 0.00075	0.94669 ± 0.00075
4.50	0.68	0.94813 ± 0.00037	1.48429 ± 0.00120	0.63999 ± 0.00034	0.94993 ± 0.00074	0.94798 ± 0.00074
4.70	0.84	0.94739 ± 0.00037	1.46765 ± 0.00118	0.64661 ± 0.00034	0.94899 ± 0.00074	0.94716 ± 0.00074
5.00	1.11	0.94246 ± 0.00038	1.43878 ± 0.00105	0.65603 ± 0.00034	0.94388 ± 0.00069	0.94222 ± 0.00069
5.50	1.58	0.92403 ± 0.00037	1.38179 ± 0.00110	0.66957 ± 0.00032	0.92520 ± 0.00072	0.92379 ± 0.00072
6.00	2.10	0.89639 ± 0.00037	1.31696 ± 0.00101	0.68145 ± 0.00032	0.89744 ± 0.00068	0.89624 ± 0.00067
6.50	2.67	0.86214 ± 0.00034	1.24730 ± 0.00098	0.69190 ± 0.00032	0.86300 ± 0.00067	0.86200 ± 0.00067
7.00	3.28	0.82326 ± 0.00034	1.17531 ± 0.00092	0.70114 ± 0.00032	0.82406 ± 0.00064	0.82322 ± 0.00064

Table A.2.7(4) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.91743 ± 0.00040	1.52706 ± 0.00129	0.60218 ± 0.00037	0.91956 ± 0.00075	0.91715 ± 0.00074
4.00	0.29	0.91807 ± 0.00037	1.52018 ± 0.00118	0.60528 ± 0.00035	0.92014 ± 0.00069	0.91785 ± 0.00069
4.175	0.42	0.91794 ± 0.00037	1.51442 ± 0.00123	0.60741 ± 0.00035	0.91988 ± 0.00071	0.91769 ± 0.00071
4.35	0.56	0.91673 ± 0.00038	1.50740 ± 0.00122	0.60952 ± 0.00038	0.91878 ± 0.00073	0.91668 ± 0.00072
4.50	0.68	0.91551 ± 0.00037	1.50002 ± 0.00116	0.61149 ± 0.00035	0.91724 ± 0.00069	0.91522 ± 0.00069
4.70	0.84	0.91276 ± 0.00038	1.48919 ± 0.00120	0.61404 ± 0.00038	0.91443 ± 0.00073	0.91250 ± 0.00072
5.00	1.11	0.90642 ± 0.00037	1.46983 ± 0.00113	0.61778 ± 0.00035	0.90803 ± 0.00068	0.90625 ± 0.00068
5.50	1.58	0.89120 ± 0.00037	1.43023 ± 0.00115	0.62406 ± 0.00035	0.89255 ± 0.00070	0.89100 ± 0.00069
6.00	2.10	0.87086 ± 0.00035	1.38326 ± 0.00110	0.63041 ± 0.00034	0.87203 ± 0.00068	0.87068 ± 0.00068
6.50	2.67	0.84578 ± 0.00038	1.33111 ± 0.00105	0.63615 ± 0.00035	0.84678 ± 0.00066	0.84561 ± 0.00066
7.00	3.28	0.81754 ± 0.00035	1.27516 ± 0.00101	0.64187 ± 0.00036	0.81848 ± 0.00064	0.81748 ± 0.00064

Table A.2.7(5) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.90740 ± 0.00040	1.52886 ± 0.00130	0.59497 ± 0.00038	0.90963 ± 0.00074	0.90719 ± 0.00074
4.00	0.29	0.89644 ± 0.00037	1.52521 ± 0.00123	0.58911 ± 0.00037	0.89852 ± 0.00070	0.89619 ± 0.00070
4.175	0.42	0.88882 ± 0.00039	1.52212 ± 0.00129	0.58523 ± 0.00038	0.89079 ± 0.00073	0.88855 ± 0.00072
4.35	0.56	0.88193 ± 0.00038	1.51834 ± 0.00118	0.58215 ± 0.00038	0.88390 ± 0.00067	0.88173 ± 0.00067
4.50	0.68	0.87612 ± 0.00037	1.51453 ± 0.00123	0.57971 ± 0.00037	0.87800 ± 0.00069	0.87591 ± 0.00068
4.70	0.84	0.86827 ± 0.00039	1.50859 ± 0.00122	0.57675 ± 0.00036	0.87008 ± 0.00067	0.86807 ± 0.00067
5.00	1.11	0.85694 ± 0.00039	1.49781 ± 0.00126	0.57329 ± 0.00039	0.85867 ± 0.00070	0.85679 ± 0.00070
5.50	1.58	0.83829 ± 0.00037	1.47494 ± 0.00119	0.56938 ± 0.00038	0.83979 ± 0.00066	0.83811 ± 0.00065
6.00	2.10	0.81863 ± 0.00037	1.44660 ± 0.00121	0.56679 ± 0.00040	0.81992 ± 0.00067	0.81842 ± 0.00067
6.50	2.67	0.79791 ± 0.00036	1.41351 ± 0.00118	0.56540 ± 0.00037	0.79920 ± 0.00064	0.79787 ± 0.00064
7.00	3.28	0.77629 ± 0.00036	1.37665 ± 0.00119	0.56469 ± 0.00038	0.77737 ± 0.00065	0.77620 ± 0.00065

Table A.2.7(6) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.89710 ± 0.00038	1.53074 ± 0.00124	0.58753 ± 0.00037	0.89936 ± 0.00070	0.89693 ± 0.00070
4.00	0.29	0.87245 ± 0.00038	1.53011 ± 0.00130	0.57157 ± 0.00037	0.87456 ± 0.00071	0.87222 ± 0.00070
4.175	0.42	0.85659 ± 0.00038	1.52956 ± 0.00130	0.56137 ± 0.00038	0.85865 ± 0.00069	0.85637 ± 0.00069
4.35	0.56	0.84180 ± 0.00037	1.52880 ± 0.00130	0.55195 ± 0.00038	0.84382 ± 0.00068	0.84161 ± 0.00068
4.50	0.68	0.82993 ± 0.00037	1.52779 ± 0.00130	0.54456 ± 0.00040	0.83197 ± 0.00067	0.82983 ± 0.00067
4.70	0.84	0.81504 ± 0.00040	1.52620 ± 0.00135	0.53529 ± 0.00042	0.81695 ± 0.00069	0.81489 ± 0.00069
5.00	1.11	0.79476 ± 0.00035	1.52287 ± 0.00129	0.52308 ± 0.00039	0.79659 ± 0.00064	0.79464 ± 0.00064
5.50	1.58	0.76377 ± 0.00037	1.51498 ± 0.00133	0.50520 ± 0.00041	0.76536 ± 0.00064	0.76360 ± 0.00063
6.00	2.10	0.73690 ± 0.00036	1.50401 ± 0.00139	0.49095 ± 0.00043	0.73839 ± 0.00064	0.73679 ± 0.00064
6.50	2.67	0.71251 ± 0.00037	1.49039 ± 0.00137	0.47899 ± 0.00044	0.71388 ± 0.00062	0.71243 ± 0.00061
7.00	3.28	0.68994 ± 0.00037	1.47437 ± 0.00140	0.46873 ± 0.00043	0.69108 ± 0.00061	0.68977 ± 0.00061

Table A.2.7(7) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.88669 ± 0.00038	1.53302 ± 0.00125	0.57977 ± 0.00038	0.88880 ± 0.00070	0.88635 ± 0.00070
4.00	0.29	0.84757 ± 0.00036	1.53594 ± 0.00125	0.55327 ± 0.00037	0.84978 ± 0.00066	0.84741 ± 0.00066
4.175	0.42	0.82222 ± 0.00039	1.53805 ± 0.00131	0.53594 ± 0.00041	0.82430 ± 0.00067	0.82200 ± 0.00067
4.35	0.56	0.79878 ± 0.00039	1.54004 ± 0.00147	0.51998 ± 0.00042	0.80079 ± 0.00072	0.79856 ± 0.00071
4.50	0.68	0.78041 ± 0.00038	1.54170 ± 0.00142	0.50757 ± 0.00042	0.78252 ± 0.00067	0.78034 ± 0.00067
4.70	0.84	0.75745 ± 0.00037	1.54398 ± 0.00137	0.49188 ± 0.00043	0.75945 ± 0.00063	0.75735 ± 0.00063
5.00	1.11	0.72627 ± 0.00037	1.54702 ± 0.00149	0.47056 ± 0.00046	0.72797 ± 0.00065	0.72598 ± 0.00065
5.50	1.58	0.68149 ± 0.00037	1.55174 ± 0.00150	0.44025 ± 0.00047	0.68316 ± 0.00061	0.68133 ± 0.00061
6.00	2.10	0.64348 ± 0.00036	1.55650 ± 0.00156	0.41436 ± 0.00048	0.64495 ± 0.00059	0.64328 ± 0.00058
6.50	2.67	0.61009 ± 0.00036	1.56083 ± 0.00156	0.39179 ± 0.00050	0.61152 ± 0.00056	0.60999 ± 0.00056
7.00	3.28	0.58082 ± 0.00035	1.56506 ± 0.00169	0.37189 ± 0.00054	0.58203 ± 0.00056	0.58063 ± 0.00056

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the finite hexagonal lattice systems composed of

40 fuel rods are listed in Tables A.2.8(1) to A.2.8(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.2.8(1) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0, 40 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.92907 ± 0.00036	1.52470 ± 0.00118	0.61081 ± 0.00034	0.93130 ± 0.00070	0.92890 ± 0.00069
4.00	0.29	0.94983 ± 0.00036	1.51094 ± 0.00117	0.62989 ± 0.00033	0.95173 ± 0.00071	0.94950 ± 0.00071
4.175	0.42	0.96022 ± 0.00039	1.49842 ± 0.00121	0.64210 ± 0.00035	0.96214 ± 0.00076	0.96002 ± 0.00076
4.35	0.56	0.96650 ± 0.00038	1.48300 ± 0.00114	0.65295 ± 0.00034	0.96833 ± 0.00073	0.96633 ± 0.00073
4.50	0.68	0.96912 ± 0.00038	1.46792 ± 0.00112	0.66134 ± 0.00032	0.97079 ± 0.00073	0.96890 ± 0.00073
4.70	0.84	0.96900 ± 0.00036	1.44517 ± 0.00106	0.67157 ± 0.00032	0.97054 ± 0.00070	0.96877 ± 0.00070
5.00	1.11	0.96234 ± 0.00038	1.40578 ± 0.00107	0.68562 ± 0.00033	0.96382 ± 0.00073	0.96224 ± 0.00073
5.50	1.58	0.93626 ± 0.00035	1.33025 ± 0.00101	0.70461 ± 0.00030	0.93731 ± 0.00070	0.93602 ± 0.00070
6.00	2.10	0.89782 ± 0.00036	1.24715 ± 0.00094	0.72055 ± 0.00031	0.89864 ± 0.00068	0.89758 ± 0.00068
6.50	2.67	0.85119 ± 0.00033	1.16091 ± 0.00095	0.73387 ± 0.00029	0.85196 ± 0.00069	0.85109 ± 0.00069
7.00	3.28	0.80066 ± 0.00034	1.07511 ± 0.00083	0.74528 ± 0.00029	0.80126 ± 0.00062	0.80055 ± 0.00062

Table A.2.8(2) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0, 40 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.87939 ± 0.00040	1.53437 ± 0.00125	0.57468 ± 0.00040	0.88178 ± 0.00070	0.87930 ± 0.00070
4.00	0.29	0.84045 ± 0.00036	1.53720 ± 0.00130	0.54809 ± 0.00038	0.84253 ± 0.00068	0.84015 ± 0.00067
4.175	0.42	0.81549 ± 0.00039	1.53943 ± 0.00131	0.53106 ± 0.00040	0.81752 ± 0.00066	0.81520 ± 0.00066
4.35	0.56	0.79239 ± 0.00038	1.54152 ± 0.00131	0.51543 ± 0.00040	0.79455 ± 0.00064	0.79229 ± 0.00064
4.50	0.68	0.77391 ± 0.00037	1.54305 ± 0.00142	0.50283 ± 0.00043	0.77589 ± 0.00067	0.77369 ± 0.00067
4.70	0.84	0.75124 ± 0.00038	1.54519 ± 0.00143	0.48737 ± 0.00045	0.75309 ± 0.00065	0.75097 ± 0.00065
5.00	1.11	0.72035 ± 0.00038	1.54830 ± 0.00154	0.46647 ± 0.00046	0.72224 ± 0.00066	0.72022 ± 0.00066
5.50	1.58	0.67582 ± 0.00035	1.55313 ± 0.00150	0.43621 ± 0.00045	0.67749 ± 0.00060	0.67564 ± 0.00059
6.00	2.10	0.63785 ± 0.00035	1.55775 ± 0.00156	0.41044 ± 0.00047	0.63937 ± 0.00058	0.63770 ± 0.00058
6.50	2.67	0.60473 ± 0.00035	1.56196 ± 0.00162	0.38799 ± 0.00051	0.60602 ± 0.00057	0.60448 ± 0.00057
7.00	3.28	0.57563 ± 0.00034	1.56599 ± 0.00162	0.36848 ± 0.00052	0.57704 ± 0.00054	0.57563 ± 0.00054

Table A.2.8(3) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0u1, 40 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.12	0.92914 ± 0.00038	1.52462 ± 0.00124	0.61078 ± 0.00036	0.93121 ± 0.00073	0.92880 ± 0.00073
4.00	0.29	0.95013 ± 0.00038	1.51094 ± 0.00123	0.63018 ± 0.00035	0.95216 ± 0.00075	0.94994 ± 0.00074
4.175	0.42	0.96030 ± 0.00039	1.49840 ± 0.00116	0.64210 ± 0.00034	0.96212 ± 0.00073	0.96000 ± 0.00072
4.35	0.56	0.96631 ± 0.00040	1.48300 ± 0.00119	0.65271 ± 0.00035	0.96797 ± 0.00076	0.96598 ± 0.00076
4.50	0.68	0.96905 ± 0.00038	1.46801 ± 0.00112	0.66125 ± 0.00034	0.97072 ± 0.00073	0.96882 ± 0.00073
4.70	0.84	0.96900 ± 0.00036	1.44515 ± 0.00111	0.67155 ± 0.00032	0.97049 ± 0.00073	0.96873 ± 0.00073
5.00	1.11	0.96211 ± 0.00037	1.40567 ± 0.00103	0.68545 ± 0.00031	0.96352 ± 0.00070	0.96195 ± 0.00069
5.50	1.58	0.93634 ± 0.00035	1.33011 ± 0.00100	0.70469 ± 0.00031	0.93732 ± 0.00070	0.93602 ± 0.00070
6.00	2.10	0.89776 ± 0.00035	1.24721 ± 0.00094	0.72055 ± 0.00032	0.89867 ± 0.00068	0.89760 ± 0.00068
6.50	2.67	0.85131 ± 0.00036	1.16107 ± 0.00091	0.73388 ± 0.00031	0.85209 ± 0.00067	0.85121 ± 0.00067
7.00	3.28	0.80055 ± 0.00034	1.07506 ± 0.00079	0.74520 ± 0.00029	0.80113 ± 0.00060	0.80043 ± 0.00060

Table A.2.8(4) Effective neutron multiplication factor and ratio of reactions for finite hexagonal lattice systems, using JENDL-4.0u1, 40 fuel rods, density of moderator: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): νF/A_C ± 3σ	Ratio (5): A_C/(A_C+A_R) ± 3σ	Ratio (6)=(4)*(5): νF/(A_C+A_R) ± 3σ	Ratio (7): νF/(A_C+A_R+L) ± 3σ
3.75	0.12	0.87923 ± 0.00039	1.53425 ± 0.00130	0.57450 ± 0.00039	0.88142 ± 0.00072	0.87895 ± 0.00072
4.00	0.29	0.84058 ± 0.00039	1.53717 ± 0.00136	0.54823 ± 0.00039	0.84272 ± 0.00070	0.84034 ± 0.00070
4.175	0.42	0.81548 ± 0.00038	1.53939 ± 0.00136	0.53114 ± 0.00039	0.81763 ± 0.00068	0.81531 ± 0.00068
4.35	0.56	0.79226 ± 0.00037	1.54143 ± 0.00137	0.51538 ± 0.00042	0.79442 ± 0.00067	0.79216 ± 0.00066
4.50	0.68	0.77365 ± 0.00037	1.54295 ± 0.00131	0.50267 ± 0.00041	0.77560 ± 0.00062	0.77341 ± 0.00062
4.70	0.84	0.75094 ± 0.00039	1.54502 ± 0.00143	0.48724 ± 0.00044	0.75279 ± 0.00065	0.75068 ± 0.00065
5.00	1.11	0.72045 ± 0.00038	1.54801 ± 0.00143	0.46661 ± 0.00047	0.72231 ± 0.00063	0.72031 ± 0.00063
5.50	1.58	0.67602 ± 0.00037	1.55297 ± 0.00149	0.43631 ± 0.00046	0.67758 ± 0.00060	0.67575 ± 0.00060
6.00	2.10	0.63797 ± 0.00035	1.55760 ± 0.00155	0.41061 ± 0.00049	0.63957 ± 0.00059	0.63789 ± 0.00058
6.50	2.67	0.60463 ± 0.00034	1.56188 ± 0.00156	0.38802 ± 0.00050	0.60604 ± 0.00055	0.60451 ± 0.00055
7.00	3.28	0.57559 ± 0.00035	1.56609 ± 0.00162	0.36839 ± 0.00051	0.57693 ± 0.00054	0.57552 ± 0.00054

(5) Finite square lattice system composed of 57 fuel rods

The results of numerical data calculated using the JENDL-5 library for the finite square lattice systems composed of 57 fuel rods are listed in Tables A.2.9(1) to A.2.9(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.2.9(1) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 57 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): νF/A_C ± 3σ	Ratio (5): A_C/(A_C+A_R) ± 3σ	Ratio (6)=(4)*(5): νF/(A_C+A_R) ± 3σ	Ratio (7): νF/(A_C+A_R+L) ± 3σ
3.75	0.32	1.03037 ± 0.00037	1.50293 ± 0.00116	0.68667 ± 0.00031	1.03201 ± 0.00077	1.03007 ± 0.00077
4.00	0.52	1.03914 ± 0.00037	1.48176 ± 0.00109	0.70233 ± 0.00032	1.04068 ± 0.00076	1.03890 ± 0.00076
4.175	0.67	1.04023 ± 0.00038	1.46357 ± 0.00113	0.71167 ± 0.00032	1.04157 ± 0.00080	1.03990 ± 0.00080
4.35	0.82	1.03739 ± 0.00040	1.44280 ± 0.00106	0.71999 ± 0.00032	1.03881 ± 0.00076	1.03723 ± 0.00076
4.50	0.96	1.03213 ± 0.00039	1.42286 ± 0.00104	0.72624 ± 0.00032	1.03335 ± 0.00076	1.03185 ± 0.00076
4.70	1.15	1.02274 ± 0.00037	1.39418 ± 0.00096	0.73438 ± 0.00031	1.02386 ± 0.00072	1.02247 ± 0.00072
5.00	1.46	1.00182 ± 0.00037	1.34685 ± 0.00102	0.74466 ± 0.00030	1.00295 ± 0.00076	1.00172 ± 0.00076
5.50	2.01	0.95606 ± 0.00034	1.26073 ± 0.00095	0.75897 ± 0.00028	0.95686 ± 0.00072	0.95585 ± 0.00072
6.00	2.61	0.90109 ± 0.00035	1.17036 ± 0.00087	0.77047 ± 0.00028	0.90173 ± 0.00068	0.90090 ± 0.00068
6.50	3.26	0.84178 ± 0.00033	1.08023 ± 0.00080	0.77976 ± 0.00027	0.84231 ± 0.00063	0.84163 ± 0.00062
7.00	3.96	0.78167 ± 0.00032	0.99311 ± 0.00076	0.78763 ± 0.00026	0.78220 ± 0.00060	0.78164 ± 0.00060

Table A.2.9(2) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 57 fuel rods, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	1.02221 ± 0.00040	1.50668 ± 0.00116	0.67955 ± 0.00033	1.02387 ± 0.00078	1.02190 ± 0.00078
4.00	0.52	1.02922 ± 0.00039	1.48860 ± 0.00115	0.69242 ± 0.00033	1.03073 ± 0.00079	1.02890 ± 0.00079
4.175	0.67	1.03001 ± 0.00039	1.47315 ± 0.00108	0.70022 ± 0.00032	1.03152 ± 0.00075	1.02980 ± 0.00075
4.35	0.82	1.02759 ± 0.00038	1.45501 ± 0.00106	0.70726 ± 0.00031	1.02907 ± 0.00075	1.02743 ± 0.00075
4.50	0.96	1.02340 ± 0.00035	1.43790 ± 0.00100	0.71264 ± 0.00030	1.02471 ± 0.00071	1.02315 ± 0.00071
4.70	1.15	1.01520 ± 0.00035	1.41279 ± 0.00103	0.71947 ± 0.00028	1.01646 ± 0.00073	1.01501 ± 0.00073
5.00	1.46	0.99781 ± 0.00034	1.37088 ± 0.00094	0.72870 ± 0.00029	0.99897 ± 0.00069	0.99766 ± 0.00069
5.50	2.01	0.95811 ± 0.00034	1.29346 ± 0.00097	0.74147 ± 0.00028	0.95906 ± 0.00072	0.95796 ± 0.00072
6.00	2.61	0.90955 ± 0.00033	1.21068 ± 0.00091	0.75185 ± 0.00029	0.91025 ± 0.00068	0.90934 ± 0.00068
6.50	3.26	0.85617 ± 0.00033	1.12629 ± 0.00087	0.76062 ± 0.00028	0.85667 ± 0.00066	0.85591 ± 0.00066
7.00	3.96	0.80115 ± 0.00033	1.04373 ± 0.00077	0.76814 ± 0.00028	0.80173 ± 0.00060	0.80110 ± 0.00060

Table A.2.9(3) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 57 fuel rods, density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	1.01368 ± 0.00039	1.51029 ± 0.00122	0.67227 ± 0.00034	1.01532 ± 0.00080	1.01332 ± 0.00080
4.00	0.52	1.01797 ± 0.00040	1.49493 ± 0.00115	0.68196 ± 0.00034	1.01948 ± 0.00078	1.01761 ± 0.00078
4.175	0.67	1.01790 ± 0.00041	1.48195 ± 0.00114	0.68777 ± 0.00034	1.01924 ± 0.00078	1.01747 ± 0.00078
4.35	0.82	1.01577 ± 0.00039	1.46689 ± 0.00107	0.69342 ± 0.00034	1.01717 ± 0.00075	1.01547 ± 0.00075
4.50	0.96	1.01197 ± 0.00038	1.45227 ± 0.00108	0.69779 ± 0.00031	1.01338 ± 0.00074	1.01177 ± 0.00074
4.70	1.15	1.00473 ± 0.00036	1.43068 ± 0.00110	0.70322 ± 0.00031	1.00607 ± 0.00076	1.00455 ± 0.00076
5.00	1.46	0.98987 ± 0.00035	1.39449 ± 0.00101	0.71061 ± 0.00030	0.99094 ± 0.00072	0.98955 ± 0.00071
5.50	2.01	0.95599 ± 0.00036	1.32633 ± 0.00100	0.72156 ± 0.00031	0.95703 ± 0.00072	0.95585 ± 0.00072
6.00	2.61	0.91395 ± 0.00036	1.25197 ± 0.00095	0.73070 ± 0.00030	0.91482 ± 0.00069	0.91382 ± 0.00069
6.50	3.26	0.86667 ± 0.00035	1.17464 ± 0.00084	0.73837 ± 0.00029	0.86732 ± 0.00062	0.86647 ± 0.00062
7.00	3.96	0.81706 ± 0.00034	1.09721 ± 0.00085	0.74525 ± 0.00029	0.81770 ± 0.00064	0.81698 ± 0.00063

Table A.2.9(4) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 57 fuel rods, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.99377 ± 0.00040	1.51649 ± 0.00117	0.65650 ± 0.00035	0.99557 ± 0.00076	0.99352 ± 0.00076
4.00	0.52	0.99153 ± 0.00039	1.50667 ± 0.00116	0.65918 ± 0.00034	0.99317 ± 0.00075	0.99123 ± 0.00075
4.175	0.67	0.98808 ± 0.00041	1.49833 ± 0.00116	0.66044 ± 0.00035	0.98957 ± 0.00076	0.98770 ± 0.00075
4.35	0.82	0.98428 ± 0.00036	1.48838 ± 0.00110	0.66239 ± 0.00034	0.98589 ± 0.00072	0.98408 ± 0.00072
4.50	0.96	0.98024 ± 0.00037	1.47892 ± 0.00114	0.66387 ± 0.00035	0.98182 ± 0.00075	0.98008 ± 0.00075
4.70	1.15	0.97338 ± 0.00039	1.46430 ± 0.00107	0.66574 ± 0.00034	0.97484 ± 0.00071	0.97317 ± 0.00071
5.00	1.46	0.96121 ± 0.00035	1.43934 ± 0.00110	0.66870 ± 0.00032	0.96249 ± 0.00072	0.96093 ± 0.00072
5.50	2.01	0.93581 ± 0.00038	1.39073 ± 0.00111	0.67379 ± 0.00035	0.93706 ± 0.00074	0.93569 ± 0.00074
6.00	2.61	0.90476 ± 0.00036	1.33518 ± 0.00101	0.67841 ± 0.00032	0.90580 ± 0.00068	0.90460 ± 0.00068
6.50	3.26	0.86962 ± 0.00035	1.27506 ± 0.00101	0.68269 ± 0.00033	0.87047 ± 0.00068	0.86942 ± 0.00068
7.00	3.96	0.83194 ± 0.00033	1.21220 ± 0.00095	0.68689 ± 0.00032	0.83265 ± 0.00065	0.83174 ± 0.00065

Table A.2.9(5) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 57 fuel rods, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.97106 ± 0.00039	1.52185 ± 0.00118	0.63926 ± 0.00035	0.97285 ± 0.00074	0.97075 ± 0.00074
4.00	0.52	0.95860 ± 0.00037	1.51691 ± 0.00117	0.63316 ± 0.00034	0.96045 ± 0.00072	0.95843 ± 0.00072
4.175	0.67	0.95025 ± 0.00038	1.51231 ± 0.00119	0.62946 ± 0.00035	0.95193 ± 0.00072	0.94997 ± 0.00072
4.35	0.82	0.94199 ± 0.00039	1.50719 ± 0.00122	0.62615 ± 0.00035	0.94372 ± 0.00074	0.94181 ± 0.00074
4.50	0.96	0.93495 ± 0.00039	1.50191 ± 0.00121	0.62355 ± 0.00035	0.93652 ± 0.00073	0.93466 ± 0.00073
4.70	1.15	0.92553 ± 0.00036	1.49404 ± 0.00115	0.62048 ± 0.00034	0.92702 ± 0.00069	0.92522 ± 0.00069
5.00	1.46	0.91173 ± 0.00038	1.47987 ± 0.00124	0.61704 ± 0.00036	0.91313 ± 0.00074	0.91143 ± 0.00074
5.50	2.01	0.88724 ± 0.00038	1.45095 ± 0.00122	0.61243 ± 0.00037	0.88861 ± 0.00073	0.88706 ± 0.00072
6.00	2.61	0.86205 ± 0.00036	1.41648 ± 0.00103	0.60943 ± 0.00035	0.86325 ± 0.00062	0.86183 ± 0.00062
6.50	3.26	0.83578 ± 0.00036	1.37732 ± 0.00110	0.60761 ± 0.00035	0.83687 ± 0.00065	0.83559 ± 0.00065
7.00	3.96	0.80816 ± 0.00037	1.33431 ± 0.00107	0.60652 ± 0.00037	0.80928 ± 0.00063	0.80812 ± 0.00063

Table A.2.9(6) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 57 fuel rods, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.94554 ± 0.00039	1.52685 ± 0.00124	0.62048 ± 0.00037	0.94738 ± 0.00075	0.94523 ± 0.00075
4.00	0.52	0.92034 ± 0.00038	1.52585 ± 0.00124	0.60441 ± 0.00036	0.92224 ± 0.00072	0.92015 ± 0.00072
4.175	0.67	0.90401 ± 0.00039	1.52474 ± 0.00124	0.59403 ± 0.00036	0.90575 ± 0.00071	0.90370 ± 0.00070
4.35	0.82	0.88871 ± 0.00036	1.52341 ± 0.00129	0.58453 ± 0.00037	0.89047 ± 0.00072	0.88847 ± 0.00072
4.50	0.96	0.87606 ± 0.00038	1.52183 ± 0.00129	0.57686 ± 0.00038	0.87788 ± 0.00071	0.87592 ± 0.00071
4.70	1.15	0.86041 ± 0.00038	1.51938 ± 0.00129	0.56741 ± 0.00039	0.86211 ± 0.00070	0.86020 ± 0.00070
5.00	1.46	0.83822 ± 0.00038	1.51476 ± 0.00123	0.55440 ± 0.00038	0.83979 ± 0.00065	0.83795 ± 0.00065
5.50	2.01	0.80582 ± 0.00039	1.50424 ± 0.00138	0.53671 ± 0.00040	0.80734 ± 0.00070	0.80564 ± 0.00069
6.00	2.61	0.77646 ± 0.00038	1.49055 ± 0.00132	0.52192 ± 0.00042	0.77795 ± 0.00065	0.77635 ± 0.00065
6.50	3.26	0.74964 ± 0.00039	1.47374 ± 0.00140	0.50953 ± 0.00043	0.75091 ± 0.00067	0.74943 ± 0.00067
7.00	3.96	0.72447 ± 0.00037	1.45435 ± 0.00138	0.49909 ± 0.00043	0.72585 ± 0.00065	0.72448 ± 0.00064

Table A.2.9(7) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 57 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.91802 ± 0.00037	1.53199 ± 0.00124	0.60036 ± 0.00036	0.91975 ± 0.00072	0.91756 ± 0.00072
4.00	0.52	0.87795 ± 0.00040	1.53476 ± 0.00130	0.57335 ± 0.00038	0.87996 ± 0.00071	0.87782 ± 0.00071
4.175	0.67	0.85222 ± 0.00037	1.53675 ± 0.00131	0.55577 ± 0.00040	0.85409 ± 0.00070	0.85198 ± 0.00069
4.35	0.82	0.82815 ± 0.00038	1.53859 ± 0.00142	0.53944 ± 0.00041	0.82997 ± 0.00072	0.82789 ± 0.00072
4.50	0.96	0.80901 ± 0.00038	1.54021 ± 0.00131	0.52643 ± 0.00040	0.81081 ± 0.00065	0.80877 ± 0.00065
4.70	1.15	0.78487 ± 0.00037	1.54254 ± 0.00126	0.50997 ± 0.00041	0.78665 ± 0.00061	0.78466 ± 0.00061
5.00	1.46	0.75233 ± 0.00035	1.54557 ± 0.00143	0.48796 ± 0.00042	0.75418 ± 0.00065	0.75225 ± 0.00064
5.50	2.01	0.70499 ± 0.00038	1.55056 ± 0.00149	0.45574 ± 0.00046	0.70665 ± 0.00063	0.70483 ± 0.00063
6.00	2.61	0.66460 ± 0.00036	1.55514 ± 0.00150	0.42837 ± 0.00047	0.66618 ± 0.00059	0.66446 ± 0.00059
6.50	3.26	0.62905 ± 0.00035	1.55945 ± 0.00161	0.40432 ± 0.00049	0.63052 ± 0.00059	0.62890 ± 0.00059
7.00	3.96	0.59760 ± 0.00035	1.56342 ± 0.00156	0.38316 ± 0.00049	0.59903 ± 0.00054	0.59750 ± 0.00054

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the finite square lattice systems composed of 57

fuel rods are listed in Tables A.2.10(1) to A.2.10(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.2.10(1) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0, 57 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	1.02494 ± 0.00040	1.50408 ± 0.00111	0.68249 ± 0.00033	1.02652 ± 0.00075	1.02455 ± 0.00075
4.00	0.52	1.03382 ± 0.00039	1.48284 ± 0.00114	0.69819 ± 0.00033	1.03530 ± 0.00079	1.03349 ± 0.00079
4.175	0.67	1.03536 ± 0.00040	1.46447 ± 0.00107	0.70796 ± 0.00031	1.03679 ± 0.00076	1.03508 ± 0.00075
4.35	0.82	1.03275 ± 0.00038	1.44319 ± 0.00100	0.71645 ± 0.00031	1.03397 ± 0.00072	1.03237 ± 0.00072
4.50	0.96	1.02823 ± 0.00037	1.42334 ± 0.00104	0.72329 ± 0.00030	1.02949 ± 0.00075	1.02798 ± 0.00075
4.70	1.15	1.01846 ± 0.00037	1.39392 ± 0.00096	0.73145 ± 0.00030	1.01959 ± 0.00071	1.01818 ± 0.00071
5.00	1.46	0.99804 ± 0.00036	1.34567 ± 0.00106	0.74237 ± 0.00029	0.99898 ± 0.00078	0.99772 ± 0.00078
5.50	2.01	0.95166 ± 0.00034	1.25783 ± 0.00090	0.75724 ± 0.00027	0.95248 ± 0.00068	0.95145 ± 0.00068
6.00	2.61	0.89591 ± 0.00034	1.16556 ± 0.00083	0.76923 ± 0.00027	0.89658 ± 0.00064	0.89574 ± 0.00064
6.50	3.26	0.83591 ± 0.00032	1.07356 ± 0.00079	0.77912 ± 0.00026	0.83643 ± 0.00062	0.83573 ± 0.00062
7.00	3.96	0.77468 ± 0.00032	0.98482 ± 0.00076	0.78711 ± 0.00028	0.77517 ± 0.00060	0.77460 ± 0.00060

Table A.2.10(2) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0, 57 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.91114 ± 0.00037	1.53340 ± 0.00130	0.59541 ± 0.00035	0.91300 ± 0.00073	0.91080 ± 0.00073
4.00	0.52	0.87110 ± 0.00037	1.53626 ± 0.00125	0.56825 ± 0.00038	0.87298 ± 0.00068	0.87082 ± 0.00068
4.175	0.67	0.84577 ± 0.00037	1.53801 ± 0.00136	0.55112 ± 0.00038	0.84763 ± 0.00070	0.84552 ± 0.00070
4.35	0.82	0.82193 ± 0.00038	1.53999 ± 0.00131	0.53493 ± 0.00039	0.82379 ± 0.00066	0.82171 ± 0.00066
4.50	0.96	0.80291 ± 0.00038	1.54161 ± 0.00131	0.52203 ± 0.00042	0.80476 ± 0.00065	0.80272 ± 0.00065
4.70	1.15	0.77923 ± 0.00038	1.54371 ± 0.00137	0.50584 ± 0.00043	0.78087 ± 0.00066	0.77885 ± 0.00065
5.00	1.46	0.74665 ± 0.00038	1.54692 ± 0.00138	0.48377 ± 0.00043	0.74835 ± 0.00063	0.74641 ± 0.00062
5.50	2.01	0.69950 ± 0.00038	1.55180 ± 0.00148	0.45187 ± 0.00046	0.70121 ± 0.00062	0.69939 ± 0.00062
6.00	2.61	0.65886 ± 0.00037	1.55621 ± 0.00155	0.42439 ± 0.00048	0.66044 ± 0.00060	0.65871 ± 0.00060
6.50	3.26	0.62356 ± 0.00036	1.56045 ± 0.00156	0.40055 ± 0.00050	0.62504 ± 0.00057	0.62340 ± 0.00057
7.00	3.96	0.59261 ± 0.00036	1.56433 ± 0.00162	0.37974 ± 0.00053	0.59404 ± 0.00056	0.59249 ± 0.00056

Table A.2.10(3) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0u1, 57 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	1.02483 ± 0.00039	1.50425 ± 0.00117	0.68239 ± 0.00033	1.02648 ± 0.00078	1.02451 ± 0.00078
4.00	0.52	1.03392 ± 0.00038	1.48304 ± 0.00104	0.69823 ± 0.00032	1.03550 ± 0.00073	1.03369 ± 0.00073
4.175	0.67	1.03524 ± 0.00039	1.46446 ± 0.00112	0.70793 ± 0.00032	1.03674 ± 0.00079	1.03503 ± 0.00078
4.35	0.82	1.03275 ± 0.00036	1.44347 ± 0.00105	0.71650 ± 0.00030	1.03424 ± 0.00075	1.03264 ± 0.00075
4.50	0.96	1.02802 ± 0.00037	1.42315 ± 0.00109	0.72326 ± 0.00030	1.02931 ± 0.00078	1.02780 ± 0.00078
4.70	1.15	1.01848 ± 0.00038	1.39388 ± 0.00101	0.73159 ± 0.00031	1.01975 ± 0.00074	1.01834 ± 0.00074
5.00	1.46	0.99800 ± 0.00033	1.34576 ± 0.00097	0.74233 ± 0.00027	0.99900 ± 0.00071	0.99775 ± 0.00071
5.50	2.01	0.95179 ± 0.00035	1.25788 ± 0.00094	0.75732 ± 0.00029	0.95262 ± 0.00072	0.95158 ± 0.00072
6.00	2.61	0.89580 ± 0.00033	1.16568 ± 0.00088	0.76902 ± 0.00028	0.89643 ± 0.00067	0.89559 ± 0.00067
6.50	3.26	0.83568 ± 0.00031	1.07354 ± 0.00079	0.77892 ± 0.00027	0.83621 ± 0.00062	0.83551 ± 0.00062
7.00	3.96	0.77489 ± 0.00033	0.98486 ± 0.00079	0.78717 ± 0.00028	0.77525 ± 0.00063	0.77469 ± 0.00062

Table A.2.10(4) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0u1, 57 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.91101 ± 0.00035	1.53355 ± 0.00119	0.59526 ± 0.00037	0.91286 ± 0.00069	0.91066 ± 0.00069
4.00	0.52	0.87124 ± 0.00040	1.53617 ± 0.00136	0.56843 ± 0.00040	0.87321 ± 0.00074	0.87106 ± 0.00074
4.175	0.67	0.84549 ± 0.00036	1.53806 ± 0.00130	0.55092 ± 0.00038	0.84735 ± 0.00068	0.84523 ± 0.00068
4.35	0.82	0.82198 ± 0.00037	1.54011 ± 0.00131	0.53497 ± 0.00038	0.82391 ± 0.00066	0.82182 ± 0.00066
4.50	0.96	0.80302 ± 0.00036	1.54173 ± 0.00131	0.52196 ± 0.00041	0.80472 ± 0.00065	0.80267 ± 0.00065
4.70	1.15	0.77934 ± 0.00037	1.54391 ± 0.00137	0.50590 ± 0.00043	0.78107 ± 0.00066	0.77906 ± 0.00065
5.00	1.46	0.74649 ± 0.00038	1.54679 ± 0.00138	0.48370 ± 0.00043	0.74818 ± 0.00063	0.74624 ± 0.00062
5.50	2.01	0.69954 ± 0.00035	1.55199 ± 0.00138	0.45188 ± 0.00044	0.70131 ± 0.00058	0.69948 ± 0.00058
6.00	2.61	0.65906 ± 0.00035	1.55628 ± 0.00149	0.42452 ± 0.00047	0.66067 ± 0.00058	0.65894 ± 0.00058
6.50	3.26	0.62373 ± 0.00036	1.56048 ± 0.00151	0.40069 ± 0.00049	0.62527 ± 0.00056	0.62364 ± 0.00055
7.00	3.96	0.59254 ± 0.00034	1.56450 ± 0.00162	0.37967 ± 0.00050	0.59400 ± 0.00055	0.59246 ± 0.00055

(6) Finite square lattice system composed of 49 fuel rods

The results of numerical data calculated using the JENDL-5 library for the finite square lattice systems composed of 49 fuel rods are listed in Tables A.2.11(1) to A.2.11(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.2.11(1) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	1.00066 ± 0.00036	1.50428 ± 0.00116	0.66630 ± 0.00032	1.00229 ± 0.00075	1.00053 ± 0.00075
4.00	0.52	1.01049 ± 0.00040	1.48259 ± 0.00119	0.68247 ± 0.00033	1.01182 ± 0.00080	1.01020 ± 0.00080
4.175	0.67	1.01237 ± 0.00039	1.46410 ± 0.00118	0.69228 ± 0.00033	1.01356 ± 0.00080	1.01205 ± 0.00080
4.35	0.82	1.01045 ± 0.00037	1.44287 ± 0.00106	0.70107 ± 0.00031	1.01156 ± 0.00074	1.01016 ± 0.00073
4.50	0.96	1.00681 ± 0.00037	1.42308 ± 0.00109	0.70825 ± 0.00032	1.00790 ± 0.00076	1.00658 ± 0.00076
4.70	1.15	0.99771 ± 0.00037	1.39406 ± 0.00106	0.71643 ± 0.00031	0.99875 ± 0.00076	0.99753 ± 0.00076
5.00	1.46	0.97893 ± 0.00035	1.34675 ± 0.00097	0.72752 ± 0.00029	0.97979 ± 0.00071	0.97871 ± 0.00070
5.50	2.01	0.93584 ± 0.00036	1.26032 ± 0.00091	0.74304 ± 0.00030	0.93647 ± 0.00068	0.93560 ± 0.00068
6.00	2.61	0.88339 ± 0.00034	1.17006 ± 0.00087	0.75545 ± 0.00029	0.88392 ± 0.00066	0.88323 ± 0.00066
6.50	3.26	0.82650 ± 0.00032	1.07996 ± 0.00084	0.76578 ± 0.00028	0.82700 ± 0.00064	0.82645 ± 0.00064
7.00	3.96	0.76875 ± 0.00030	0.99295 ± 0.00080	0.77456 ± 0.00027	0.76910 ± 0.00062	0.76865 ± 0.00062

Table A.2.11(2) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.99274 ± 0.00039	1.50816 ± 0.00117	0.65927 ± 0.00033	0.99429 ± 0.00075	0.99249 ± 0.00075
4.00	0.52	1.00029 ± 0.00038	1.48949 ± 0.00109	0.67244 ± 0.00033	1.00160 ± 0.00073	0.99995 ± 0.00073
4.175	0.67	1.00202 ± 0.00038	1.47362 ± 0.00109	0.68076 ± 0.00031	1.00318 ± 0.00072	1.00164 ± 0.00072
4.35	0.82	1.00017 ± 0.00040	1.45532 ± 0.00112	0.68801 ± 0.00034	1.00128 ± 0.00077	0.99983 ± 0.00076
4.50	0.96	0.99688 ± 0.00038	1.43795 ± 0.00110	0.69395 ± 0.00032	0.99786 ± 0.00076	0.99649 ± 0.00076
4.70	1.15	0.98931 ± 0.00036	1.41281 ± 0.00108	0.70102 ± 0.00030	0.99041 ± 0.00074	0.98913 ± 0.00074
5.00	1.46	0.97339 ± 0.00037	1.37073 ± 0.00104	0.71076 ± 0.00030	0.97426 ± 0.00073	0.97312 ± 0.00073
5.50	2.01	0.93637 ± 0.00035	1.29321 ± 0.00097	0.72461 ± 0.00030	0.93707 ± 0.00070	0.93614 ± 0.00070
6.00	2.61	0.89064 ± 0.00034	1.21064 ± 0.00091	0.73615 ± 0.00030	0.89120 ± 0.00067	0.89043 ± 0.00067
6.50	3.26	0.83935 ± 0.00033	1.12631 ± 0.00088	0.74567 ± 0.00028	0.83986 ± 0.00065	0.83923 ± 0.00065
7.00	3.96	0.78643 ± 0.00034	1.04347 ± 0.00080	0.75400 ± 0.00028	0.78678 ± 0.00061	0.78627 ± 0.00061

Table A.2.11(3) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.98397 ± 0.00037	1.51164 ± 0.00111	0.65201 ± 0.00033	0.98561 ± 0.00071	0.98380 ± 0.00071
4.00	0.52	0.98882 ± 0.00038	1.49603 ± 0.00115	0.66196 ± 0.00035	0.99031 ± 0.00076	0.98863 ± 0.00075
4.175	0.67	0.98932 ± 0.00040	1.48276 ± 0.00114	0.66812 ± 0.00034	0.99066 ± 0.00075	0.98907 ± 0.00075
4.35	0.82	0.98776 ± 0.00037	1.46721 ± 0.00112	0.67404 ± 0.00033	0.98896 ± 0.00075	0.98746 ± 0.00074
4.50	0.96	0.98458 ± 0.00037	1.45237 ± 0.00106	0.67880 ± 0.00032	0.98586 ± 0.00071	0.98444 ± 0.00071
4.70	1.15	0.97827 ± 0.00038	1.43084 ± 0.00105	0.68449 ± 0.00034	0.97940 ± 0.00072	0.97807 ± 0.00072
5.00	1.46	0.96450 ± 0.00038	1.39442 ± 0.00106	0.69241 ± 0.00031	0.96550 ± 0.00073	0.96430 ± 0.00073
5.50	2.01	0.93312 ± 0.00035	1.32604 ± 0.00101	0.70430 ± 0.00031	0.93392 ± 0.00070	0.93293 ± 0.00070
6.00	2.61	0.89340 ± 0.00034	1.25172 ± 0.00095	0.71420 ± 0.00029	0.89399 ± 0.00067	0.89315 ± 0.00067
6.50	3.26	0.84851 ± 0.00034	1.17451 ± 0.00091	0.72293 ± 0.00030	0.84909 ± 0.00066	0.84840 ± 0.00066
7.00	3.96	0.80093 ± 0.00034	1.09710 ± 0.00089	0.73047 ± 0.00031	0.80140 ± 0.00065	0.80083 ± 0.00065

Table A.2.11(4) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.96438 ± 0.00037	1.51833 ± 0.00123	0.63624 ± 0.00034	0.96603 ± 0.00076	0.96418 ± 0.00075
4.00	0.52	0.96208 ± 0.00038	1.50805 ± 0.00116	0.63898 ± 0.00033	0.96361 ± 0.00072	0.96187 ± 0.00072
4.175	0.67	0.95945 ± 0.00036	1.49955 ± 0.00121	0.64090 ± 0.00034	0.96106 ± 0.00075	0.95940 ± 0.00075
4.35	0.82	0.95570 ± 0.00037	1.48924 ± 0.00115	0.64263 ± 0.00033	0.95702 ± 0.00072	0.95544 ± 0.00072
4.50	0.96	0.95199 ± 0.00039	1.47946 ± 0.00114	0.64426 ± 0.00035	0.95316 ± 0.00072	0.95164 ± 0.00072
4.70	1.15	0.94574 ± 0.00033	1.46468 ± 0.00107	0.64658 ± 0.00033	0.94703 ± 0.00068	0.94559 ± 0.00068
5.00	1.46	0.93462 ± 0.00038	1.43964 ± 0.00111	0.64995 ± 0.00033	0.93570 ± 0.00070	0.93437 ± 0.00070
5.50	2.01	0.91049 ± 0.00038	1.39066 ± 0.00111	0.65546 ± 0.00033	0.91152 ± 0.00071	0.91037 ± 0.00071
6.00	2.61	0.88123 ± 0.00036	1.33485 ± 0.00106	0.66073 ± 0.00034	0.88198 ± 0.00069	0.88099 ± 0.00069
6.50	3.26	0.84775 ± 0.00036	1.27477 ± 0.00105	0.66559 ± 0.00033	0.84848 ± 0.00068	0.84763 ± 0.00068
7.00	3.96	0.81213 ± 0.00036	1.21208 ± 0.00095	0.67055 ± 0.00034	0.81277 ± 0.00064	0.81204 ± 0.00063

Table A.2.11(5) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.94169 ± 0.00038	1.52415 ± 0.00123	0.61904 ± 0.00036	0.94351 ± 0.00074	0.94163 ± 0.00074
4.00	0.52	0.92981 ± 0.00038	1.51869 ± 0.00129	0.61327 ± 0.00037	0.93138 ± 0.00076	0.92958 ± 0.00076
4.175	0.67	0.92161 ± 0.00037	1.51415 ± 0.00123	0.60976 ± 0.00036	0.92326 ± 0.00072	0.92154 ± 0.00072
4.35	0.82	0.91337 ± 0.00036	1.50855 ± 0.00118	0.60648 ± 0.00035	0.91491 ± 0.00069	0.91324 ± 0.00069
4.50	0.96	0.90678 ± 0.00038	1.50320 ± 0.00117	0.60423 ± 0.00036	0.90828 ± 0.00068	0.90666 ± 0.00068
4.70	1.15	0.89786 ± 0.00039	1.49499 ± 0.00120	0.60153 ± 0.00037	0.89928 ± 0.00071	0.89773 ± 0.00070
5.00	1.46	0.88426 ± 0.00037	1.48056 ± 0.00120	0.59806 ± 0.00033	0.88547 ± 0.00068	0.88402 ± 0.00068
5.50	2.01	0.86099 ± 0.00038	1.45132 ± 0.00122	0.59398 ± 0.00038	0.86206 ± 0.00070	0.86078 ± 0.00070
6.00	2.61	0.83667 ± 0.00037	1.41649 ± 0.00119	0.59134 ± 0.00037	0.83763 ± 0.00068	0.83649 ± 0.00068
6.50	3.26	0.81147 ± 0.00037	1.37728 ± 0.00114	0.58985 ± 0.00036	0.81239 ± 0.00065	0.81139 ± 0.00065
7.00	3.96	0.78496 ± 0.00035	1.33408 ± 0.00116	0.58897 ± 0.00037	0.78573 ± 0.00066	0.78484 ± 0.00065

Table A.2.11(6) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.91660 ± 0.00038	1.52931 ± 0.00124	0.60045 ± 0.00035	0.91827 ± 0.00071	0.91634 ± 0.00071
4.00	0.52	0.89197 ± 0.00038	1.52827 ± 0.00130	0.58471 ± 0.00038	0.89359 ± 0.00073	0.89174 ± 0.00073
4.175	0.67	0.87580 ± 0.00039	1.52716 ± 0.00129	0.57456 ± 0.00038	0.87745 ± 0.00071	0.87567 ± 0.00071
4.35	0.82	0.86121 ± 0.00038	1.52553 ± 0.00124	0.56549 ± 0.00038	0.86268 ± 0.00067	0.86094 ± 0.00067
4.50	0.96	0.84918 ± 0.00037	1.52398 ± 0.00124	0.55812 ± 0.00038	0.85056 ± 0.00066	0.84888 ± 0.00066
4.70	1.15	0.83377 ± 0.00040	1.52143 ± 0.00134	0.54898 ± 0.00040	0.83523 ± 0.00070	0.83361 ± 0.00070
5.00	1.46	0.81227 ± 0.00037	1.51647 ± 0.00128	0.53659 ± 0.00038	0.81372 ± 0.00065	0.81218 ± 0.00065
5.50	2.01	0.78056 ± 0.00038	1.50562 ± 0.00127	0.51930 ± 0.00041	0.78186 ± 0.00063	0.78047 ± 0.00063
6.00	2.61	0.75180 ± 0.00036	1.49141 ± 0.00136	0.50485 ± 0.00042	0.75294 ± 0.00065	0.75168 ± 0.00065
6.50	3.26	0.72567 ± 0.00036	1.47428 ± 0.00135	0.49288 ± 0.00043	0.72664 ± 0.00063	0.72549 ± 0.00062
7.00	3.96	0.70107 ± 0.00036	1.45470 ± 0.00138	0.48257 ± 0.00043	0.70199 ± 0.00062	0.70095 ± 0.00062

Table A.2.11(7) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 49 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.88964 ± 0.00037	1.53524 ± 0.00125	0.58052 ± 0.00037	0.89123 ± 0.00070	0.88928 ± 0.00069
4.00	0.52	0.85093 ± 0.00036	1.53786 ± 0.00125	0.55433 ± 0.00037	0.85249 ± 0.00066	0.85060 ± 0.00066
4.175	0.67	0.82605 ± 0.00040	1.53984 ± 0.00131	0.53743 ± 0.00041	0.82756 ± 0.00067	0.82573 ± 0.00067
4.35	0.82	0.80313 ± 0.00037	1.54205 ± 0.00131	0.52188 ± 0.00040	0.80477 ± 0.00065	0.80299 ± 0.00064
4.50	0.96	0.78483 ± 0.00036	1.54347 ± 0.00137	0.50953 ± 0.00040	0.78645 ± 0.00065	0.78471 ± 0.00065
4.70	1.15	0.76168 ± 0.00037	1.54586 ± 0.00137	0.49373 ± 0.00041	0.76324 ± 0.00063	0.76156 ± 0.00063
5.00	1.46	0.73060 ± 0.00037	1.54902 ± 0.00148	0.47258 ± 0.00044	0.73204 ± 0.00065	0.73046 ± 0.00065
5.50	2.01	0.68472 ± 0.00036	1.55395 ± 0.00145	0.44145 ± 0.00047	0.68600 ± 0.00059	0.68453 ± 0.00059
6.00	2.61	0.64592 ± 0.00036	1.55842 ± 0.00145	0.41522 ± 0.00046	0.64709 ± 0.00055	0.64575 ± 0.00055
6.50	3.26	0.61139 ± 0.00035	1.56266 ± 0.00162	0.39198 ± 0.00051	0.61253 ± 0.00058	0.61130 ± 0.00057
7.00	3.96	0.58091 ± 0.00035	1.56665 ± 0.00167	0.37151 ± 0.00052	0.58202 ± 0.00056	0.58088 ± 0.00056

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the finite square lattice systems composed of 49

fuel rods are listed in Tables A.2.12(1) to A.2.12(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.2.12(1) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0, 49 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.99528 ± 0.00038	1.50550 ± 0.00116	0.66208 ± 0.00034	0.99677 ± 0.00076	0.99498 ± 0.00076
4.00	0.52	1.00512 ± 0.00037	1.48351 ± 0.00115	0.67845 ± 0.00033	1.00648 ± 0.00077	1.00485 ± 0.00076
4.175	0.67	1.00722 ± 0.00036	1.46478 ± 0.00108	0.68848 ± 0.00031	1.00847 ± 0.00073	1.00694 ± 0.00073
4.35	0.82	1.00599 ± 0.00037	1.44344 ± 0.00106	0.69774 ± 0.00030	1.00715 ± 0.00073	1.00573 ± 0.00072
4.50	0.96	1.00174 ± 0.00036	1.42314 ± 0.00104	0.70470 ± 0.00031	1.00289 ± 0.00073	1.00154 ± 0.00073
4.70	1.15	0.99341 ± 0.00037	1.39399 ± 0.00106	0.71340 ± 0.00029	0.99447 ± 0.00074	0.99323 ± 0.00074
5.00	1.46	0.97453 ± 0.00035	1.34552 ± 0.00097	0.72488 ± 0.00029	0.97534 ± 0.00070	0.97424 ± 0.00070
5.50	2.01	0.93126 ± 0.00034	1.25771 ± 0.00095	0.74096 ± 0.00029	0.93192 ± 0.00070	0.93103 ± 0.00070
6.00	2.61	0.87840 ± 0.00035	1.16554 ± 0.00087	0.75422 ± 0.00029	0.87907 ± 0.00066	0.87835 ± 0.00066
6.50	3.26	0.82048 ± 0.00033	1.07351 ± 0.00087	0.76476 ± 0.00029	0.82098 ± 0.00066	0.82040 ± 0.00066
7.00	3.96	0.76170 ± 0.00033	0.98489 ± 0.00076	0.77373 ± 0.00027	0.76204 ± 0.00059	0.76157 ± 0.00059

Table A.2.12(2) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0, 49 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.88258 ± 0.00038	1.53653 ± 0.00130	0.57545 ± 0.00038	0.88420 ± 0.00072	0.88223 ± 0.00071
4.00	0.52	0.84435 ± 0.00039	1.53943 ± 0.00131	0.54952 ± 0.00039	0.84595 ± 0.00068	0.84405 ± 0.00068
4.175	0.67	0.81985 ± 0.00037	1.54103 ± 0.00131	0.53305 ± 0.00041	0.82145 ± 0.00067	0.81959 ± 0.00067
4.35	0.82	0.79712 ± 0.00037	1.54321 ± 0.00131	0.51758 ± 0.00041	0.79874 ± 0.00065	0.79695 ± 0.00064
4.50	0.96	0.77867 ± 0.00036	1.54501 ± 0.00131	0.50507 ± 0.00041	0.78035 ± 0.00063	0.77859 ± 0.00062
4.70	1.15	0.75607 ± 0.00037	1.54703 ± 0.00137	0.48978 ± 0.00044	0.75770 ± 0.00064	0.75600 ± 0.00063
5.00	1.46	0.72476 ± 0.00038	1.55035 ± 0.00143	0.46845 ± 0.00044	0.72626 ± 0.00062	0.72465 ± 0.00062
5.50	2.01	0.67940 ± 0.00036	1.55530 ± 0.00144	0.43766 ± 0.00046	0.68070 ± 0.00058	0.67922 ± 0.00058
6.00	2.61	0.64048 ± 0.00034	1.55966 ± 0.00155	0.41143 ± 0.00048	0.64169 ± 0.00058	0.64033 ± 0.00058
6.50	3.26	0.60606 ± 0.00035	1.56364 ± 0.00151	0.38827 ± 0.00049	0.60712 ± 0.00054	0.60587 ± 0.00053
7.00	3.96	0.57578 ± 0.00034	1.56754 ± 0.00168	0.36798 ± 0.00051	0.57682 ± 0.00055	0.57567 ± 0.00055

Table A.2.12(3) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0u1, 49 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.99488 ± 0.00038	1.50549 ± 0.00122	0.66183 ± 0.00033	0.99638 ± 0.00078	0.99459 ± 0.00078
4.00	0.52	1.00536 ± 0.00037	1.48356 ± 0.00114	0.67854 ± 0.00033	1.00665 ± 0.00076	1.00503 ± 0.00076
4.175	0.67	1.00751 ± 0.00039	1.46482 ± 0.00118	0.68863 ± 0.00032	1.00871 ± 0.00079	1.00718 ± 0.00079
4.35	0.82	1.00596 ± 0.00039	1.44359 ± 0.00116	0.69765 ± 0.00032	1.00712 ± 0.00079	1.00569 ± 0.00079
4.50	0.96	1.00211 ± 0.00038	1.42335 ± 0.00109	0.70491 ± 0.00032	1.00333 ± 0.00076	1.00197 ± 0.00076
4.70	1.15	0.99334 ± 0.00035	1.39380 ± 0.00101	0.71337 ± 0.00030	0.99429 ± 0.00072	0.99304 ± 0.00072
5.00	1.46	0.97479 ± 0.00035	1.34562 ± 0.00097	0.72509 ± 0.00029	0.97569 ± 0.00070	0.97459 ± 0.00070
5.50	2.01	0.93110 ± 0.00034	1.25762 ± 0.00094	0.74090 ± 0.00029	0.93177 ± 0.00070	0.93089 ± 0.00070
6.00	2.61	0.87819 ± 0.00033	1.16548 ± 0.00090	0.75393 ± 0.00028	0.87869 ± 0.00068	0.87797 ± 0.00068
6.50	3.26	0.82041 ± 0.00034	1.07325 ± 0.00083	0.76468 ± 0.00030	0.82070 ± 0.00064	0.82012 ± 0.00064
7.00	3.96	0.76175 ± 0.00032	0.98490 ± 0.00082	0.77376 ± 0.00027	0.76208 ± 0.00063	0.76161 ± 0.00063

Table A.2.12(4) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0u1, 49 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.88254 ± 0.00039	1.53629 ± 0.00136	0.57552 ± 0.00038	0.88417 ± 0.00074	0.88222 ± 0.00074
4.00	0.52	0.84457 ± 0.00039	1.53931 ± 0.00136	0.54972 ± 0.00041	0.84619 ± 0.00071	0.84429 ± 0.00071
4.175	0.67	0.81996 ± 0.00038	1.54138 ± 0.00131	0.53298 ± 0.00040	0.82152 ± 0.00066	0.81967 ± 0.00066
4.35	0.82	0.79697 ± 0.00038	1.54324 ± 0.00131	0.51734 ± 0.00041	0.79838 ± 0.00064	0.79659 ± 0.00064
4.50	0.96	0.77861 ± 0.00038	1.54477 ± 0.00145	0.50507 ± 0.00043	0.78022 ± 0.00068	0.77847 ± 0.00067
4.70	1.15	0.75574 ± 0.00038	1.54700 ± 0.00137	0.48949 ± 0.00044	0.75724 ± 0.00064	0.75555 ± 0.00063
5.00	1.46	0.72460 ± 0.00037	1.55024 ± 0.00149	0.46842 ± 0.00045	0.72616 ± 0.00065	0.72455 ± 0.00064
5.50	2.01	0.67918 ± 0.00037	1.55520 ± 0.00155	0.43754 ± 0.00047	0.68047 ± 0.00062	0.67899 ± 0.00062
6.00	2.61	0.64051 ± 0.00037	1.55959 ± 0.00156	0.41138 ± 0.00049	0.64159 ± 0.00059	0.64024 ± 0.00059
6.50	3.26	0.60624 ± 0.00035	1.56379 ± 0.00167	0.38832 ± 0.00052	0.60725 ± 0.00059	0.60600 ± 0.00059
7.00	3.96	0.57597 ± 0.00036	1.56771 ± 0.00173	0.36803 ± 0.00053	0.57697 ± 0.00057	0.57582 ± 0.00057

(7) Finite square lattice system composed of 44 fuel rods

The results of numerical data calculated using the JENDL-5 library for the finite square lattice systems composed of 44 fuel rods are listed in Tables A.2.13(1) to A.2.13(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.2.13(1) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 44 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.97658 ± 0.00037	1.50455 ± 0.00111	0.65035 ± 0.00032	0.97848 ± 0.00070	0.97632 ± 0.00070
4.00	0.52	0.98739 ± 0.00038	1.48266 ± 0.00109	0.66708 ± 0.00033	0.98905 ± 0.00072	0.98705 ± 0.00072
4.175	0.67	0.98968 ± 0.00037	1.46393 ± 0.00109	0.67719 ± 0.00031	0.99136 ± 0.00072	0.98947 ± 0.00072
4.35	0.82	0.98858 ± 0.00037	1.44291 ± 0.00110	0.68616 ± 0.00032	0.99007 ± 0.00075	0.98830 ± 0.00075
4.50	0.96	0.98533 ± 0.00038	1.42293 ± 0.00109	0.69347 ± 0.00032	0.98677 ± 0.00075	0.98510 ± 0.00075
4.70	1.15	0.97767 ± 0.00036	1.39403 ± 0.00107	0.70224 ± 0.00031	0.97895 ± 0.00074	0.97739 ± 0.00074
5.00	1.46	0.95995 ± 0.00034	1.34630 ± 0.00102	0.71391 ± 0.00032	0.96114 ± 0.00073	0.95975 ± 0.00073
5.50	2.01	0.91926 ± 0.00038	1.26030 ± 0.00095	0.73020 ± 0.00031	0.92026 ± 0.00070	0.91912 ± 0.00069
6.00	2.61	0.86901 ± 0.00033	1.17027 ± 0.00092	0.74327 ± 0.00029	0.86982 ± 0.00068	0.86889 ± 0.00068
6.50	3.26	0.81441 ± 0.00032	1.08016 ± 0.00083	0.75452 ± 0.00028	0.81500 ± 0.00063	0.81424 ± 0.00063
7.00	3.96	0.75816 ± 0.00033	0.99310 ± 0.00080	0.76393 ± 0.00029	0.75866 ± 0.00061	0.75802 ± 0.00061

Table A.2.13(2) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 44 fuel rods, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.96822 ± 0.00038	1.50851 ± 0.00122	0.64306 ± 0.00034	0.97007 ± 0.00076	0.96790 ± 0.00076
4.00	0.52	0.97680 ± 0.00035	1.48962 ± 0.00109	0.65695 ± 0.00033	0.97861 ± 0.00071	0.97657 ± 0.00071
4.175	0.67	0.97872 ± 0.00037	1.47362 ± 0.00108	0.66531 ± 0.00032	0.98041 ± 0.00071	0.97849 ± 0.00071
4.35	0.82	0.97791 ± 0.00035	1.45523 ± 0.00107	0.67307 ± 0.00032	0.97947 ± 0.00071	0.97765 ± 0.00071
4.50	0.96	0.97499 ± 0.00037	1.43781 ± 0.00106	0.67921 ± 0.00033	0.97658 ± 0.00071	0.97484 ± 0.00071
4.70	1.15	0.96856 ± 0.00037	1.41254 ± 0.00108	0.68676 ± 0.00032	0.97008 ± 0.00073	0.96845 ± 0.00073
5.00	1.46	0.95403 ± 0.00037	1.37059 ± 0.00105	0.69706 ± 0.00032	0.95538 ± 0.00072	0.95392 ± 0.00072
5.50	2.01	0.91906 ± 0.00036	1.29321 ± 0.00097	0.71151 ± 0.00032	0.92013 ± 0.00069	0.91890 ± 0.00069
6.00	2.61	0.87506 ± 0.00033	1.21050 ± 0.00091	0.72360 ± 0.00029	0.87591 ± 0.00065	0.87489 ± 0.00065
6.50	3.26	0.82598 ± 0.00034	1.12626 ± 0.00087	0.73406 ± 0.00029	0.82674 ± 0.00064	0.82588 ± 0.00064
7.00	3.96	0.77481 ± 0.00033	1.04376 ± 0.00088	0.74289 ± 0.00031	0.77540 ± 0.00065	0.77468 ± 0.00065

Table A.2.13(3) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 44 fuel rods, density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.95939 ± 0.00039	1.51202 ± 0.00117	0.63570 ± 0.00035	0.96119 ± 0.00073	0.95899 ± 0.00072
4.00	0.52	0.96495 ± 0.00037	1.49613 ± 0.00121	0.64613 ± 0.00034	0.96669 ± 0.00076	0.96463 ± 0.00076
4.175	0.67	0.96632 ± 0.00037	1.48281 ± 0.00114	0.65289 ± 0.00035	0.96811 ± 0.00074	0.96613 ± 0.00073
4.35	0.82	0.96489 ± 0.00036	1.46727 ± 0.00108	0.65874 ± 0.00032	0.96655 ± 0.00070	0.96468 ± 0.00069
4.50	0.96	0.96232 ± 0.00036	1.45239 ± 0.00111	0.66366 ± 0.00031	0.96390 ± 0.00072	0.96210 ± 0.00072
4.70	1.15	0.95693 ± 0.00036	1.43070 ± 0.00109	0.66991 ± 0.00032	0.95844 ± 0.00072	0.95675 ± 0.00072
5.00	1.46	0.94462 ± 0.00035	1.39420 ± 0.00106	0.67855 ± 0.00030	0.94603 ± 0.00070	0.94449 ± 0.00070
5.50	2.01	0.91456 ± 0.00035	1.32584 ± 0.00101	0.69059 ± 0.00032	0.91561 ± 0.00069	0.91430 ± 0.00069
6.00	2.61	0.87652 ± 0.00033	1.25143 ± 0.00099	0.70121 ± 0.00030	0.87752 ± 0.00068	0.87640 ± 0.00068
6.50	3.26	0.83348 ± 0.00034	1.17441 ± 0.00096	0.71040 ± 0.00031	0.83430 ± 0.00067	0.83336 ± 0.00067
7.00	3.96	0.78777 ± 0.00035	1.09738 ± 0.00089	0.71852 ± 0.00031	0.78848 ± 0.00064	0.78768 ± 0.00064

Table A.2.13(4) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 44 fuel rods, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.93967 ± 0.00038	1.51875 ± 0.00123	0.62000 ± 0.00035	0.94162 ± 0.00073	0.93937 ± 0.00073
4.00	0.52	0.93796 ± 0.00038	1.50821 ± 0.00117	0.62316 ± 0.00036	0.93985 ± 0.00071	0.93772 ± 0.00071
4.175	0.67	0.93556 ± 0.00036	1.49950 ± 0.00110	0.62511 ± 0.00034	0.93735 ± 0.00068	0.93529 ± 0.00068
4.35	0.82	0.93230 ± 0.00038	1.48942 ± 0.00115	0.62717 ± 0.00035	0.93412 ± 0.00071	0.93215 ± 0.00070
4.50	0.96	0.92889 ± 0.00038	1.47936 ± 0.00119	0.62899 ± 0.00035	0.93051 ± 0.00073	0.92859 ± 0.00073
4.70	1.15	0.92353 ± 0.00038	1.46449 ± 0.00118	0.63169 ± 0.00034	0.92510 ± 0.00072	0.92327 ± 0.00072
5.00	1.46	0.91243 ± 0.00034	1.43925 ± 0.00115	0.63494 ± 0.00034	0.91383 ± 0.00071	0.91214 ± 0.00071
5.50	2.01	0.88974 ± 0.00034	1.39021 ± 0.00101	0.64093 ± 0.00034	0.89103 ± 0.00064	0.88954 ± 0.00064
6.00	2.61	0.86231 ± 0.00036	1.33481 ± 0.00106	0.64694 ± 0.00033	0.86354 ± 0.00067	0.86223 ± 0.00067
6.50	3.26	0.83055 ± 0.00036	1.27468 ± 0.00100	0.65246 ± 0.00036	0.83167 ± 0.00065	0.83053 ± 0.00065
7.00	3.96	0.79609 ± 0.00036	1.21203 ± 0.00100	0.65753 ± 0.00034	0.79695 ± 0.00065	0.79595 ± 0.00065

Table A.2.13(5) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 44 fuel rods, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.91700 ± 0.00036	1.52475 ± 0.00124	0.60274 ± 0.00035	0.91903 ± 0.00072	0.91674 ± 0.00071
4.00	0.52	0.90535 ± 0.00037	1.51915 ± 0.00118	0.59729 ± 0.00036	0.90737 ± 0.00068	0.90517 ± 0.00068
4.175	0.67	0.89760 ± 0.00040	1.51449 ± 0.00128	0.59401 ± 0.00037	0.89961 ± 0.00073	0.89748 ± 0.00073
4.35	0.82	0.89019 ± 0.00038	1.50882 ± 0.00123	0.59125 ± 0.00037	0.89208 ± 0.00070	0.89001 ± 0.00070
4.50	0.96	0.88355 ± 0.00036	1.50348 ± 0.00122	0.58886 ± 0.00036	0.88534 ± 0.00069	0.88333 ± 0.00069
4.70	1.15	0.87466 ± 0.00037	1.49507 ± 0.00121	0.58615 ± 0.00038	0.87633 ± 0.00069	0.87439 ± 0.00069
5.00	1.46	0.86140 ± 0.00038	1.48053 ± 0.00120	0.58292 ± 0.00038	0.86303 ± 0.00068	0.86120 ± 0.00067
5.50	2.01	0.83953 ± 0.00038	1.45120 ± 0.00116	0.57951 ± 0.00037	0.84098 ± 0.00065	0.83931 ± 0.00065
6.00	2.61	0.81611 ± 0.00037	1.41632 ± 0.00119	0.57714 ± 0.00038	0.81742 ± 0.00066	0.81591 ± 0.00066
6.50	3.26	0.79187 ± 0.00038	1.37684 ± 0.00120	0.57606 ± 0.00038	0.79314 ± 0.00066	0.79178 ± 0.00066
7.00	3.96	0.76649 ± 0.00037	1.33365 ± 0.00111	0.57545 ± 0.00037	0.76744 ± 0.00062	0.76622 ± 0.00062

Table A.2.13(6) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 44 fuel rods, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.89207 ± 0.00040	1.53021 ± 0.00129	0.58430 ± 0.00039	0.89410 ± 0.00073	0.89178 ± 0.00073
4.00	0.52	0.86809 ± 0.00039	1.52897 ± 0.00130	0.56909 ± 0.00039	0.87012 ± 0.00071	0.86786 ± 0.00070
4.175	0.67	0.85277 ± 0.00039	1.52778 ± 0.00124	0.55949 ± 0.00039	0.85478 ± 0.00067	0.85257 ± 0.00067
4.35	0.82	0.83801 ± 0.00036	1.52621 ± 0.00130	0.55030 ± 0.00039	0.83988 ± 0.00068	0.83774 ± 0.00068
4.50	0.96	0.82630 ± 0.00036	1.52469 ± 0.00129	0.54323 ± 0.00040	0.82826 ± 0.00067	0.82616 ± 0.00067
4.70	1.15	0.81117 ± 0.00039	1.52199 ± 0.00135	0.53421 ± 0.00041	0.81305 ± 0.00068	0.81103 ± 0.00068
5.00	1.46	0.79036 ± 0.00036	1.51695 ± 0.00129	0.52214 ± 0.00039	0.79206 ± 0.00064	0.79012 ± 0.00063
5.50	2.01	0.75971 ± 0.00037	1.50602 ± 0.00133	0.50559 ± 0.00041	0.76143 ± 0.00063	0.75964 ± 0.00063
6.00	2.61	0.73181 ± 0.00036	1.49153 ± 0.00137	0.49157 ± 0.00042	0.73319 ± 0.00063	0.73153 ± 0.00063
6.50	3.26	0.70637 ± 0.00037	1.47455 ± 0.00135	0.48000 ± 0.00044	0.70779 ± 0.00061	0.70626 ± 0.00061
7.00	3.96	0.68237 ± 0.00037	1.45468 ± 0.00138	0.47001 ± 0.00045	0.68372 ± 0.00061	0.68231 ± 0.00061

Table A.2.13(7) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 44 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.86543 ± 0.00040	1.53622 ± 0.00136	0.56475 ± 0.00040	0.86757 ± 0.00073	0.86521 ± 0.00073
4.00	0.52	0.82740 ± 0.00038	1.53886 ± 0.00136	0.53914 ± 0.00041	0.82967 ± 0.00070	0.82738 ± 0.00069
4.175	0.67	0.80342 ± 0.00036	1.54101 ± 0.00137	0.52267 ± 0.00041	0.80545 ± 0.00067	0.80320 ± 0.00067
4.35	0.82	0.78132 ± 0.00038	1.54319 ± 0.00131	0.50758 ± 0.00042	0.78330 ± 0.00063	0.78110 ± 0.00063
4.50	0.96	0.76346 ± 0.00039	1.54472 ± 0.00137	0.49552 ± 0.00044	0.76545 ± 0.00064	0.76329 ± 0.00064
4.70	1.15	0.74072 ± 0.00034	1.54698 ± 0.00137	0.48005 ± 0.00041	0.74263 ± 0.00061	0.74054 ± 0.00061
5.00	1.46	0.71037 ± 0.00037	1.55010 ± 0.00143	0.45934 ± 0.00046	0.71202 ± 0.00062	0.71000 ± 0.00061
5.50	2.01	0.66644 ± 0.00037	1.55536 ± 0.00150	0.42958 ± 0.00047	0.66816 ± 0.00059	0.66628 ± 0.00059
6.00	2.61	0.62825 ± 0.00037	1.55959 ± 0.00156	0.40390 ± 0.00049	0.62992 ± 0.00057	0.62817 ± 0.00057
6.50	3.26	0.59525 ± 0.00032	1.56398 ± 0.00156	0.38160 ± 0.00049	0.59681 ± 0.00054	0.59518 ± 0.00054
7.00	3.96	0.56587 ± 0.00033	1.56789 ± 0.00168	0.36183 ± 0.00053	0.56731 ± 0.00055	0.56579 ± 0.00054

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the finite square lattice systems composed of 44

fuel rods are listed in Tables A.2.14(1) to TA.2.14(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.2.14(1) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0, 44 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): νF/A_C ± 3σ	Ratio (5): A_C/(A_C+A_R) ± 3σ	Ratio (6)=(4)*(5): νF/(A_C+A_R) ± 3σ	Ratio (7): νF/(A_C+A_R+L) ± 3σ
3.75	0.32	0.97049 ± 0.00039	1.50557 ± 0.00116	0.64580 ± 0.00035	0.97230 ± 0.00074	0.97013 ± 0.00073
4.00	0.52	0.98189 ± 0.00038	1.48367 ± 0.00114	0.66301 ± 0.00033	0.98369 ± 0.00074	0.98168 ± 0.00074
4.175	0.67	0.98493 ± 0.00038	1.46488 ± 0.00113	0.67347 ± 0.00033	0.98655 ± 0.00075	0.98465 ± 0.00074
4.35	0.82	0.98375 ± 0.00037	1.44320 ± 0.00106	0.68275 ± 0.00031	0.98534 ± 0.00071	0.98355 ± 0.00071
4.50	0.96	0.98066 ± 0.00036	1.42306 ± 0.00109	0.69016 ± 0.00032	0.98214 ± 0.00074	0.98044 ± 0.00074
4.70	1.15	0.97308 ± 0.00034	1.39365 ± 0.00102	0.69924 ± 0.00031	0.97450 ± 0.00071	0.97292 ± 0.00071
5.00	1.46	0.95584 ± 0.00037	1.34536 ± 0.00097	0.71135 ± 0.00030	0.95702 ± 0.00069	0.95561 ± 0.00069
5.50	2.01	0.91438 ± 0.00035	1.25749 ± 0.00095	0.72797 ± 0.00029	0.91541 ± 0.00069	0.91424 ± 0.00068
6.00	2.61	0.86366 ± 0.00033	1.16531 ± 0.00087	0.74184 ± 0.00029	0.86448 ± 0.00065	0.86352 ± 0.00065
6.50	3.26	0.80813 ± 0.00033	1.07360 ± 0.00087	0.75336 ± 0.00028	0.80881 ± 0.00065	0.80802 ± 0.00065
7.00	3.96	0.75132 ± 0.00032	0.98519 ± 0.00079	0.76325 ± 0.00029	0.75194 ± 0.00060	0.75130 ± 0.00060

Table A.2.14(2) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0, 44 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): νF/A_C ± 3σ	Ratio (5): A_C/(A_C+A_R) ± 3σ	Ratio (6)=(4)*(5): νF/(A_C+A_R) ± 3σ	Ratio (7): νF/(A_C+A_R+L) ± 3σ
3.75	0.32	0.85847 ± 0.00040	1.53763 ± 0.00130	0.55969 ± 0.00041	0.86059 ± 0.00070	0.85823 ± 0.00070
4.00	0.52	0.82098 ± 0.00038	1.54024 ± 0.00143	0.53432 ± 0.00041	0.82299 ± 0.00071	0.82069 ± 0.00071
4.175	0.67	0.79722 ± 0.00036	1.54228 ± 0.00126	0.51819 ± 0.00041	0.79920 ± 0.00062	0.79695 ± 0.00062
4.35	0.82	0.77479 ± 0.00036	1.54431 ± 0.00137	0.50298 ± 0.00040	0.77676 ± 0.00064	0.77456 ± 0.00064
4.50	0.96	0.75697 ± 0.00039	1.54615 ± 0.00137	0.49078 ± 0.00043	0.75882 ± 0.00063	0.75667 ± 0.00063
4.70	1.15	0.73495 ± 0.00037	1.54834 ± 0.00143	0.47596 ± 0.00043	0.73695 ± 0.00063	0.73485 ± 0.00063
5.00	1.46	0.70460 ± 0.00036	1.55155 ± 0.00144	0.45531 ± 0.00044	0.70644 ± 0.00060	0.70442 ± 0.00060
5.50	2.01	0.66043 ± 0.00038	1.55625 ± 0.00161	0.42554 ± 0.00049	0.66225 ± 0.00062	0.66037 ± 0.00062
6.00	2.61	0.62274 ± 0.00035	1.56083 ± 0.00150	0.40003 ± 0.00048	0.62437 ± 0.00055	0.62261 ± 0.00055
6.50	3.26	0.58986 ± 0.00034	1.56502 ± 0.00157	0.37787 ± 0.00051	0.59137 ± 0.00054	0.58973 ± 0.00054
7.00	3.96	0.56051 ± 0.00035	1.56876 ± 0.00168	0.35817 ± 0.00053	0.56189 ± 0.00054	0.56035 ± 0.00054

Table A.2.14(3) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0u1, 44 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): νF/A_C ± 3σ	Ratio (5): A_C/(A_C+A_R) ± 3σ	Ratio (6)=(4)*(5): νF/(A_C+A_R) ± 3σ	Ratio (7): νF/(A_C+A_R+L) ± 3σ
3.75	0.32	0.97051 ± 0.00037	1.50570 ± 0.00111	0.64588 ± 0.00033	0.97250 ± 0.00070	0.97033 ± 0.00070
4.00	0.52	0.98169 ± 0.00036	1.48372 ± 0.00114	0.66283 ± 0.00032	0.98345 ± 0.00074	0.98143 ± 0.00073
4.175	0.67	0.98455 ± 0.00038	1.46486 ± 0.00113	0.67326 ± 0.00034	0.98624 ± 0.00075	0.98433 ± 0.00075
4.35	0.82	0.98386 ± 0.00038	1.44332 ± 0.00111	0.68273 ± 0.00032	0.98540 ± 0.00074	0.98360 ± 0.00074
4.50	0.96	0.98059 ± 0.00034	1.42310 ± 0.00109	0.69010 ± 0.00030	0.98207 ± 0.00073	0.98037 ± 0.00073
4.70	1.15	0.97315 ± 0.00038	1.39365 ± 0.00106	0.69927 ± 0.00032	0.97455 ± 0.00074	0.97297 ± 0.00073
5.00	1.46	0.95580 ± 0.00037	1.34544 ± 0.00097	0.71129 ± 0.00032	0.95699 ± 0.00070	0.95558 ± 0.00069
5.50	2.01	0.91450 ± 0.00034	1.25746 ± 0.00099	0.72804 ± 0.00029	0.91548 ± 0.00071	0.91432 ± 0.00071
6.00	2.61	0.86374 ± 0.00036	1.16552 ± 0.00091	0.74181 ± 0.00030	0.86459 ± 0.00067	0.86363 ± 0.00067
6.50	3.26	0.80810 ± 0.00034	1.07361 ± 0.00080	0.75335 ± 0.00028	0.80880 ± 0.00060	0.80801 ± 0.00060
7.00	3.96	0.75125 ± 0.00033	0.98516 ± 0.00082	0.76304 ± 0.00028	0.75172 ± 0.00062	0.75107 ± 0.00062

Table A.2.14(4) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0u1, 44 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.85836 ± 0.00038	1.53746 ± 0.00130	0.55965 ± 0.00038	0.86044 ± 0.00070	0.85807 ± 0.00069
4.00	0.52	0.82102 ± 0.00037	1.54038 ± 0.00125	0.53431 ± 0.00039	0.82304 ± 0.00064	0.82073 ± 0.00064
4.175	0.67	0.79712 ± 0.00039	1.54239 ± 0.00131	0.51810 ± 0.00041	0.79911 ± 0.00065	0.79686 ± 0.00064
4.35	0.82	0.77504 ± 0.00038	1.54448 ± 0.00143	0.50317 ± 0.00042	0.77714 ± 0.00067	0.77493 ± 0.00067
4.50	0.96	0.75697 ± 0.00040	1.54603 ± 0.00154	0.49082 ± 0.00044	0.75882 ± 0.00070	0.75666 ± 0.00069
4.70	1.15	0.73529 ± 0.00038	1.54826 ± 0.00143	0.47614 ± 0.00044	0.73719 ± 0.00063	0.73508 ± 0.00063
5.00	1.46	0.70456 ± 0.00038	1.55159 ± 0.00143	0.45529 ± 0.00045	0.70642 ± 0.00061	0.70440 ± 0.00061
5.50	2.01	0.66061 ± 0.00036	1.55635 ± 0.00150	0.42554 ± 0.00046	0.66229 ± 0.00058	0.66041 ± 0.00058
6.00	2.61	0.62287 ± 0.00034	1.56087 ± 0.00162	0.40004 ± 0.00050	0.62441 ± 0.00059	0.62265 ± 0.00058
6.50	3.26	0.58983 ± 0.00034	1.56503 ± 0.00162	0.37786 ± 0.00052	0.59137 ± 0.00056	0.58972 ± 0.00055
7.00	3.96	0.56055 ± 0.00033	1.56891 ± 0.00163	0.35827 ± 0.00051	0.56210 ± 0.00052	0.56056 ± 0.00052

(8) Finite square lattice system composed of 40 fuel rods

The results of numerical data calculated using the JENDL-5 library for the finite square lattice systems composed of 40 fuel rods are listed in Tables A.2.15(1) to A.2.15(7). The densities of the moderator water were set to be in the range of 100 to 0 %.

Table A.2.15(1) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.95316 ± 0.00038	1.50496 ± 0.00127	0.63465 ± 0.00034	0.95511 ± 0.00077	0.95307 ± 0.00077
4.00	0.52	0.96470 ± 0.00040	1.48283 ± 0.00120	0.65174 ± 0.00034	0.96642 ± 0.00076	0.96453 ± 0.00076
4.175	0.67	0.96830 ± 0.00040	1.46422 ± 0.00123	0.66231 ± 0.00034	0.96976 ± 0.00079	0.96798 ± 0.00079
4.35	0.82	0.96789 ± 0.00036	1.44304 ± 0.00106	0.67178 ± 0.00031	0.96940 ± 0.00070	0.96772 ± 0.00069
4.50	0.96	0.96491 ± 0.00037	1.42299 ± 0.00114	0.67907 ± 0.00033	0.96632 ± 0.00076	0.96473 ± 0.00076
4.70	1.15	0.95785 ± 0.00037	1.39389 ± 0.00107	0.68811 ± 0.00032	0.95915 ± 0.00072	0.95767 ± 0.00072
5.00	1.46	0.94204 ± 0.00037	1.34655 ± 0.00097	0.70047 ± 0.00032	0.94322 ± 0.00069	0.94190 ± 0.00068
5.50	2.01	0.90345 ± 0.00036	1.26045 ± 0.00099	0.71758 ± 0.00030	0.90448 ± 0.00071	0.90339 ± 0.00070
6.00	2.61	0.85549 ± 0.00035	1.17025 ± 0.00091	0.73167 ± 0.00029	0.85624 ± 0.00066	0.85535 ± 0.00066
6.50	3.26	0.80255 ± 0.00033	1.08032 ± 0.00084	0.74345 ± 0.00029	0.80316 ± 0.00062	0.80243 ± 0.00062
7.00	3.96	0.74807 ± 0.00033	0.99326 ± 0.00084	0.75358 ± 0.00030	0.74850 ± 0.00063	0.74790 ± 0.00063

Table A.2.15(2) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 90 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.94478 ± 0.00039	1.50873 ± 0.00123	0.62729 ± 0.00036	0.94642 ± 0.00075	0.94436 ± 0.00074
4.00	0.52	0.95383 ± 0.00037	1.48980 ± 0.00120	0.64135 ± 0.00033	0.95548 ± 0.00074	0.95355 ± 0.00074
4.175	0.67	0.95655 ± 0.00040	1.47373 ± 0.00113	0.65024 ± 0.00037	0.95828 ± 0.00074	0.95644 ± 0.00073
4.35	0.82	0.95651 ± 0.00039	1.45537 ± 0.00122	0.65823 ± 0.00034	0.95797 ± 0.00078	0.95625 ± 0.00078
4.50	0.96	0.95424 ± 0.00037	1.43803 ± 0.00105	0.66459 ± 0.00033	0.95570 ± 0.00069	0.95406 ± 0.00069
4.70	1.15	0.94846 ± 0.00037	1.41252 ± 0.00113	0.67242 ± 0.00033	0.94980 ± 0.00074	0.94827 ± 0.00074
5.00	1.46	0.93533 ± 0.00033	1.37050 ± 0.00099	0.68324 ± 0.00030	0.93638 ± 0.00067	0.93500 ± 0.00067
5.50	2.01	0.90207 ± 0.00037	1.29295 ± 0.00097	0.69845 ± 0.00031	0.90306 ± 0.00068	0.90189 ± 0.00068
6.00	2.61	0.86001 ± 0.00035	1.21043 ± 0.00099	0.71120 ± 0.00031	0.86086 ± 0.00070	0.85989 ± 0.00070
6.50	3.26	0.81312 ± 0.00034	1.12652 ± 0.00092	0.72243 ± 0.00031	0.81384 ± 0.00066	0.81304 ± 0.00066
7.00	3.96	0.76322 ± 0.00033	1.04363 ± 0.00088	0.73180 ± 0.00030	0.76372 ± 0.00064	0.76306 ± 0.00064

Table A.2.15(3) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 80 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.93559 ± 0.00040	1.51235 ± 0.00122	0.61981 ± 0.00036	0.93737 ± 0.00074	0.93528 ± 0.00074
4.00	0.52	0.94200 ± 0.00038	1.49646 ± 0.00110	0.63065 ± 0.00034	0.94374 ± 0.00068	0.94179 ± 0.00068
4.175	0.67	0.94374 ± 0.00036	1.48294 ± 0.00119	0.63758 ± 0.00034	0.94549 ± 0.00074	0.94362 ± 0.00074
4.35	0.82	0.94292 ± 0.00034	1.46725 ± 0.00107	0.64376 ± 0.00031	0.94455 ± 0.00067	0.94278 ± 0.00067
4.50	0.96	0.94106 ± 0.00039	1.45247 ± 0.00117	0.64899 ± 0.00035	0.94263 ± 0.00074	0.94093 ± 0.00074
4.70	1.15	0.93635 ± 0.00037	1.43060 ± 0.00115	0.65547 ± 0.00035	0.93771 ± 0.00074	0.93612 ± 0.00074
5.00	1.46	0.92488 ± 0.00035	1.39428 ± 0.00106	0.66427 ± 0.00032	0.92618 ± 0.00069	0.92472 ± 0.00069
5.50	2.01	0.89690 ± 0.00036	1.32572 ± 0.00105	0.67738 ± 0.00032	0.89801 ± 0.00070	0.89677 ± 0.00070
6.00	2.61	0.86060 ± 0.00034	1.25153 ± 0.00095	0.68835 ± 0.00030	0.86149 ± 0.00064	0.86044 ± 0.00064
6.50	3.26	0.81953 ± 0.00034	1.17445 ± 0.00092	0.69849 ± 0.00031	0.82033 ± 0.00064	0.81944 ± 0.00064
7.00	3.96	0.77520 ± 0.00034	1.09716 ± 0.00085	0.70712 ± 0.00031	0.77583 ± 0.00060	0.77508 ± 0.00060

Table A.2.15(4) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 60 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.91598 ± 0.00037	1.51916 ± 0.00123	0.60416 ± 0.00037	0.91782 ± 0.00072	0.91569 ± 0.00072
4.00	0.52	0.91477 ± 0.00037	1.50878 ± 0.00122	0.60742 ± 0.00037	0.91647 ± 0.00072	0.91446 ± 0.00072
4.175	0.67	0.91291 ± 0.00036	1.49986 ± 0.00121	0.60982 ± 0.00035	0.91465 ± 0.00071	0.91272 ± 0.00071
4.35	0.82	0.90993 ± 0.00036	1.48949 ± 0.00115	0.61207 ± 0.00035	0.91167 ± 0.00068	0.90980 ± 0.00068
4.50	0.96	0.90704 ± 0.00038	1.47960 ± 0.00119	0.61411 ± 0.00036	0.90864 ± 0.00071	0.90684 ± 0.00071
4.70	1.15	0.90184 ± 0.00038	1.46465 ± 0.00112	0.61677 ± 0.00035	0.90335 ± 0.00068	0.90163 ± 0.00068
5.00	1.46	0.89221 ± 0.00036	1.43934 ± 0.00115	0.62077 ± 0.00035	0.89350 ± 0.00070	0.89191 ± 0.00070
5.50	2.01	0.87115 ± 0.00036	1.39043 ± 0.00106	0.62745 ± 0.00034	0.87242 ± 0.00065	0.87103 ± 0.00065
6.00	2.61	0.84460 ± 0.00037	1.33459 ± 0.00111	0.63368 ± 0.00035	0.84571 ± 0.00068	0.84448 ± 0.00068
6.50	3.26	0.81426 ± 0.00035	1.27456 ± 0.00105	0.63959 ± 0.00034	0.81520 ± 0.00066	0.81413 ± 0.00066
7.00	3.96	0.78138 ± 0.00034	1.21211 ± 0.00095	0.64529 ± 0.00032	0.78216 ± 0.00060	0.78123 ± 0.00060

Table A.2.15(5) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 40 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.89326 ± 0.00038	1.52529 ± 0.00123	0.58693 ± 0.00036	0.89524 ± 0.00070	0.89308 ± 0.00069
4.00	0.52	0.88213 ± 0.00040	1.51964 ± 0.00129	0.58172 ± 0.00039	0.88401 ± 0.00072	0.88195 ± 0.00072
4.175	0.67	0.87497 ± 0.00038	1.51478 ± 0.00117	0.57877 ± 0.00037	0.87672 ± 0.00066	0.87471 ± 0.00066
4.35	0.82	0.86750 ± 0.00037	1.50927 ± 0.00128	0.57597 ± 0.00038	0.86930 ± 0.00070	0.86736 ± 0.00070
4.50	0.96	0.86129 ± 0.00040	1.50374 ± 0.00122	0.57389 ± 0.00040	0.86298 ± 0.00068	0.86108 ± 0.00068
4.70	1.15	0.85341 ± 0.00038	1.49532 ± 0.00126	0.57180 ± 0.00037	0.85502 ± 0.00069	0.85320 ± 0.00069
5.00	1.46	0.84079 ± 0.00037	1.48066 ± 0.00115	0.56884 ± 0.00038	0.84226 ± 0.00063	0.84054 ± 0.00063
5.50	2.01	0.81955 ± 0.00038	1.45114 ± 0.00122	0.56573 ± 0.00038	0.82096 ± 0.00066	0.81940 ± 0.00066
6.00	2.61	0.79741 ± 0.00036	1.41618 ± 0.00119	0.56398 ± 0.00038	0.79869 ± 0.00064	0.79729 ± 0.00064
6.50	3.26	0.77407 ± 0.00038	1.37655 ± 0.00114	0.56307 ± 0.00041	0.77509 ± 0.00063	0.77383 ± 0.00063
7.00	3.96	0.74983 ± 0.00036	1.33376 ± 0.00115	0.56303 ± 0.00038	0.75095 ± 0.00062	0.74980 ± 0.00062

Table A.2.15(6) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 20 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.86848 ± 0.00038	1.53093 ± 0.00125	0.56863 ± 0.00040	0.87054 ± 0.00069	0.86834 ± 0.00069
4.00	0.52	0.84512 ± 0.00038	1.52958 ± 0.00130	0.55373 ± 0.00039	0.84698 ± 0.00068	0.84486 ± 0.00068
4.175	0.67	0.83031 ± 0.00038	1.52830 ± 0.00124	0.54449 ± 0.00039	0.83215 ± 0.00065	0.83009 ± 0.00065
4.35	0.82	0.81603 ± 0.00039	1.52660 ± 0.00141	0.53563 ± 0.00042	0.81770 ± 0.00071	0.81569 ± 0.00071
4.50	0.96	0.80465 ± 0.00036	1.52504 ± 0.00135	0.52880 ± 0.00039	0.80645 ± 0.00067	0.80449 ± 0.00067
4.70	1.15	0.79013 ± 0.00037	1.52231 ± 0.00129	0.52015 ± 0.00041	0.79183 ± 0.00064	0.78993 ± 0.00064
5.00	1.46	0.77048 ± 0.00036	1.51742 ± 0.00128	0.50884 ± 0.00041	0.77213 ± 0.00062	0.77033 ± 0.00062
5.50	2.01	0.74065 ± 0.00037	1.50621 ± 0.00138	0.49268 ± 0.00044	0.74208 ± 0.00064	0.74042 ± 0.00064
6.00	2.61	0.71393 ± 0.00035	1.49186 ± 0.00132	0.47954 ± 0.00044	0.71541 ± 0.00060	0.71387 ± 0.00060
6.50	3.26	0.68962 ± 0.00035	1.47468 ± 0.00130	0.46848 ± 0.00044	0.69086 ± 0.00058	0.68943 ± 0.00058
7.00	3.96	0.66679 ± 0.00035	1.45471 ± 0.00133	0.45912 ± 0.00043	0.66789 ± 0.00057	0.66658 ± 0.00057

Table A.2.15(7) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-5, 40 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective with 3σ	Ratio (4): $\nu F/A_C$ with 3σ	Ratio (5): $A_C/(A_C+A_R)$ with 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ with 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.84197 ± 0.00038	1.53683 ± 0.00130	0.54914 ± 0.00040	0.84394 ± 0.00069	0.84172 ± 0.00069
4.00	0.52	0.80524 ± 0.00038	1.53966 ± 0.00132	0.52423 ± 0.00041	0.80713 ± 0.00065	0.80498 ± 0.00065
4.175	0.67	0.78190 ± 0.00036	1.54176 ± 0.00131	0.50840 ± 0.00042	0.78384 ± 0.00063	0.78173 ± 0.00063
4.35	0.82	0.75992 ± 0.00038	1.54360 ± 0.00137	0.49348 ± 0.00044	0.76174 ± 0.00064	0.75969 ± 0.00064
4.50	0.96	0.74292 ± 0.00037	1.54548 ± 0.00137	0.48188 ± 0.00044	0.74473 ± 0.00062	0.74272 ± 0.00062
4.70	1.15	0.72169 ± 0.00038	1.54790 ± 0.00138	0.46735 ± 0.00044	0.72341 ± 0.00060	0.72145 ± 0.00060
5.00	1.46	0.69207 ± 0.00036	1.55106 ± 0.00144	0.44728 ± 0.00047	0.69375 ± 0.00060	0.69188 ± 0.00060
5.50	2.01	0.65009 ± 0.00036	1.55630 ± 0.00155	0.41873 ± 0.00047	0.65167 ± 0.00059	0.64993 ± 0.00059
6.00	2.61	0.61404 ± 0.00035	1.56085 ± 0.00156	0.39439 ± 0.00049	0.61559 ± 0.00056	0.61396 ± 0.00056
6.50	3.26	0.58249 ± 0.00035	1.56497 ± 0.00162	0.37309 ± 0.00050	0.58387 ± 0.00054	0.58235 ± 0.00054
7.00	3.96	0.55430 ± 0.00033	1.56897 ± 0.00162	0.35413 ± 0.00052	0.55562 ± 0.00052	0.55420 ± 0.00052

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries for the finite square lattice systems composed of 40

fuel rods are listed in Tables A.2.16(1) to A.2.16(4). The densities of the moderator water were set to be 100 and 0 %.

Table A.2.16(1) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0, 40 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.94706 ± 0.00040	1.50614 ± 0.00127	0.63001 ± 0.00036	0.94888 ± 0.00078	0.94681 ± 0.00077
4.00	0.52	0.95914 ± 0.00037	1.48391 ± 0.00109	0.64748 ± 0.00034	0.96080 ± 0.00070	0.95889 ± 0.00070
4.175	0.67	0.96279 ± 0.00037	1.46493 ± 0.00113	0.65833 ± 0.00032	0.96440 ± 0.00072	0.96258 ± 0.00072
4.35	0.82	0.96282 ± 0.00039	1.44348 ± 0.00110	0.66803 ± 0.00033	0.96429 ± 0.00073	0.96258 ± 0.00073
4.50	0.96	0.96027 ± 0.00037	1.42306 ± 0.00109	0.67575 ± 0.00031	0.96163 ± 0.00072	0.96002 ± 0.00072
4.70	1.15	0.95375 ± 0.00037	1.39366 ± 0.00101	0.68520 ± 0.00033	0.95494 ± 0.00069	0.95344 ± 0.00069
5.00	1.46	0.93769 ± 0.00034	1.34529 ± 0.00102	0.69777 ± 0.00031	0.93870 ± 0.00070	0.93736 ± 0.00070
5.50	2.01	0.89853 ± 0.00034	1.25747 ± 0.00099	0.71533 ± 0.00031	0.89951 ± 0.00070	0.89840 ± 0.00070
6.00	2.61	0.85002 ± 0.00038	1.16546 ± 0.00099	0.73006 ± 0.00032	0.85086 ± 0.00072	0.84996 ± 0.00072
6.50	3.26	0.79615 ± 0.00032	1.07371 ± 0.00087	0.74214 ± 0.00030	0.79685 ± 0.00064	0.79610 ± 0.00064
7.00	3.96	0.74109 ± 0.00033	0.98528 ± 0.00079	0.75265 ± 0.00028	0.74157 ± 0.00059	0.74096 ± 0.00059

Table A.2.16(2) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0, 40 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.83519 ± 0.00037	1.53824 ± 0.00130	0.54428 ± 0.00040	0.83724 ± 0.00068	0.83499 ± 0.00068
4.00	0.52	0.79871 ± 0.00039	1.54103 ± 0.00136	0.51959 ± 0.00043	0.80070 ± 0.00067	0.79854 ± 0.00067
4.175	0.67	0.77564 ± 0.00037	1.54306 ± 0.00143	0.50385 ± 0.00042	0.77747 ± 0.00067	0.77535 ± 0.00067
4.35	0.82	0.75405 ± 0.00035	1.54511 ± 0.00143	0.48923 ± 0.00043	0.75591 ± 0.00065	0.75384 ± 0.00065
4.50	0.96	0.73707 ± 0.00039	1.54684 ± 0.00143	0.47771 ± 0.00043	0.73894 ± 0.00063	0.73692 ± 0.00063
4.70	1.15	0.71581 ± 0.00039	1.54911 ± 0.00148	0.46326 ± 0.00046	0.71765 ± 0.00064	0.71568 ± 0.00064
5.00	1.46	0.68636 ± 0.00038	1.55231 ± 0.00143	0.44327 ± 0.00046	0.68810 ± 0.00059	0.68622 ± 0.00059
5.50	2.01	0.64461 ± 0.00037	1.55734 ± 0.00161	0.41494 ± 0.00050	0.64621 ± 0.00061	0.64445 ± 0.00061
6.00	2.61	0.60860 ± 0.00037	1.56173 ± 0.00167	0.39067 ± 0.00051	0.61013 ± 0.00059	0.60849 ± 0.00059
6.50	3.26	0.57722 ± 0.00034	1.56629 ± 0.00162	0.36947 ± 0.00052	0.57869 ± 0.00054	0.57716 ± 0.00054
7.00	3.96	0.54945 ± 0.00034	1.56991 ± 0.00163	0.35082 ± 0.00053	0.55075 ± 0.00051	0.54931 ± 0.00051

Table A.2.16(3) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0u1, 40 fuel rods, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.94741 ± 0.00036	1.50611 ± 0.00111	0.63026 ± 0.00035	0.94924 ± 0.00069	0.94717 ± 0.00069
4.00	0.52	0.95925 ± 0.00040	1.48378 ± 0.00119	0.64762 ± 0.00036	0.96093 ± 0.00076	0.95902 ± 0.00076
4.175	0.67	0.96273 ± 0.00038	1.46497 ± 0.00117	0.65833 ± 0.00033	0.96443 ± 0.00075	0.96263 ± 0.00075
4.35	0.82	0.96270 ± 0.00039	1.44345 ± 0.00116	0.66802 ± 0.00034	0.96425 ± 0.00076	0.96254 ± 0.00076
4.50	0.96	0.96038 ± 0.00037	1.42314 ± 0.00109	0.67579 ± 0.00032	0.96174 ± 0.00072	0.96013 ± 0.00072
4.70	1.15	0.95342 ± 0.00036	1.39360 ± 0.00106	0.68503 ± 0.00031	0.95466 ± 0.00071	0.95316 ± 0.00071
5.00	1.46	0.93750 ± 0.00035	1.34532 ± 0.00102	0.69763 ± 0.00032	0.93853 ± 0.00071	0.93719 ± 0.00071
5.50	2.01	0.89867 ± 0.00032	1.25751 ± 0.00094	0.71541 ± 0.00030	0.89963 ± 0.00067	0.89852 ± 0.00067
6.00	2.61	0.85014 ± 0.00036	1.16547 ± 0.00095	0.73009 ± 0.00031	0.85090 ± 0.00069	0.85000 ± 0.00069
6.50	3.26	0.79611 ± 0.00033	1.07362 ± 0.00087	0.74211 ± 0.00029	0.79674 ± 0.00064	0.79600 ± 0.00064
7.00	3.96	0.74139 ± 0.00033	0.98530 ± 0.00076	0.75299 ± 0.00028	0.74192 ± 0.00057	0.74131 ± 0.00057

Table A.2.16(4) Effective neutron multiplication factor and ratio of reactions for finite square lattice systems, using JENDL-4.0u1, 40 fuel rods, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
3.75	0.32	0.83508 ± 0.00039	1.53819 ± 0.00125	0.54416 ± 0.00042	0.83702 ± 0.00066	0.83479 ± 0.00066
4.00	0.52	0.79883 ± 0.00038	1.54104 ± 0.00137	0.51959 ± 0.00040	0.80071 ± 0.00067	0.79854 ± 0.00066
4.175	0.67	0.77544 ± 0.00038	1.54304 ± 0.00137	0.50382 ± 0.00042	0.77742 ± 0.00065	0.77529 ± 0.00065
4.35	0.82	0.75417 ± 0.00039	1.54504 ± 0.00142	0.48940 ± 0.00045	0.75614 ± 0.00066	0.75408 ± 0.00065
4.50	0.96	0.73707 ± 0.00038	1.54683 ± 0.00154	0.47773 ± 0.00046	0.73897 ± 0.00068	0.73695 ± 0.00068
4.70	1.15	0.71545 ± 0.00037	1.54900 ± 0.00148	0.46297 ± 0.00045	0.71714 ± 0.00064	0.71518 ± 0.00063
5.00	1.46	0.68649 ± 0.00037	1.55255 ± 0.00144	0.44327 ± 0.00045	0.68820 ± 0.00059	0.68632 ± 0.00059
5.50	2.01	0.64436 ± 0.00036	1.55747 ± 0.00161	0.41480 ± 0.00050	0.64604 ± 0.00061	0.64428 ± 0.00061
6.00	2.61	0.60846 ± 0.00034	1.56174 ± 0.00156	0.39055 ± 0.00050	0.60994 ± 0.00056	0.60830 ± 0.00055
6.50	3.26	0.57709 ± 0.00035	1.56616 ± 0.00167	0.36946 ± 0.00053	0.57864 ± 0.00056	0.57710 ± 0.00056
7.00	3.96	0.54922 ± 0.00034	1.57011 ± 0.00174	0.35068 ± 0.00056	0.55061 ± 0.00055	0.54917 ± 0.00055

Appendix-3 Numerical Data Tables of Finite Lattice Systems for Search on Criticality under No Moderator Water Condition

The results of numerical data calculated using the JENDL-5 library for the criticality search on the finite hexagonal lattice systems containing no moderator water under the water-reflected and no-water-reflected conditions are listed in Tables A.3.1(1) and A.3.1(2), respectively. The densities of the moderator water were set to be 0 %. For the no-water-reflected-condition, the water reflector was replaced with void. The lattice pitch was fixed to be the minimum value as 3.75 cm (VR=0.12) whilst the number of fuel rods was changed in the range of 61 to 217 rods.

It is found that there are large discrepancies between the values of Ratio(6) and those of effective neutron multiplication factors (k_{eff}'s) in the case of the no-water-reflected condition due to the effect of the neutron leakage from the systems even though the values of k_{eff}'s and their variation with the number of fuel rods under the water-reflected condition can be reproduced by Ratio(6) to some extent. It is also seen that the values of k_{eff}'s under the no-water-reflected condition well agree with the values of Ratio(7) in which the neutron leakage is taken into account.

Table A.3.1(1) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, water-reflected, using JENDL-5.

The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
61	0.97862 ± 0.00037	1.52714 ± 0.00124	0.64263 ± 0.00033	0.98139 ± 0.00077	0.97817 ± 0.00076
91	1.05922 ± 0.00038	1.52440 ± 0.00118	0.69646 ± 0.00032	1.06168 ± 0.00081	1.05893 ± 0.00081
127	1.11866 ± 0.00039	1.52224 ± 0.00112	0.73617 ± 0.00030	1.12062 ± 0.00082	1.11827 ± 0.00082
169	1.16353 ± 0.00036	1.52085 ± 0.00106	0.76598 ± 0.00027	1.16493 ± 0.00081	1.16291 ± 0.00081
217	1.19784 ± 0.00036	1.51983 ± 0.00101	0.78900 ± 0.00027	1.19914 ± 0.00080	1.19741 ± 0.00080

Table A.3.1(2) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, no-water-reflected, using JENDL-5.

The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
61	0.81001 ± 0.00036	1.49279 ± 0.00127	0.98878 ± 0.00005	1.47604 ± 0.00125	0.80971 ± 0.00060
91	0.93636 ± 0.00036	1.49871 ± 0.00121	0.98627 ± 0.00006	1.47814 ± 0.00119	0.93589 ± 0.00068
127	1.02693 ± 0.00041	1.50206 ± 0.00121	0.98424 ± 0.00007	1.47839 ± 0.00119	1.02627 ± 0.00075
169	1.09362 ± 0.00036	1.50435 ± 0.00111	0.98256 ± 0.00006	1.47811 ± 0.00109	1.09285 ± 0.00074
217	1.14375 ± 0.00034	1.50600 ± 0.00110	0.98120 ± 0.00007	1.47768 ± 0.00108	1.14289 ± 0.00078

Tables A.3.2(1) and A.3.2(2) list the results of numerical data calculated using the JENDL-5 library in the case that the axial graphite reflector was replaced with void in order to confirm reactivity effect by the graphite reflector. It is seen that the negative reactivity in the range of -0.032 to -0.022 $\Delta k_{eff}/k_{eff}$ is added by the replacement.

Table A.3.2(1) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, water-reflected, using JENDL-5, axial graphite reflector replaced with void.

Lattice pitch (cm)	The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	Replacement of graphite with void: $\Delta k_{eff}/k_{eff}$ ± 3σ
3.75	61	0.95733 ± 0.00038	1.52686 ± 0.00124	0.62888 ± 0.00035	0.96022 ± 0.00075	0.95695 ± 0.00075	-0.02175 ± 0.00054
3.75	91	1.03426 ± 0.00041	1.52384 ± 0.00117	0.68033 ± 0.00034	1.03671 ± 0.00079	1.03388 ± 0.00079	-0.02356 ± 0.00053
3.75	127	1.09079 ± 0.00038	1.52180 ± 0.00118	0.71817 ± 0.00031	1.09292 ± 0.00083	1.09046 ± 0.00083	-0.02491 ± 0.00048
3.75	169	1.13326 ± 0.00038	1.52030 ± 0.00117	0.74651 ± 0.00030	1.13491 ± 0.00087	1.13278 ± 0.00086	-0.02602 ± 0.00045
3.75	217	1.16630 ± 0.00037	1.51913 ± 0.00112	0.76870 ± 0.00028	1.16776 ± 0.00085	1.16588 ± 0.00085	-0.02633 ± 0.00042

Table A.3.2(2) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, no-water-reflected, using JENDL-5, axial graphite reflector replaced with void.

Lattice pitch (cm)	The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	Replacement of graphite with void: $\Delta k_{eff}/k_{eff}$ ± 3σ
3.75	61	0.79209 ± 0.00037	1.49204 ± 0.00137	0.99116 ± 0.00005	1.47885 ± 0.00135	0.79150 ± 0.00063	-0.02212 ± 0.00063
3.75	91	0.91164 ± 0.00035	1.49759 ± 0.00121	0.98938 ± 0.00005	1.48169 ± 0.00120	0.91110 ± 0.00066	-0.02640 ± 0.00053
3.75	127	0.99787 ± 0.00035	1.50107 ± 0.00118	0.98794 ± 0.00005	1.48297 ± 0.00116	0.99722 ± 0.00070	-0.02830 ± 0.00052
3.75	169	1.06072 ± 0.00035	1.50326 ± 0.00111	0.98657 ± 0.00005	1.48308 ± 0.00109	1.05997 ± 0.00071	-0.03008 ± 0.00045
3.75	217	1.10782 ± 0.00037	1.50448 ± 0.00116	0.98544 ± 0.00005	1.48257 ± 0.00114	1.10689 ± 0.00079	-0.03141 ± 0.00043

For reference, the results of numerical data calculated using the JENDL-4.0 and JENDL-4.0u1 libraries are listed in Tables A.3.3(1) to Table A.3.3(8).

Table A.3.3(1) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, water-reflected, using JENDL-4.0.

The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
61	0.97164 ± 0.00038	1.52867 ± 0.00118	0.63744 ± 0.00035	0.97444 ± 0.00074	0.97121 ± 0.00073
91	1.05228 ± 0.00039	1.52558 ± 0.00118	0.69131 ± 0.00033	1.05466 ± 0.00080	1.05190 ± 0.00080
127	1.11229 ± 0.00036	1.52368 ± 0.00112	0.73133 ± 0.00029	1.11432 ± 0.00081	1.11196 ± 0.00081
169	1.15737 ± 0.00037	1.52230 ± 0.00108	0.76133 ± 0.00028	1.15897 ± 0.00081	1.15695 ± 0.00081
217	1.19240 ± 0.00036	1.52110 ± 0.00101	0.78470 ± 0.00027	1.19360 ± 0.00080	1.19184 ± 0.00080

Table A.3.3(2) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, no-water-reflected, using JENDL-4.0.

The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
61	0.79806 ± 0.00037	1.49389 ± 0.00132	0.98855 ± 0.00006	1.47678 ± 0.00130	0.79768 ± 0.00061
91	0.92529 ± 0.00035	1.49972 ± 0.00121	0.98599 ± 0.00006	1.47872 ± 0.00119	0.92464 ± 0.00067
127	1.01696 ± 0.00037	1.50323 ± 0.00121	0.98395 ± 0.00007	1.47911 ± 0.00119	1.01640 ± 0.00074
169	1.08496 ± 0.00034	1.50544 ± 0.00111	0.98227 ± 0.00007	1.47875 ± 0.00108	1.08418 ± 0.00073
217	1.13585 ± 0.00035	1.50719 ± 0.00110	0.98091 ± 0.00007	1.47841 ± 0.00108	1.13520 ± 0.00077

Table A.3.3(3) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, water-reflected, using JENDL-4.0u1.

The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
61	0.97163 ± 0.00042	1.52864 ± 0.00129	0.63761 ± 0.00037	0.97467 ± 0.00080	0.97145 ± 0.00080
91	1.05223 ± 0.00040	1.52566 ± 0.00113	0.69122 ± 0.00033	1.05457 ± 0.00077	1.05180 ± 0.00077
127	1.11215 ± 0.00040	1.52370 ± 0.00112	0.73127 ± 0.00032	1.11423 ± 0.00082	1.11188 ± 0.00082
169	1.15757 ± 0.00039	1.52219 ± 0.00106	0.76147 ± 0.00029	1.15910 ± 0.00081	1.15707 ± 0.00081
217	1.19221 ± 0.00036	1.52116 ± 0.00101	0.78459 ± 0.00027	1.19350 ± 0.00080	1.19174 ± 0.00080

Table A.3.3(4) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, no-water-reflected, using JENDL-4.0u1.

The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ
61	0.79819 ± 0.00038	1.49394 ± 0.00132	0.98856 ± 0.00005	1.47686 ± 0.00130	0.79777 ± 0.00061
91	0.92518 ± 0.00038	1.49960 ± 0.00126	0.98604 ± 0.00006	1.47866 ± 0.00124	0.92464 ± 0.00070
127	1.01700 ± 0.00037	1.50322 ± 0.00116	0.98392 ± 0.00007	1.47904 ± 0.00114	1.01641 ± 0.00071
169	1.08495 ± 0.00036	1.50542 ± 0.00116	0.98224 ± 0.00006	1.47869 ± 0.00114	1.08415 ± 0.00077
217	1.13578 ± 0.00034	1.50704 ± 0.00100	0.98086 ± 0.00006	1.47820 ± 0.00098	1.13492 ± 0.00070

Table A.3.3(5) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, water-reflected, using JENDL-4.0, axial graphite reflector replaced with void.

Lattice pitch (cm)	The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	Effect by lack of axial graphite: $\Delta k_{eff}/k_{eff}$ ± 3σ
3.75	61	0.95016 ± 0.00038	1.52840 ± 0.00124	0.62356 ± 0.00034	0.95305 ± 0.00074	0.94979 ± 0.00074	-0.02211 ± 0.00054
3.75	91	1.02725 ± 0.00037	1.52527 ± 0.00112	0.67516 ± 0.00032	1.02980 ± 0.00075	1.02697 ± 0.00075	-0.02379 ± 0.00050
3.75	127	1.08398 ± 0.00041	1.52318 ± 0.00113	0.71305 ± 0.00033	1.08611 ± 0.00080	1.08365 ± 0.00080	-0.02545 ± 0.00048
3.75	169	1.12672 ± 0.00039	1.52162 ± 0.00112	0.74175 ± 0.00030	1.12866 ± 0.00083	1.12651 ± 0.00083	-0.02648 ± 0.00046
3.75	217	1.15991 ± 0.00039	1.52040 ± 0.00103	0.76381 ± 0.00029	1.16130 ± 0.00079	1.15940 ± 0.00079	-0.02725 ± 0.00044

Table A.3.3(6) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, no-water-reflected, using JENDL-4.0, axial graphite reflector replaced with void.

Lattice pitch (cm)	The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	Effect by lack of axial graphite: $\Delta k_{eff}/k_{eff}$ ± 3σ
3.75	61	0.77943 ± 0.00036	1.49288 ± 0.00132	0.99094 ± 0.00005	1.47935 ± 0.00130	0.77877 ± 0.00060	-0.02335 ± 0.00064
3.75	91	0.90055 ± 0.00036	1.49880 ± 0.00127	0.98916 ± 0.00005	1.48255 ± 0.00125	0.89986 ± 0.00068	-0.02674 ± 0.00053
3.75	127	0.98695 ± 0.00036	1.50198 ± 0.00116	0.98761 ± 0.00005	1.48338 ± 0.00115	0.98619 ± 0.00069	-0.02951 ± 0.00050
3.75	169	1.05087 ± 0.00037	1.50423 ± 0.00111	0.98626 ± 0.00006	1.48357 ± 0.00109	1.05013 ± 0.00071	-0.03142 ± 0.00045
3.75	217	1.09895 ± 0.00037	1.50581 ± 0.00111	0.98507 ± 0.00006	1.48333 ± 0.00109	1.09805 ± 0.00074	-0.03249 ± 0.00044

Table A.3.3(7) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, water-reflected, using JENDL-4.0u1, axial graphite reflector replaced with void.

Lattice pitch (cm)	The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	Effect by lack of axial graphite: $\Delta k_{eff}/k_{eff}$ ± 3σ
3.75	61	0.94974 ± 0.00039	1.52826 ± 0.00124	0.62335 ± 0.00035	0.95264 ± 0.00075	0.94949 ± 0.00074	-0.02253 ± 0.00058
3.75	91	1.02661 ± 0.00038	1.52515 ± 0.00113	0.67477 ± 0.00032	1.02913 ± 0.00075	1.02643 ± 0.00075	-0.02435 ± 0.00052
3.75	127	1.08384 ± 0.00040	1.52311 ± 0.00113	0.71293 ± 0.00032	1.08586 ± 0.00080	1.08357 ± 0.00080	-0.02546 ± 0.00051
3.75	169	1.12651 ± 0.00039	1.52161 ± 0.00112	0.74144 ± 0.00032	1.12818 ± 0.00084	1.12620 ± 0.00083	-0.02683 ± 0.00047
3.75	217	1.16002 ± 0.00038	1.52042 ± 0.00107	0.76383 ± 0.00028	1.16134 ± 0.00081	1.15963 ± 0.00081	-0.02700 ± 0.00043

Table A.3.3(8) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems under no moderator water condition, no-water-reflected, using JENDL-4.0u1, axial graphite reflector replaced with void.

Lattice pitch (cm)	The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	Effect by lack of axial graphite: $\Delta k_{eff}/k_{eff}$ ± 3σ
3.75	61	0.77922 ± 0.00034	1.49288 ± 0.00132	0.99093 ± 0.00005	1.47934 ± 0.00131	0.78956 ± 0.00061	-0.02376 ± 0.00063
3.75	91	0.90044 ± 0.00037	1.49877 ± 0.00127	0.98920 ± 0.00005	1.48258 ± 0.00125	0.91670 ± 0.00069	-0.02675 ± 0.00057
3.75	127	0.98681 ± 0.00038	1.50213 ± 0.00121	0.98756 ± 0.00006	1.48345 ± 0.00119	1.00883 ± 0.00074	-0.02969 ± 0.00051
3.75	169	1.05101 ± 0.00038	1.50416 ± 0.00116	0.98631 ± 0.00006	1.48357 ± 0.00114	1.07744 ± 0.00076	-0.03128 ± 0.00047
3.75	217	1.09942 ± 0.00039	1.50577 ± 0.00116	0.98510 ± 0.00006	1.48334 ± 0.00114	1.12939 ± 0.00081	-0.03201 ± 0.00045

Appendix-4 Comparison with Calculated Results Using JENDL-4.0 and JENDL-4.0u1 Libraries

The comparisons with the previous versions of the JENDL libraries, JENDL-4.0 and JENDL-4.0u1 are shown below for the calculated results under the condition that the densities of the moderator water were set to be 100 and 0 %.

(1) Infinite neutron multiplication factor and ratio of reactions for hexagonal and square lattice systems

For the infinite hexagonal lattice systems under the condition that the density of the moderator water was set to be 100 %, the differences in infinite neutron multiplication factor (k_{inf}) and the related ratio of reactions among the different JENDL libraries are shown in Figs.A.4.1(1) and A.4.1(2), respectively.

It is found from Fig.A.4.1(1) that the differences in k_{inf} between the JENDL-5 and JENDL-4.0 libraries are nearly constant in the range below 0.7 of moderator water to fuel volume ratio (VR), but the differences become larger in the range beyond 0.7 of VR as VR increases. On the other hand, it is confirmed that the differences between the JENDL-4.0 and JENDL-4.0u1 libraries are smaller than three times their standard deviations (σ's).

As seen in the difference between the JENDL-5 and JENDL-4.0 libraries of Fig.A.4.1(2), it is confirmed that the differences in Ratio(1) are nearly constant in the whole range of VR, but those in Ratio(2) vary largely as VR increases with the same tendency as seen in k_{inf}. Therefore, it is clarified that the differences in Ratio(2) between the JENDL-5 and JENDL-4.0 libraries largely affect those in k_{inf}.

For the infinite square lattice systems under the condition that the density of the moderator water was set to be 100 %, the differences in k_{inf} and the related ratio of reactions among the different JENDL libraries are shown in Figs.A.4.2(1) and A.4.2(2), respectively. It is also confirmed that the differences in k_{inf} among the different JENDL libraries are characterized by Ratio(2), similar to the infinite hexagonal lattice systems as described above.

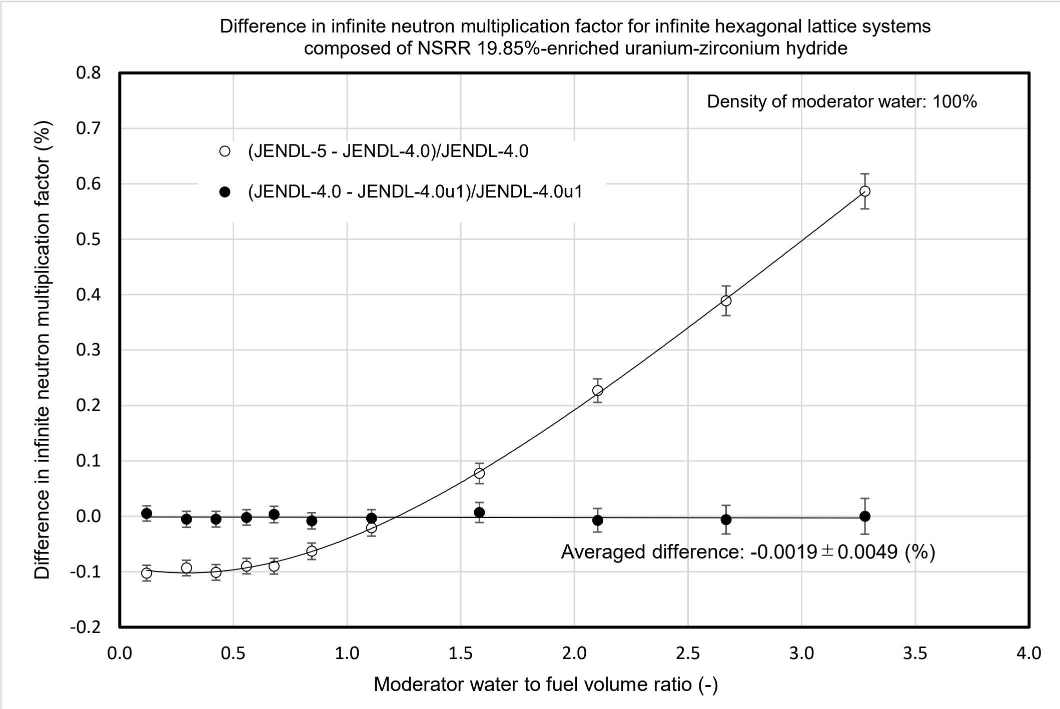

Fig.A.4.1(1) Difference in infinite neutron multiplication factor for infinite hexagonal lattice systems among different JENDL libraries, density of moderator water: 100 %.

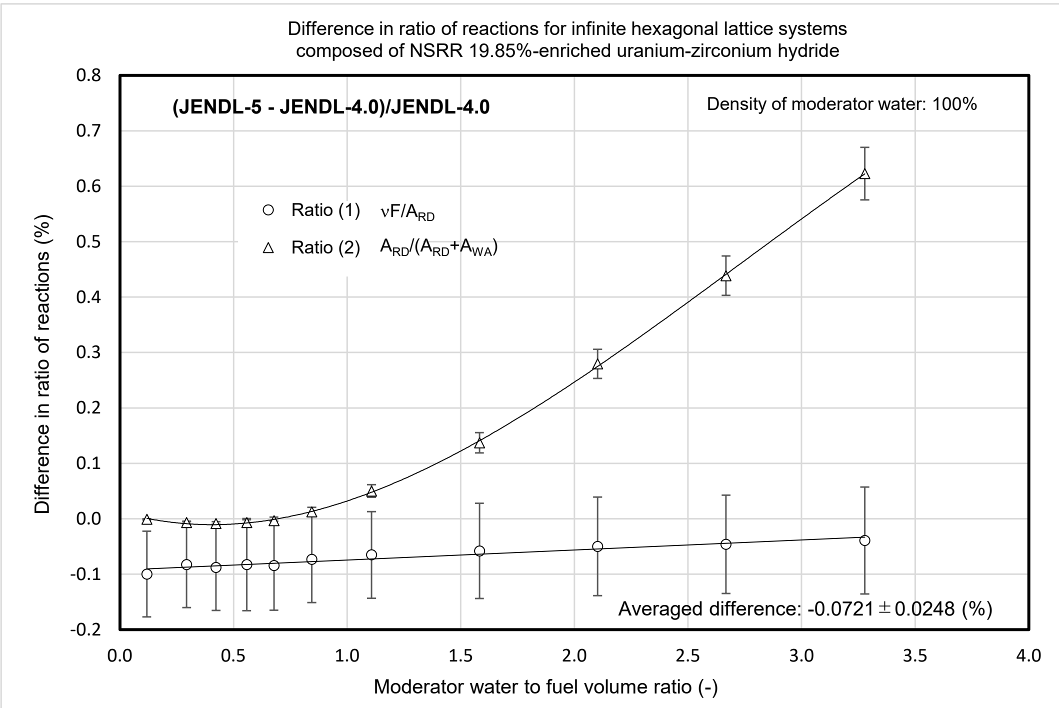

Fig.A.4.1(2) Difference in ratio of reactions for infinite hexagonal lattice systems between JENDL-5 and JENDL-4.0 libraries, density of moderator water: 100 %.

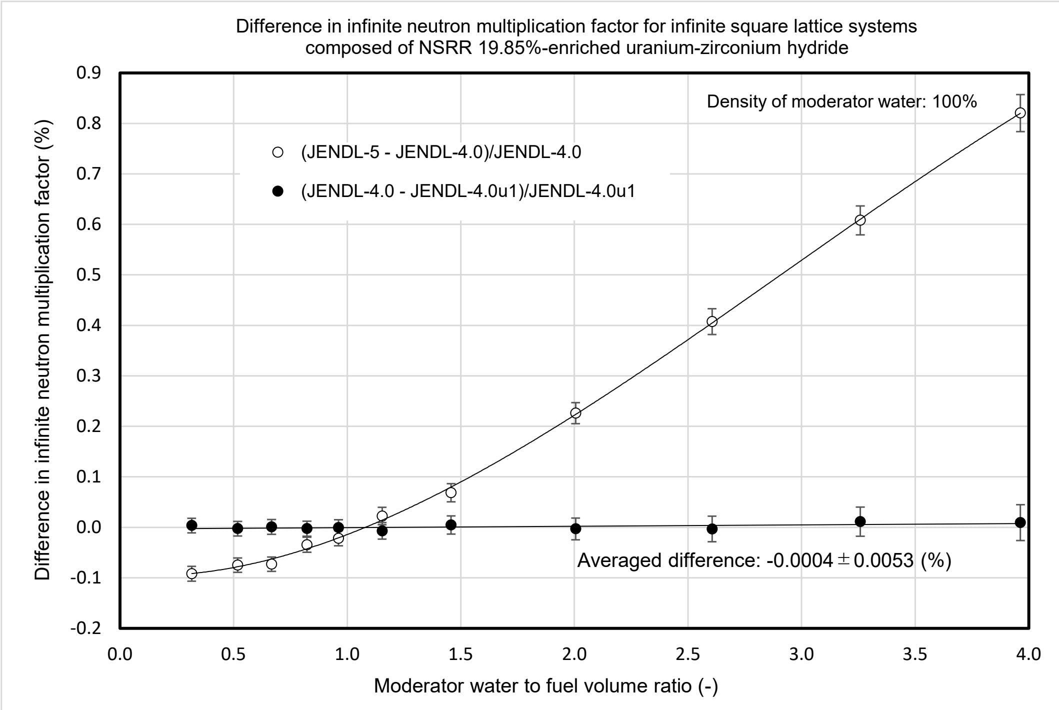

Fig.A.4.2(1) Difference in infinite neutron multiplication factor for infinite square lattice systems among different JENDL libraries, density of moderator water: 100 %.

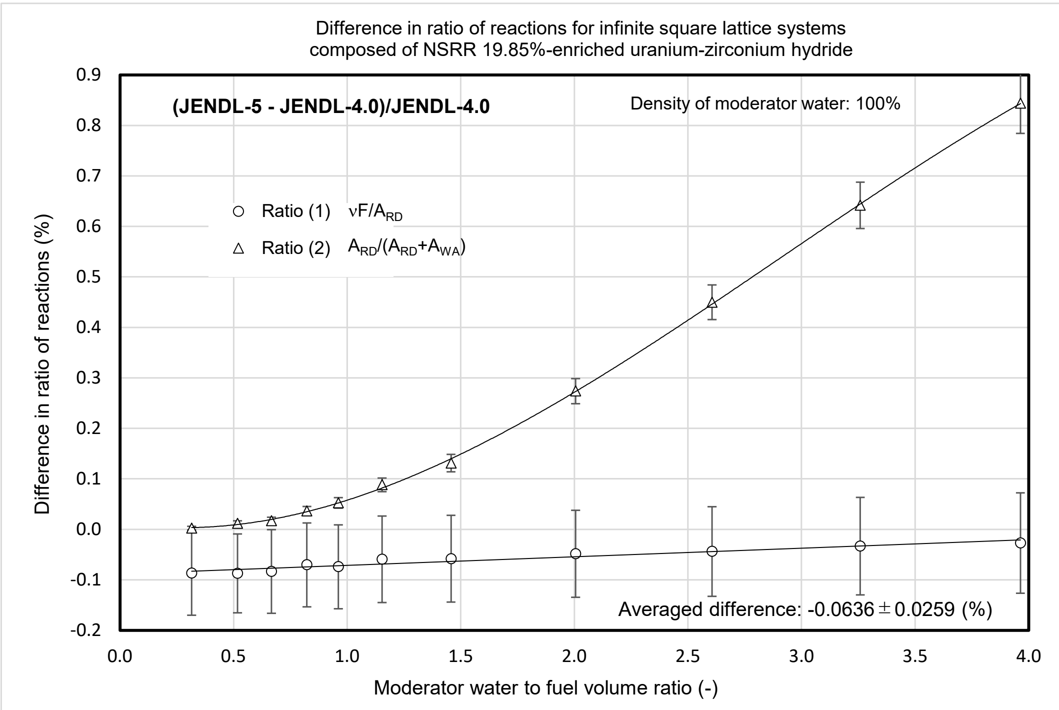

Fig.A.4.2(2) Difference in ratio of reactions for infinite square lattice systems between JENDL-5 and JENDL-4.0 libraries, density of moderator water: 100 %.

For the infinite hexagonal lattice systems under the condition that the density of the moderator water was set to be 0 %, the differences in k_{inf} and the related ratio of reactions among the different JENDL libraries are shown in Figs.A.4.3(1) and A.4.3(2), respectively.

It is found from Fig.A.4.3(1) that the differences in k_{inf} between the JENDL-5 and JENDL-4.0 libraries are nearly constant in the full range of VR. It is also seen that the differences between the JENDL-4.0 and JENDL-4.0u1 libraries are smaller than three times their σ's.

As shown in the differences between the JENDL-5 and JENDL-4.0 libraries of Fig.A.4.3(2), it is confirmed that the differences in Ratio(1) are nearly constant in the full range of VR. The values of Ratio(2) in the case of 0 % of the density are identical to unity due to its definition. Therefore, it is mentioned that the differences in k_{inf} between the JENDL-5 and JENDL-4.0 libraries are characterized by the those in Ratio(2) only.

For the infinite square lattice systems under the condition that the density of the moderator water was set to be 0 %, the same features of the differences in k_{inf} and ratio of reactions as the infinite hexagonal lattice systems mentioned above are seen in Figs.A.4.4(1) and A.4.4(2), respectively.

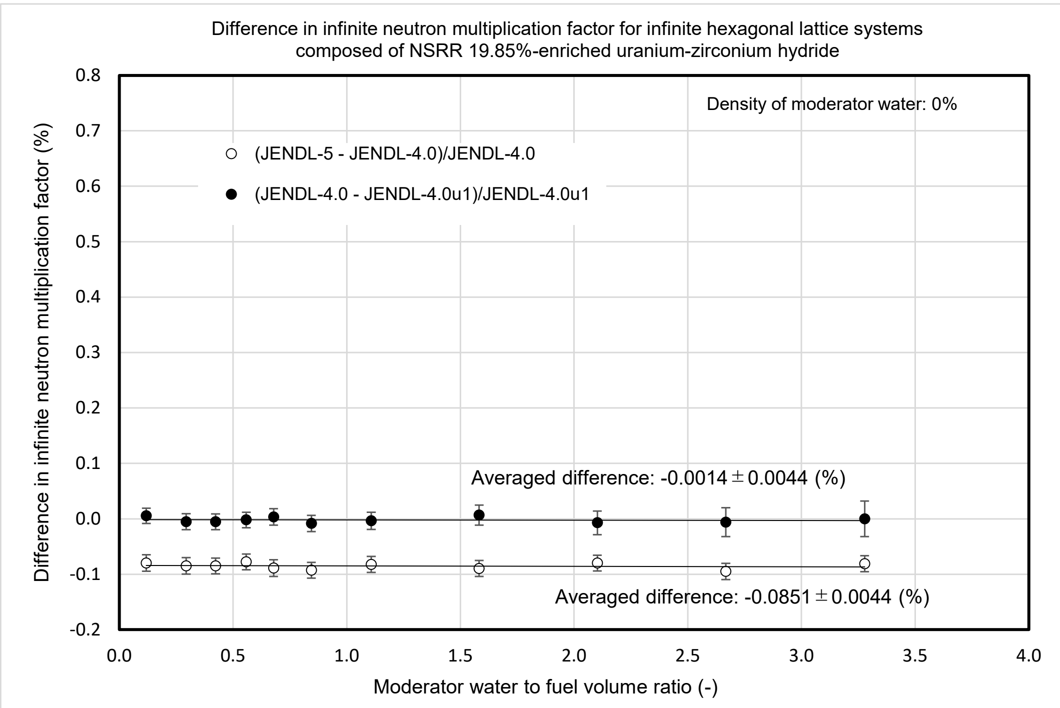

Fig.A.4.3(1) Difference in infinite neutron multiplication factor for infinite hexagonal lattice systems among different JENDL libraries, density of moderator water: 0 %.

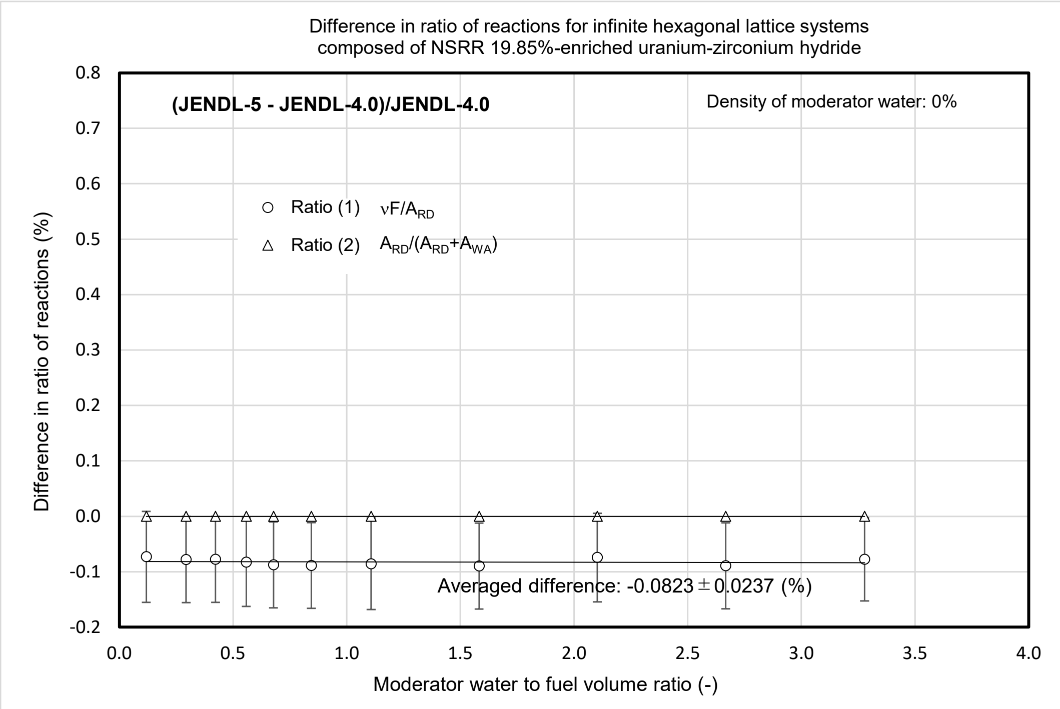

Fig.A.4.3(2) Difference in ratio of reactions for infinite hexagonal lattice systems between JENDL-5 and JENDL-4.0 libraries, density of moderator water: 0 %.

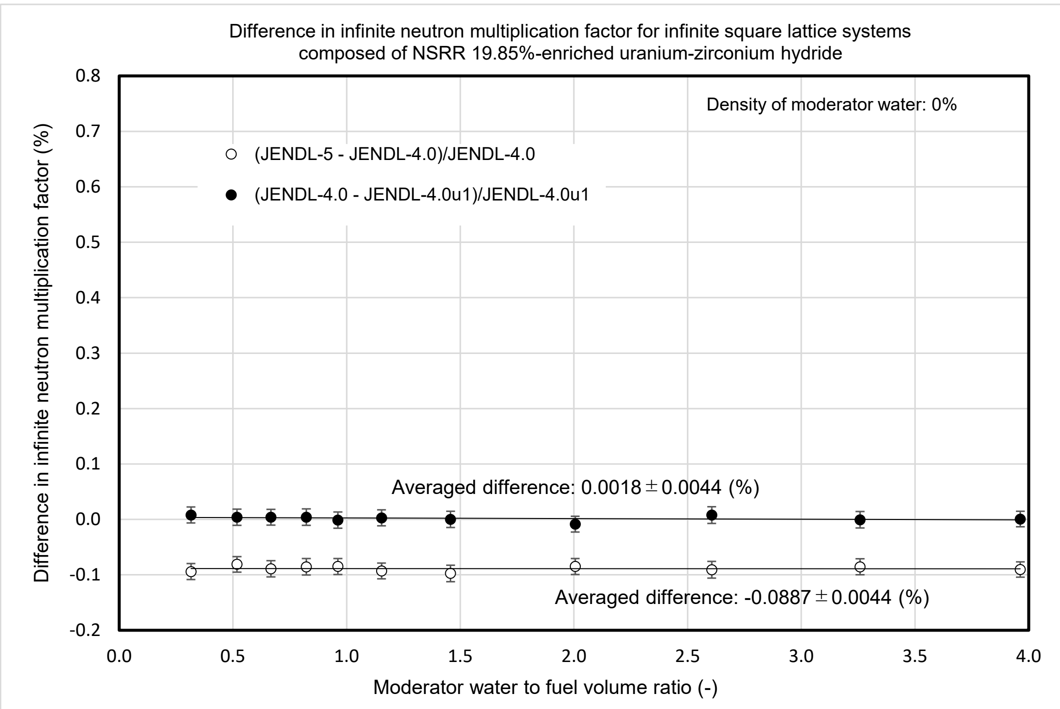

Fig.A.4.4(1) Difference in infinite neutron multiplication factor for infinite square lattice systems among different JENDL libraries, density of moderator water: 0 %.

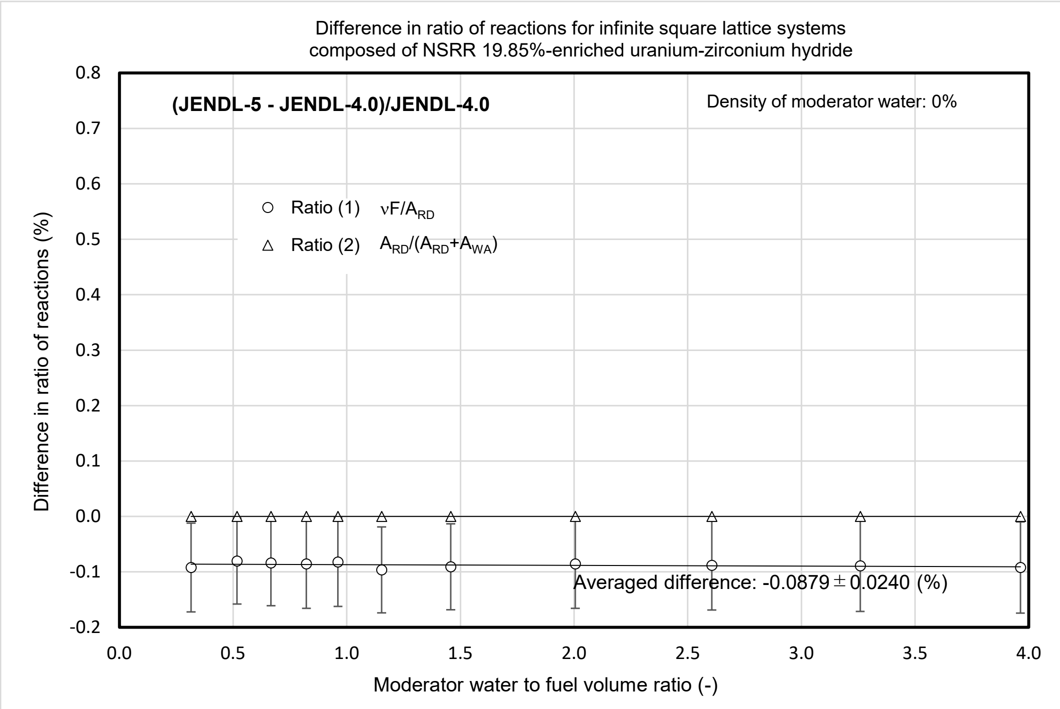

Fig.A.4.4(2) Difference in ratio of reactions for infinite square lattice systems between JENDL-5 and JENDL-4.0 libraries, density of moderator water: 0 %.

(2) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems composed of 55, 49, 43 and 40 fuel rods, and for square lattice systems composed of 57, 49, 44 and 40 fuel rods

For the water-reflected hexagonal lattice systems composed of 55, 49, 43 and 40 fuel rods under the condition that the density of the moderator water was set to be 100 %, the differences in effective neutron multiplication factor (k_{eff}) are shown in Figs.A.4.5(1) to A.4.5(4), and those in the related ratio of reactions among the different JENDL libraries are also shown in Figs.A.4.5(5) to A.4.5(8). Similarly, the differences in k_{eff} under the condition of 0 % of the density are shown in Figs.A.4.5(9) to A.4.5(12), and those in the related ratio of reactions among the different JENDL libraries are shown in Figs.A.4.5(13) to A.4.5(16). Here, the features of the differences in k_{eff} and ratio of reactions among the different JENDL libraries are discussed with the lattice system composed of 55 fuel rods as the representative.

For the density of the moderator water was set to be 100 %, it is found in Fig.A.4.5(1) that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries are changed along a convex downward curve as VR increases. On the other hand, it is seen that the differences between the JENDL-4.0 and JENDL-

4.0u1 libraries are smaller than three times their σ's. As seen in the difference between the JENDL-5 and JENDL-4.0 libraries of Fig.A.4.5(5), it is confirmed that the differences in Ratio(4) increase monotonically as VR increases, which are the same values as those in k_{inf}. On the contrary, those in Ratio(5) decrease monotonically as VR increases. It is shown that the differences in k_{eff} are caused by those in Ratio(5) in the range of the smaller VR than about 2.0, but the differences are due to the Ratio(4) in the range of the larger VR than about 2.0. For this reason, the differences in k_{eff} are changed as the convex downward function of VR as mentioned above.

For the density of the moderator water was set to be 0 %, it is found in Fig.A.4.5(9) that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries increase slightly as VR increases. In addition, it is seen that the differences between the JENDL-5 and JENDL-4.0 libraries for 0 % of the density is larger than those for 100 % of the density. On the other hand, it is confirmed that the differences between the JENDL-4.0 and JENDL-4.0u1 libraries are smaller than three times their σ's, similar to the results for 100 % of the density. As seen in the difference between the JENDL-5 and JENDL-4.0 libraries of Fig.A.4.5(13), it is confirmed that the differences in Ratio(4) are nearly constant in the full range of VR, which are the same values as those in k_{inf}. It is also confirmed that the differences in Ratio(5) are larger than those in Ratio(4). Therefore, it is clarified that the differences in Ratio(5) between the JENDL-5 and JENDL-4.0 libraries largely affect those in k_{eff} in the case of 0 % of the density.

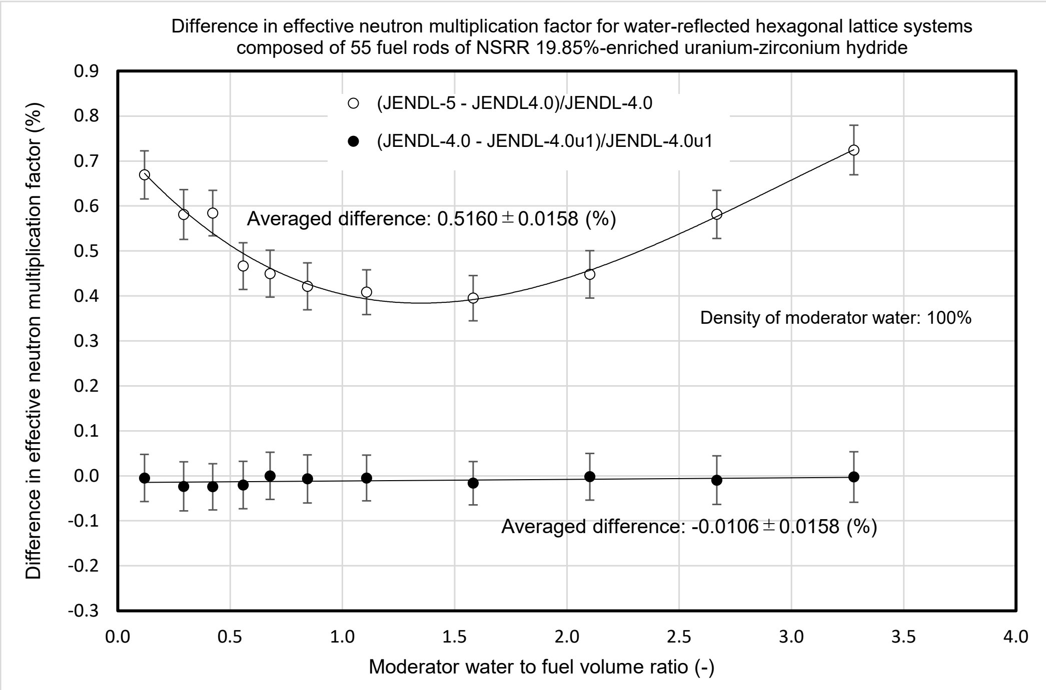

Fig.A.4.5(1) Difference in effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 55 fuel rods among different JENDL libraries, density of moderator water: 100 %.

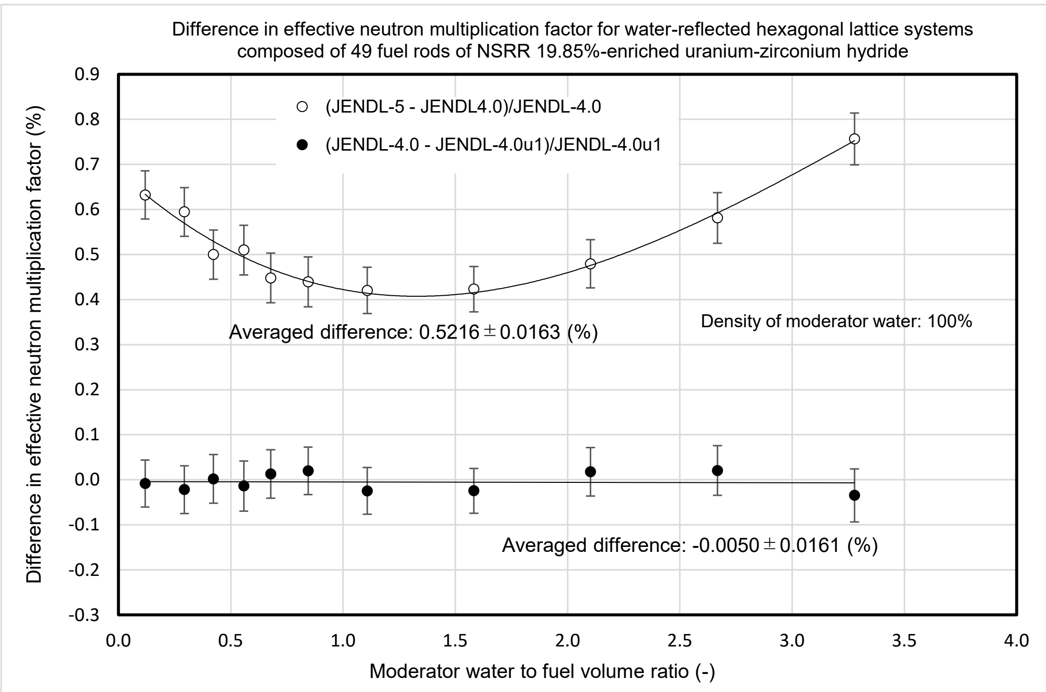

Fig.A.4.5(2) Difference in effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 49 fuel rods among different JENDL libraries, density of moderator water: 100 %.

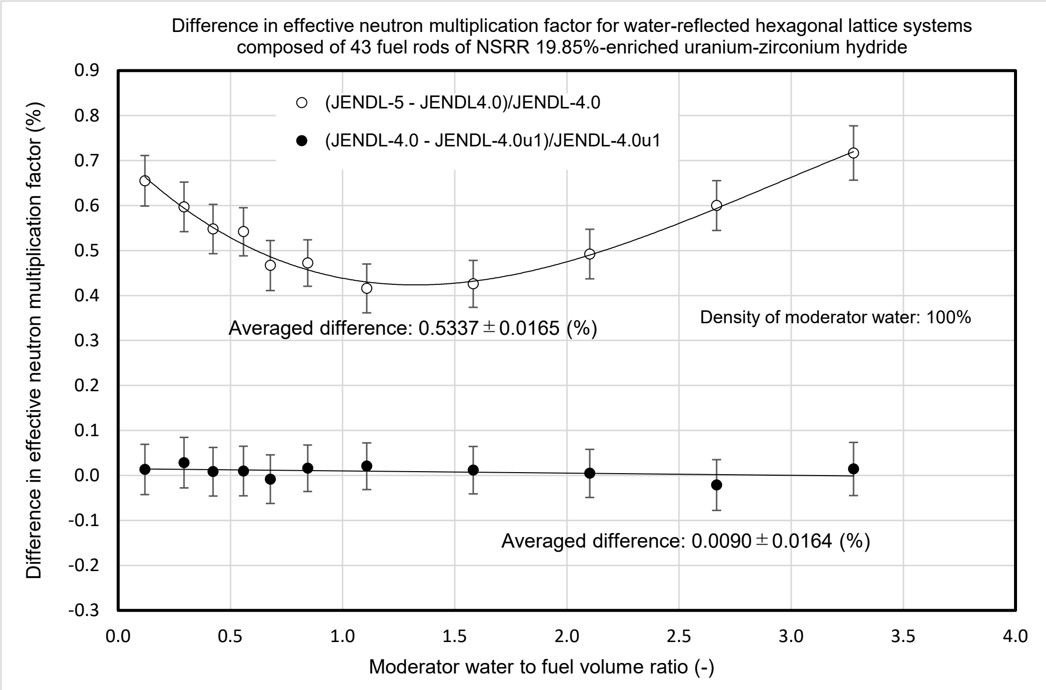

Fig.A.4.5(3) Difference in effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 43 fuel rods among different JENDL libraries, density of moderator water: 100 %.

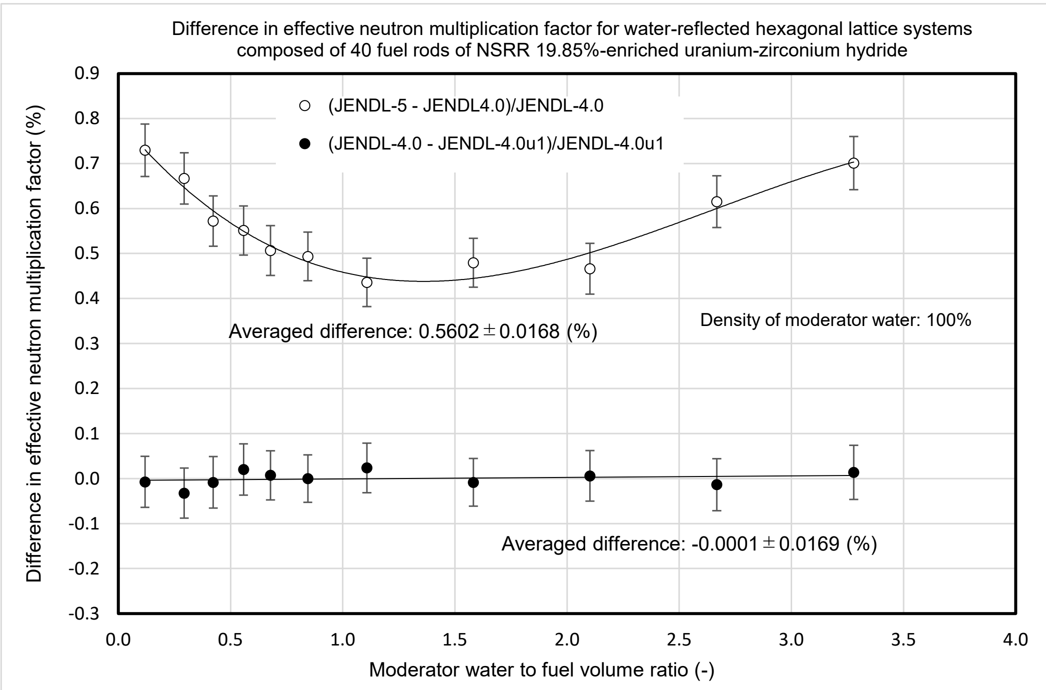

Fig.A.4.5(4) Difference in effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 40 fuel rods among different JENDL libraries, density of moderator water: 100 %.

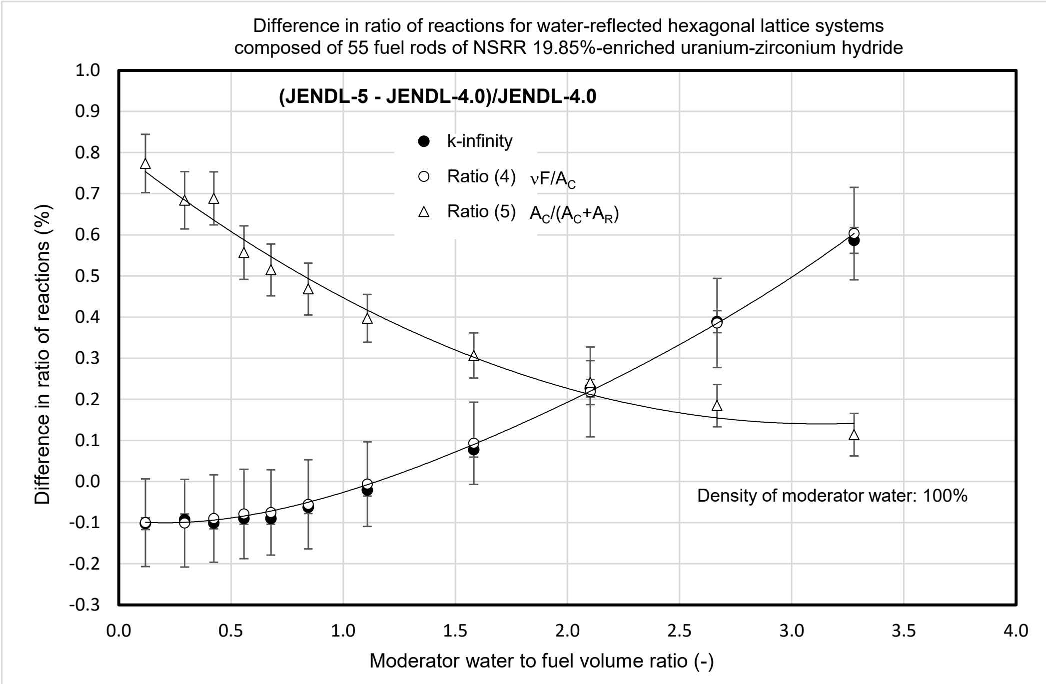

Fig.A.4.5(5) Difference in ratio of reactions
for water-reflected hexagonal lattice systems composed of 55 fuel rods
among different JENDL libraries, density of moderator water: 100 %.

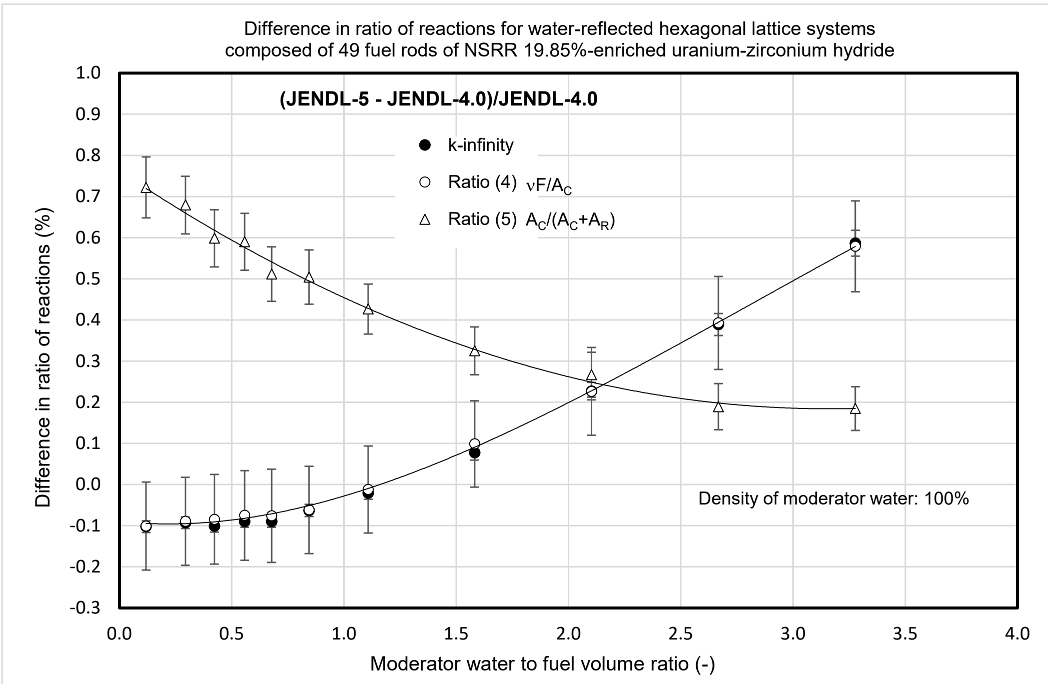

Fig.A.4.5(6) Difference in ratio of reactions
for water-reflected hexagonal lattice systems composed of 49 fuel rods
among different JENDL libraries, density of moderator water: 100 %.

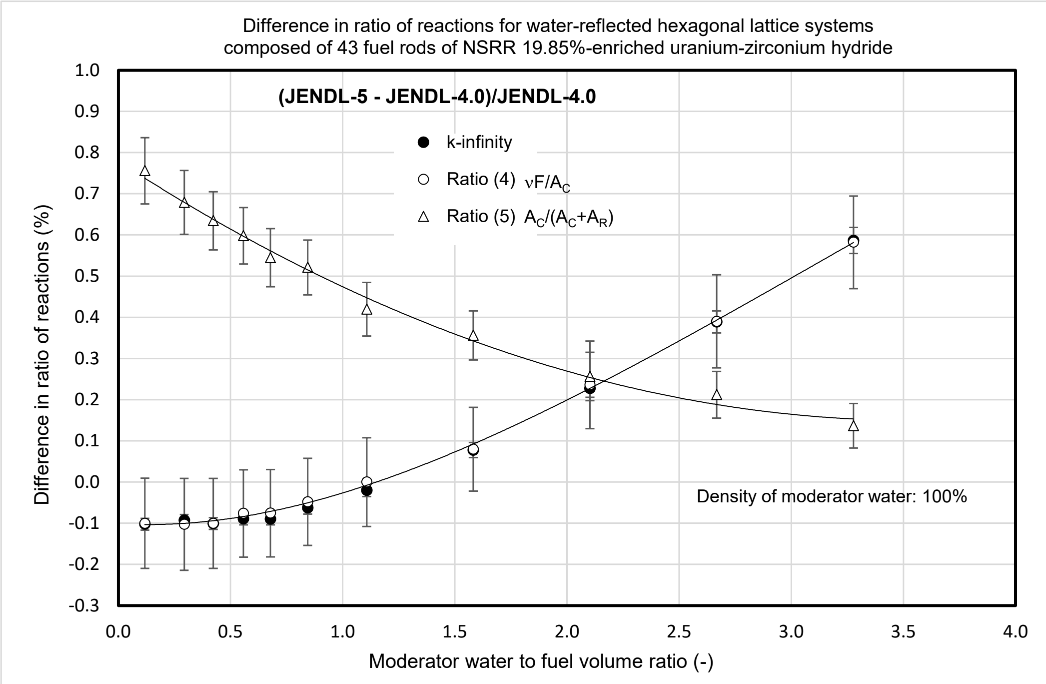

Fig.A.4.5(7) Difference in ratio of reactions
for water-reflected hexagonal lattice systems composed of 43 fuel rods
among different JENDL libraries, density of moderator water: 100 %.

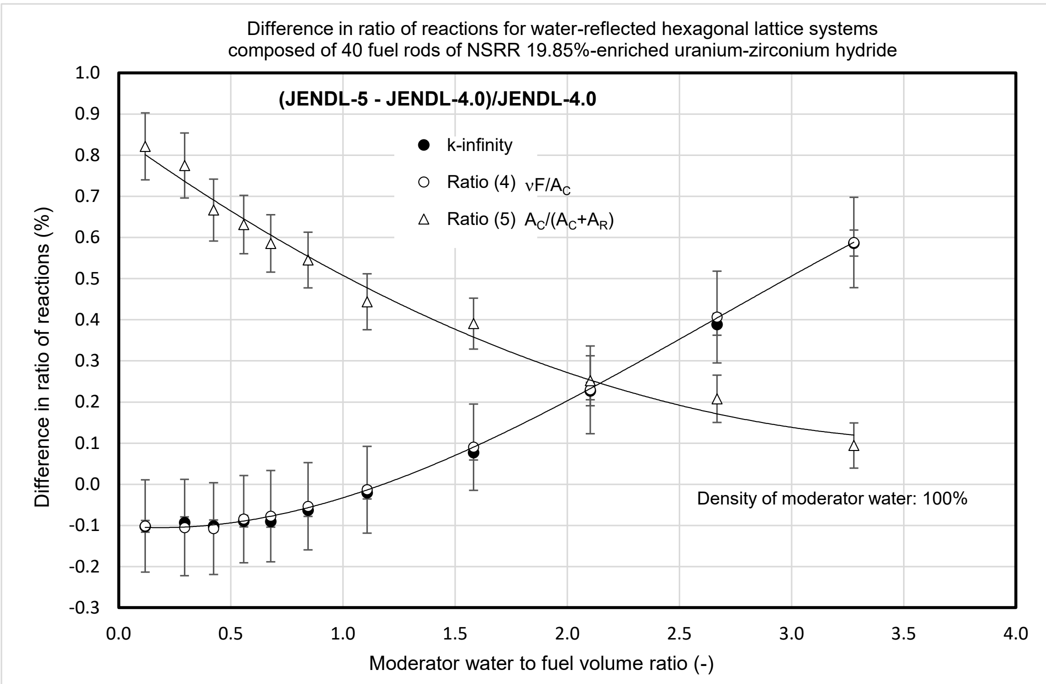

Fig.A.4.5(8) Difference in ratio of reactions
for water-reflected hexagonal lattice systems composed of 40 fuel rods
among different JENDL libraries, density of moderator water: 100 %.

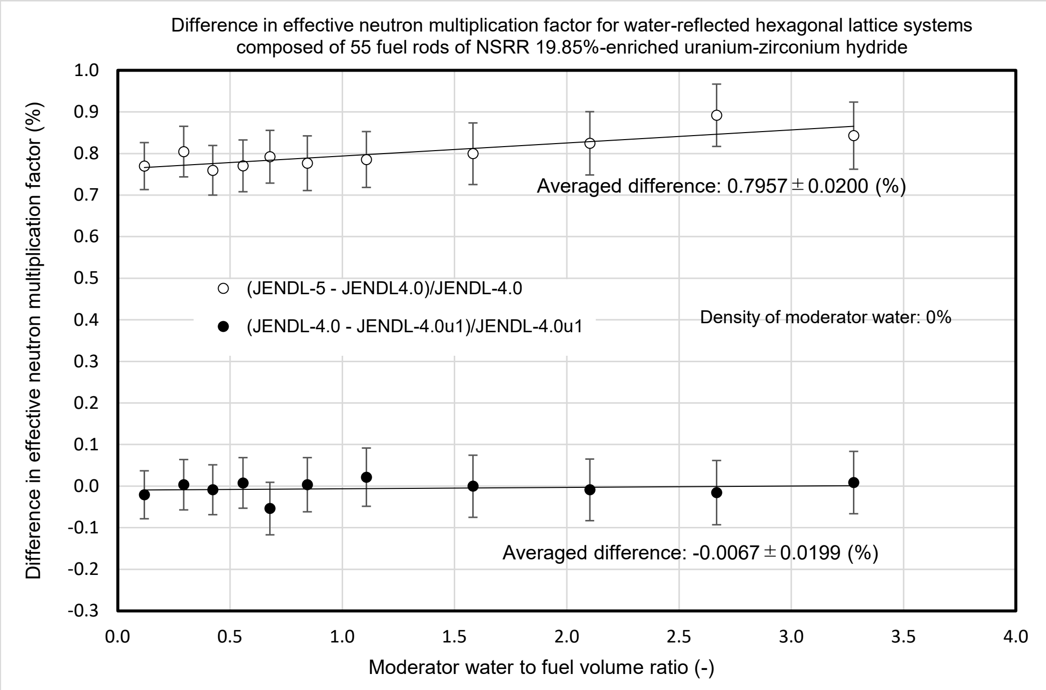

Fig.A.4.5(9) Difference in effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 55 fuel rods among different JENDL libraries, density of moderator water: 0 %.

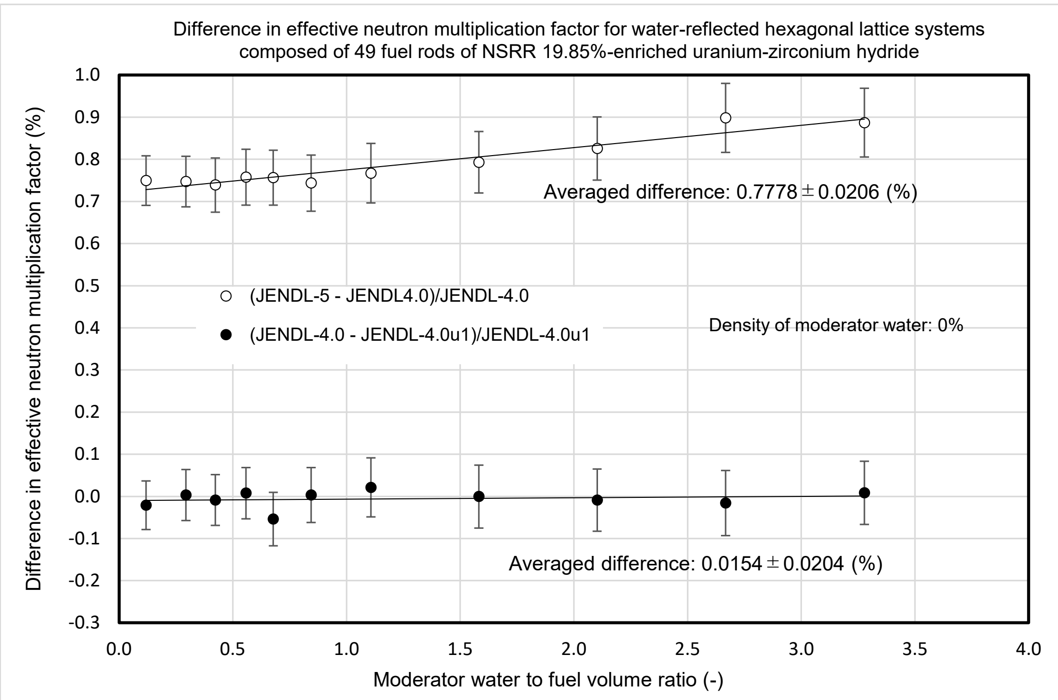

Fig.A.4.5(10) Difference in effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 49 fuel rods among different JENDL libraries, density of moderator water: 0 %.

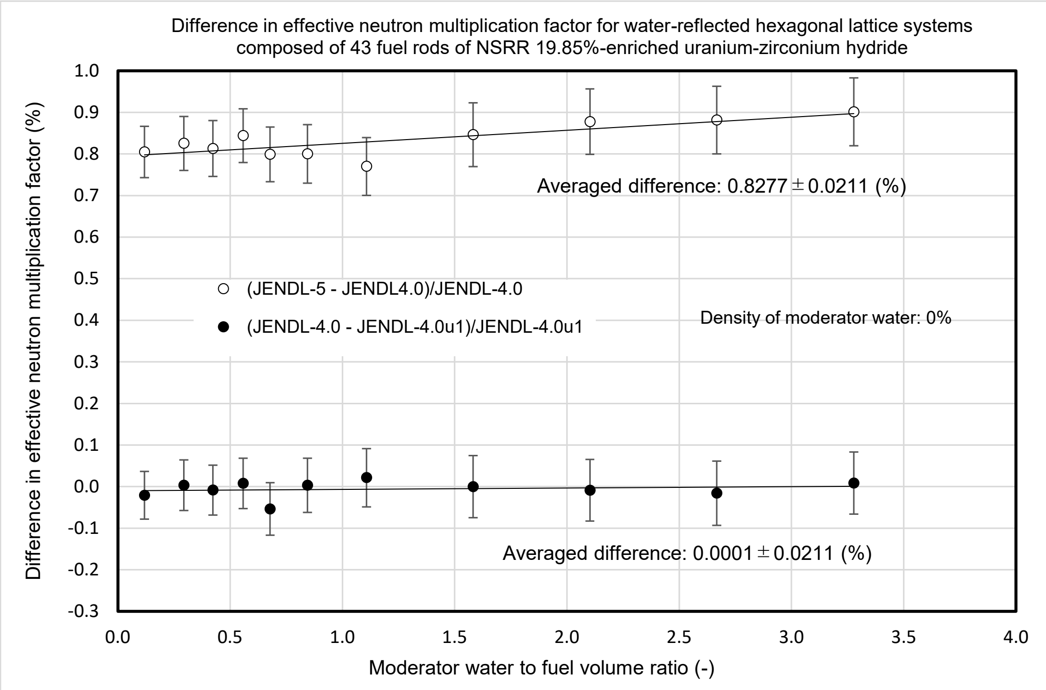

Fig.A.4.5(11) Difference in effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 43 fuel rods among different JENDL libraries, density of moderator water: 0 %.

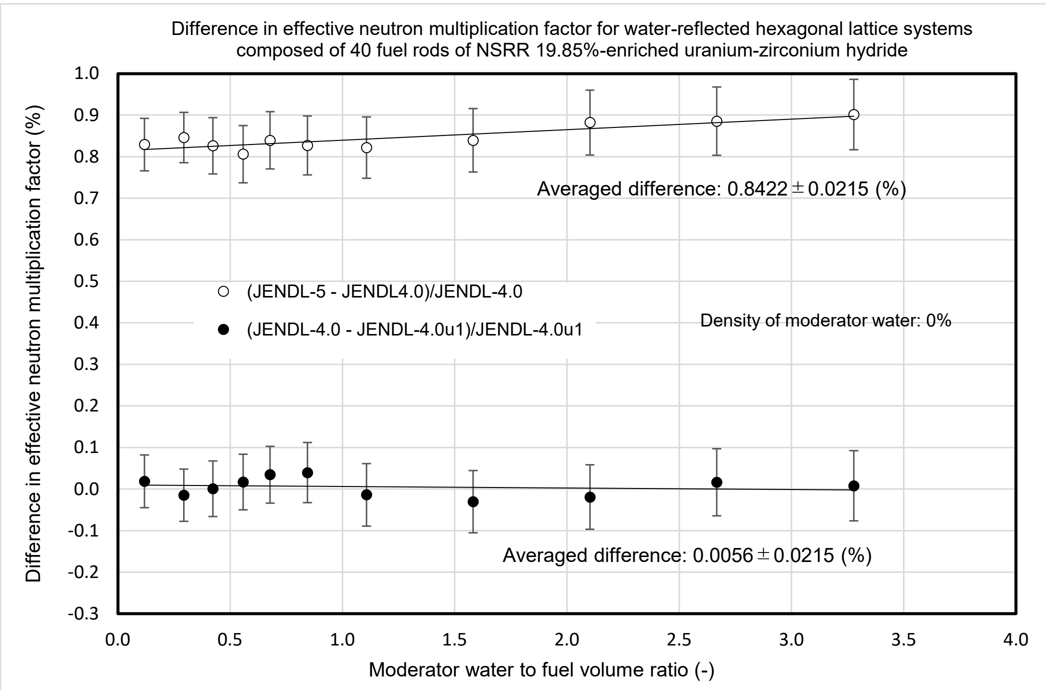

Fig.A.4.5(12) Difference in effective neutron multiplication factor for water-reflected hexagonal lattice systems composed of 40 fuel rods among different JENDL libraries, density of moderator water: 0 %.

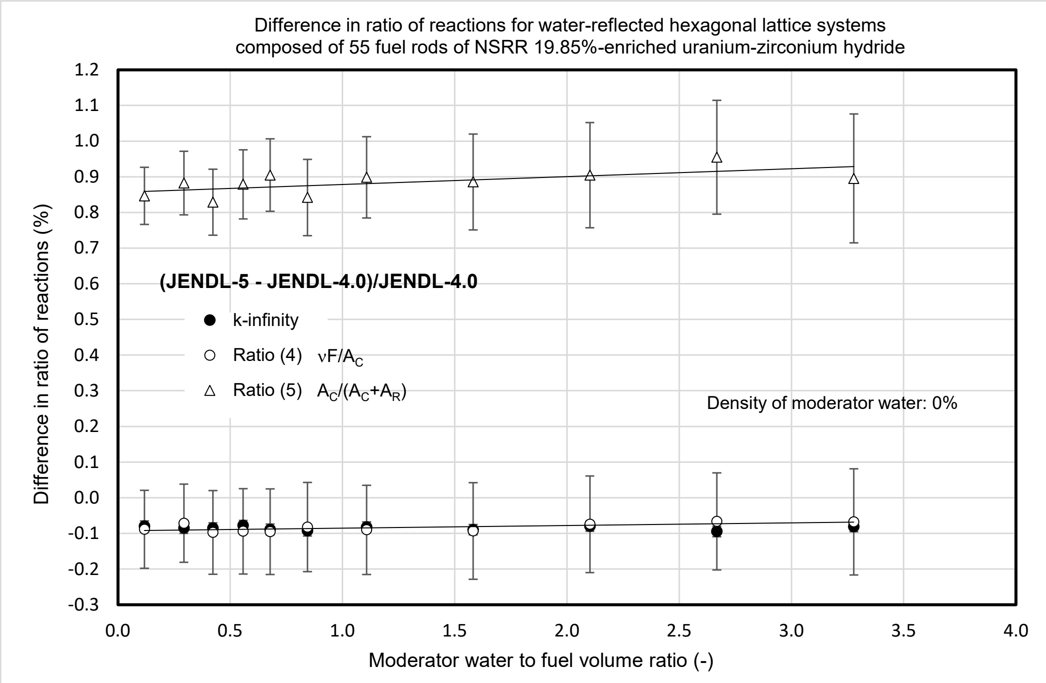

Fig.A.4.5(13) Difference in ratio of reactions
for water-reflected hexagonal lattice systems composed of 55 fuel rods
among different JENDL libraries, density of moderator water: 0 %.

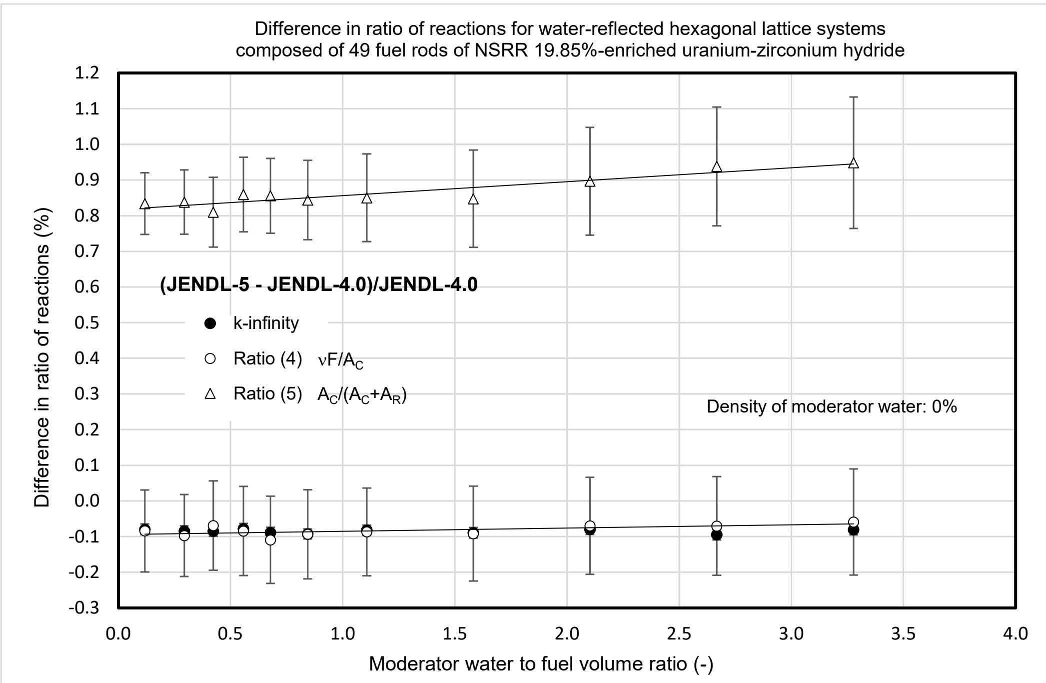

Fig.A.4.5(14) Difference in ratio of reactions
for water-reflected hexagonal lattice systems composed of 49 fuel rods
among different JENDL libraries, density of moderator water: 0 %.

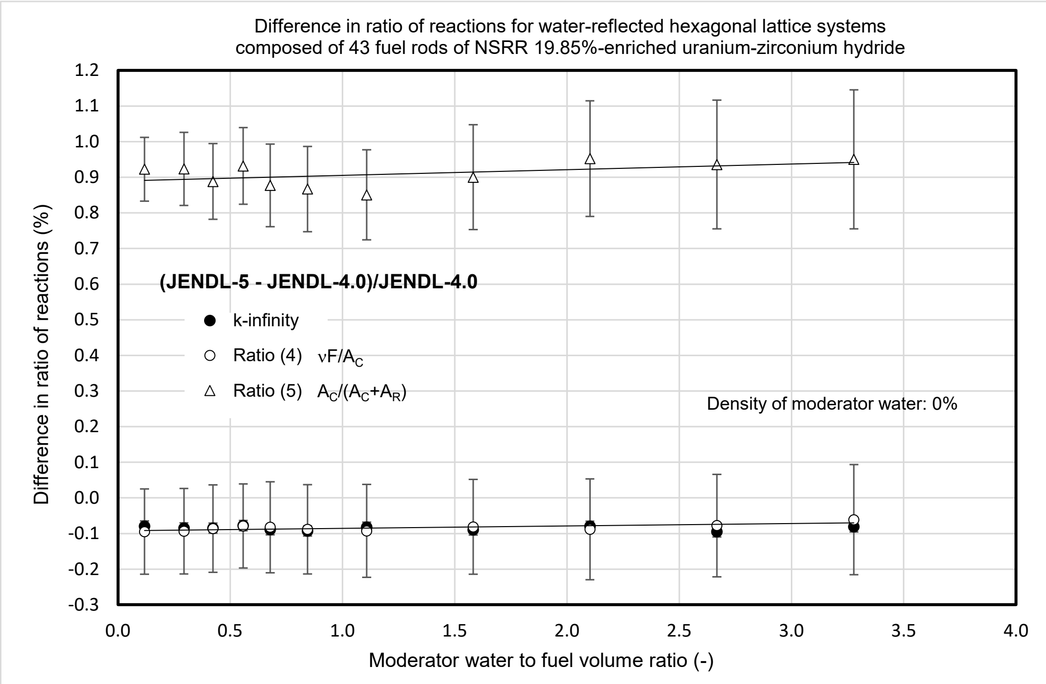

Fig.A.4.5(15) Difference in ratio of reactions
for water-reflected hexagonal lattice systems composed of 43 fuel rods
among different JENDL libraries, density of moderator water: 0 %.

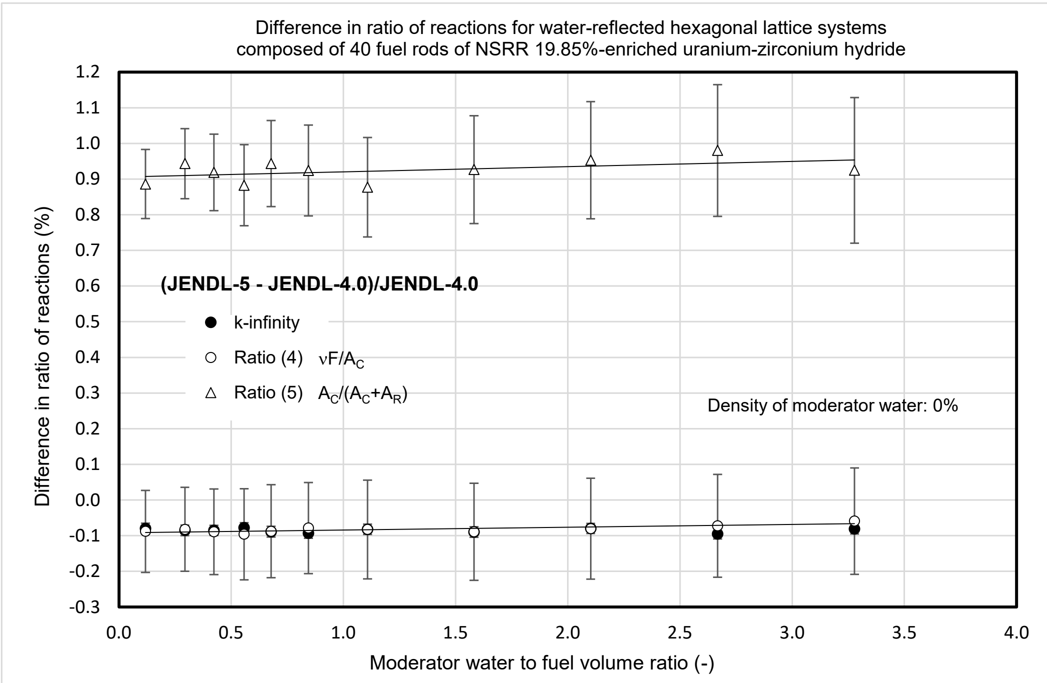

Fig.A.4.5(16) Difference in ratio of reactions
for water-reflected hexagonal lattice systems composed of 40 fuel rods
among different JENDL libraries, density of moderator water: 0 %.

For the water-reflected square lattice systems composed of 57, 49, 44 and 40 fuel rods under the condition that the density of the moderator water was set to be 100 %, the differences in k_{eff} are shown in Figs.A.4.6(1) to A.4.6(4), and those in the related ratio of reactions among the different JENDL libraries are also shown in Figs.A.4.6(5) to A.4.6(8). Similarly, the differences in k_{eff} under the condition of 0 % of the density are shown in Figs.A.4.6(9) to A.4.6(12), and those in the related ratio of reactions among the different JENDL libraries are shown in Figs.A.4.6(13) to A.4.6(16).

It is confirmed that the features of the differences in k_{eff} and ratio of reactions among the different JENDL libraries are same as those for the water-reflected hexagonal lattice systems as mentioned above.

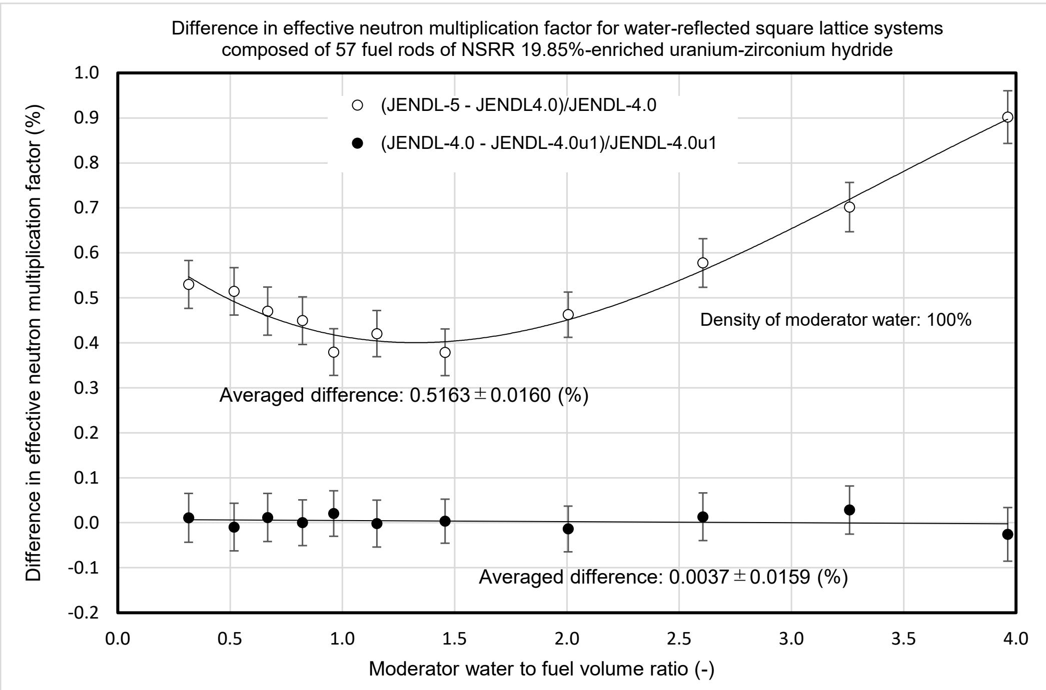

Fig.A.4.6(1) Difference in effective neutron multiplication factor for water-reflected square lattice systems composed of 57 fuel rods among different JENDL libraries, density of moderator water: 100 %.

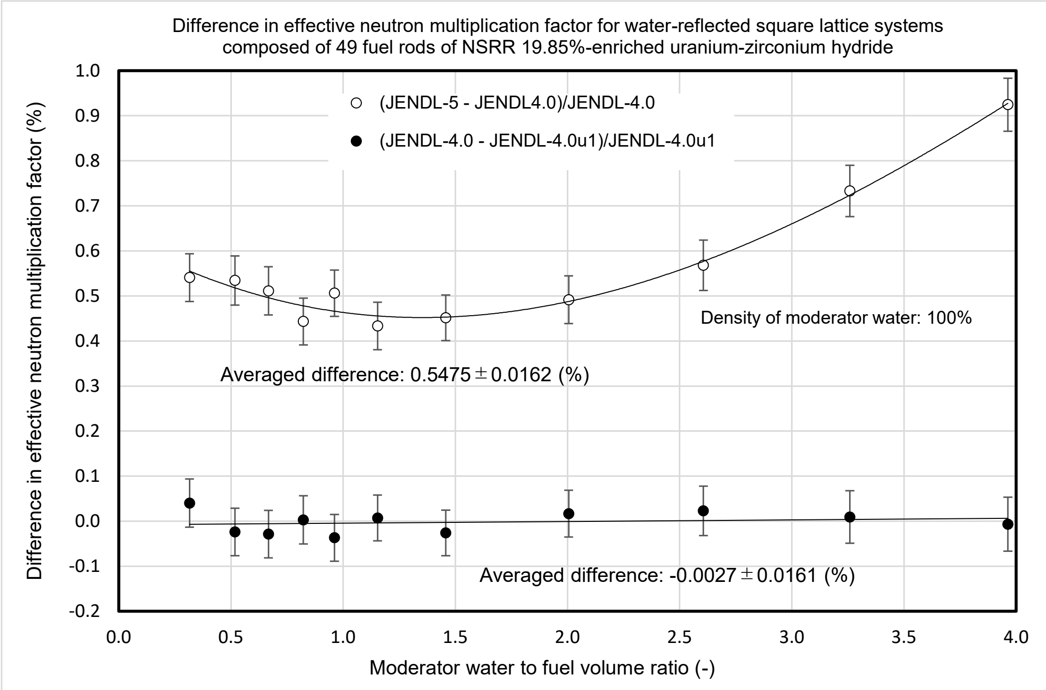

Fig.A.4.6(2) Difference in effective neutron multiplication factor for water-reflected square lattice systems composed of 49 fuel rods among different JENDL libraries, density of moderator water: 100 %.

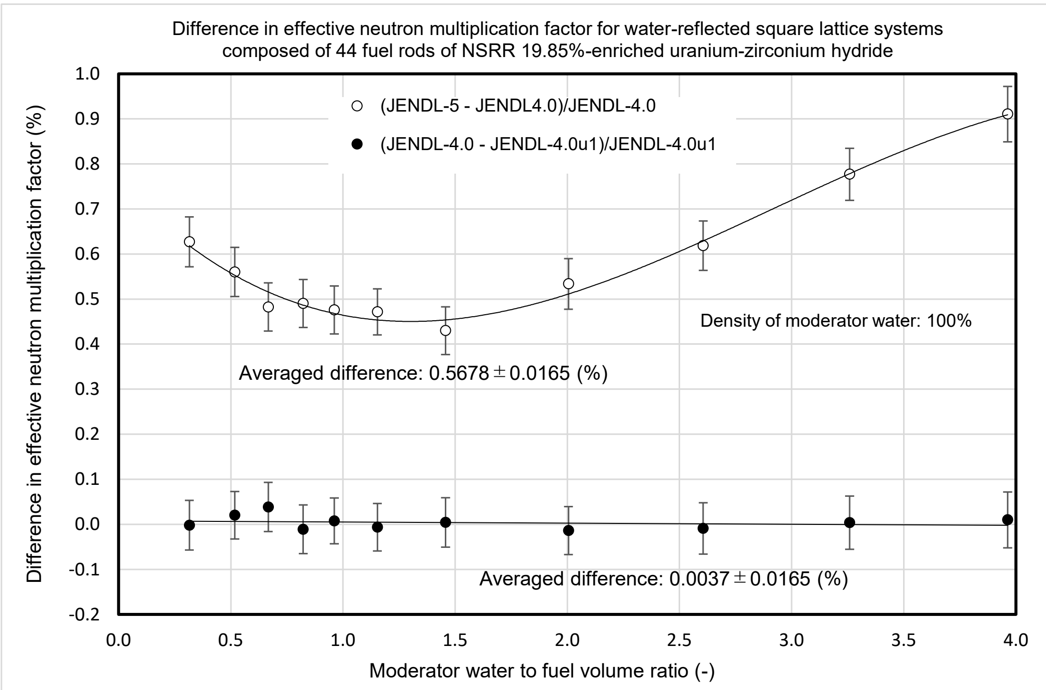

Fig.A.4.6(3) Difference in effective neutron multiplication factor for water-reflected square lattice systems composed of 44 fuel rods among different JENDL libraries, density of moderator water: 100 %.

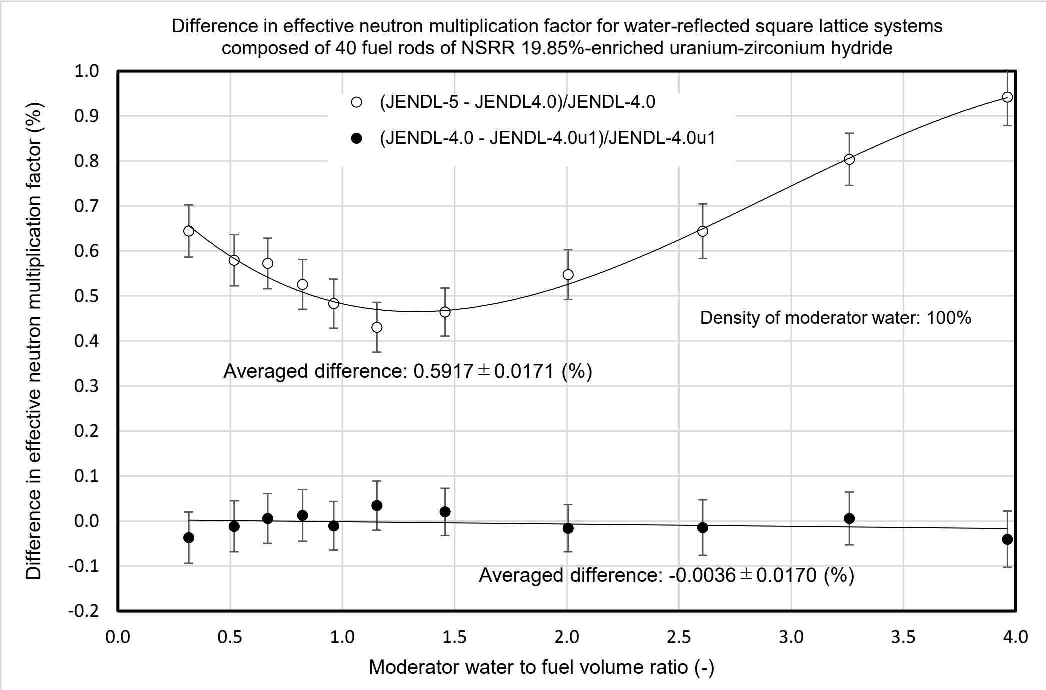

Fig.A.4.6(4) Difference in effective neutron multiplication factor for water-reflected square lattice systems composed of 40 fuel rods among different JENDL libraries, density of moderator water: 100 %.

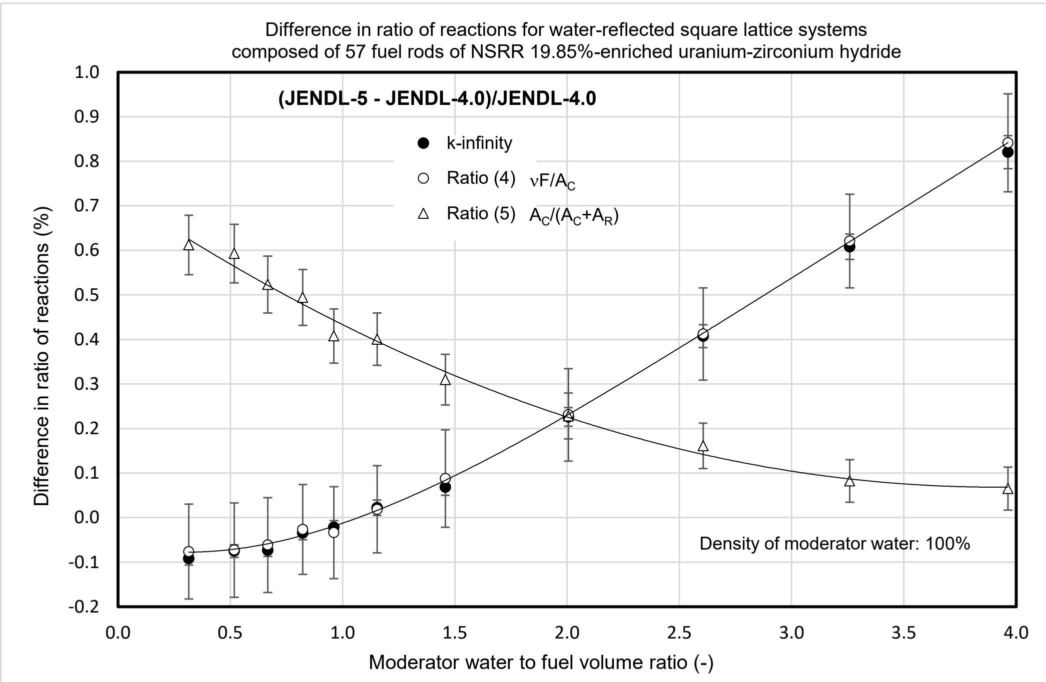

Fig.A.4.6(5) Difference in ratio of reactions for water-reflected square lattice systems composed of 57 fuel rods among different JENDL libraries, density of moderator water: 100 %.

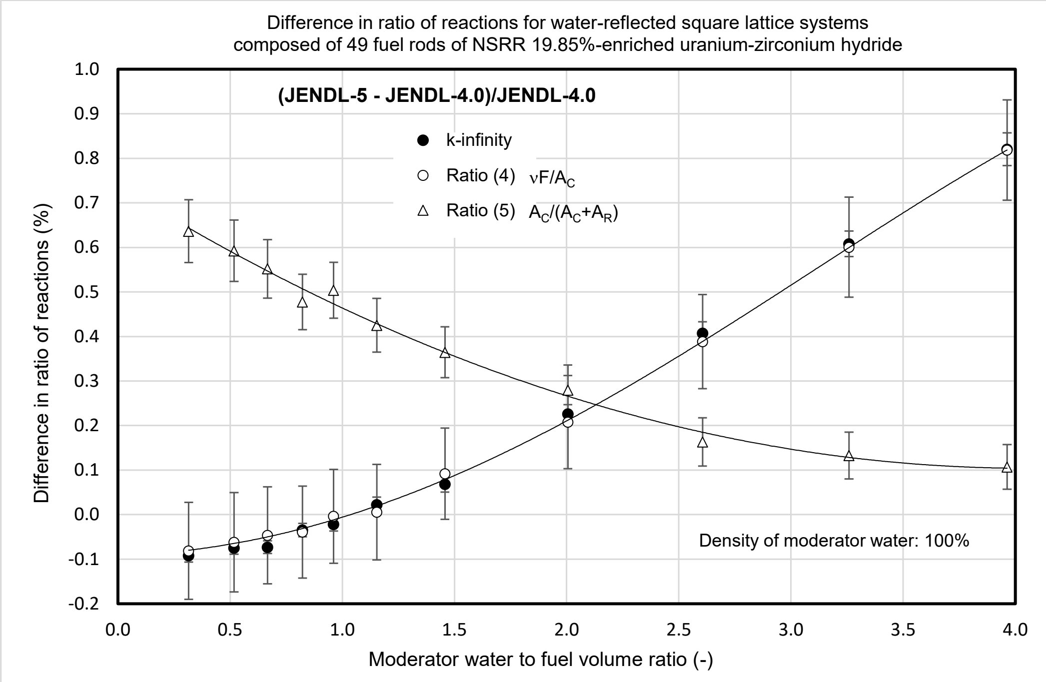

Fig.A.4.6(6) Difference in ratio of reactions
for water-reflected square lattice systems composed of 49 fuel rods
among different JENDL libraries, density of moderator water: 100 %.

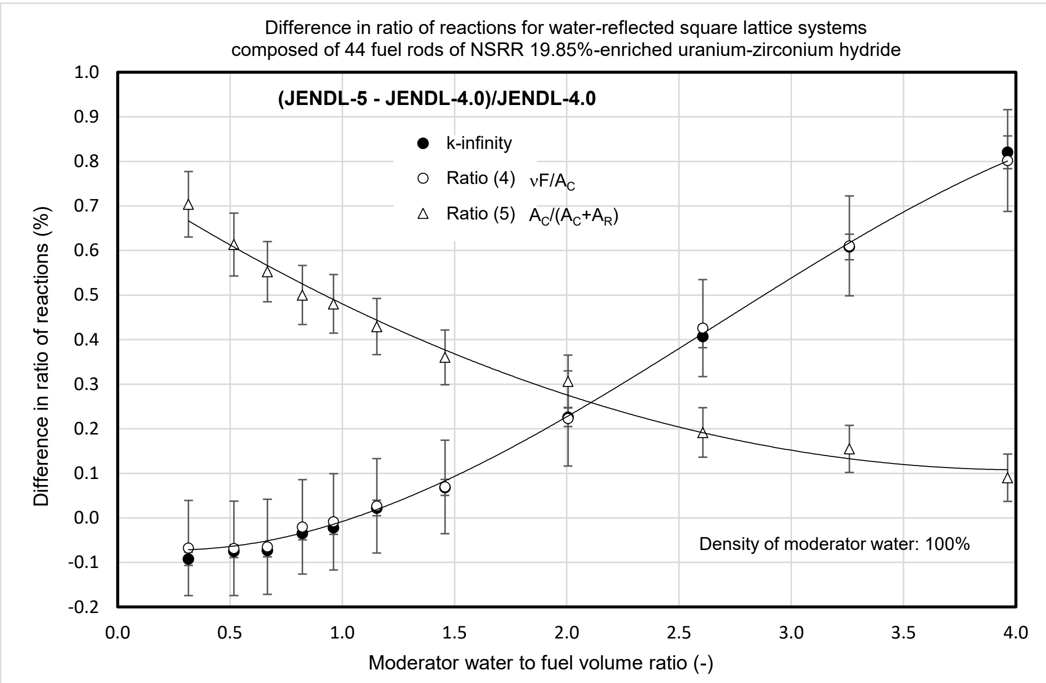

Fig.A.4.6(7) Difference in ratio of reactions
for water-reflected square lattice systems composed of 44 fuel rods
among different JENDL libraries, density of moderator water: 100 %.

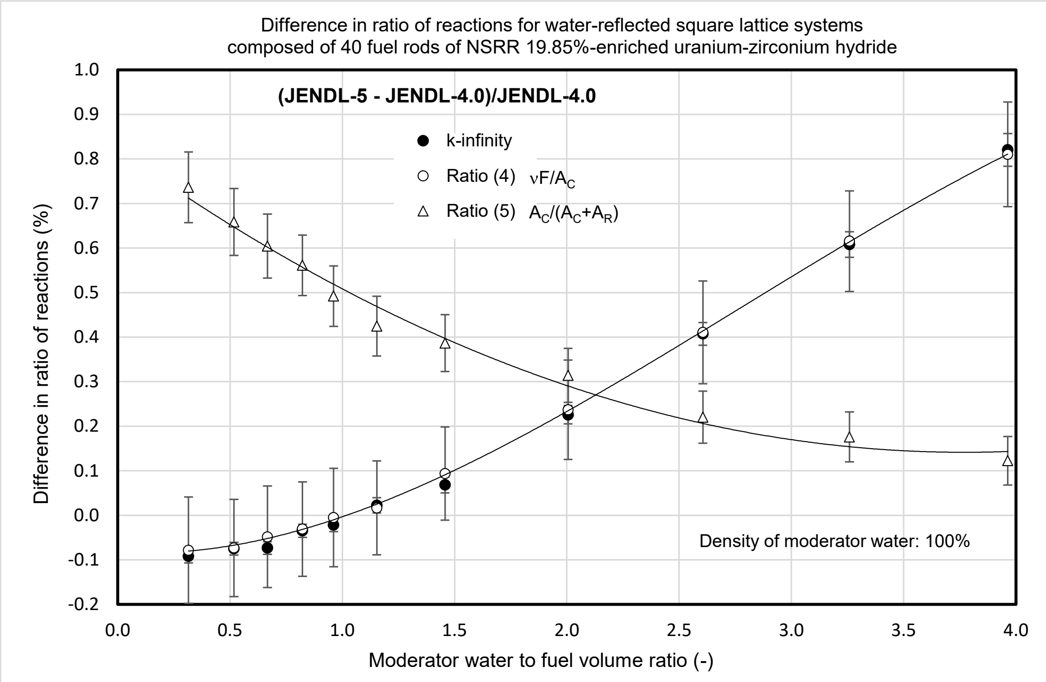

Fig.A.4.6(8) Difference in ratio of reactions
for water-reflected square lattice systems composed of 40 fuel rods
among different JENDL libraries, density of moderator water: 100 %.

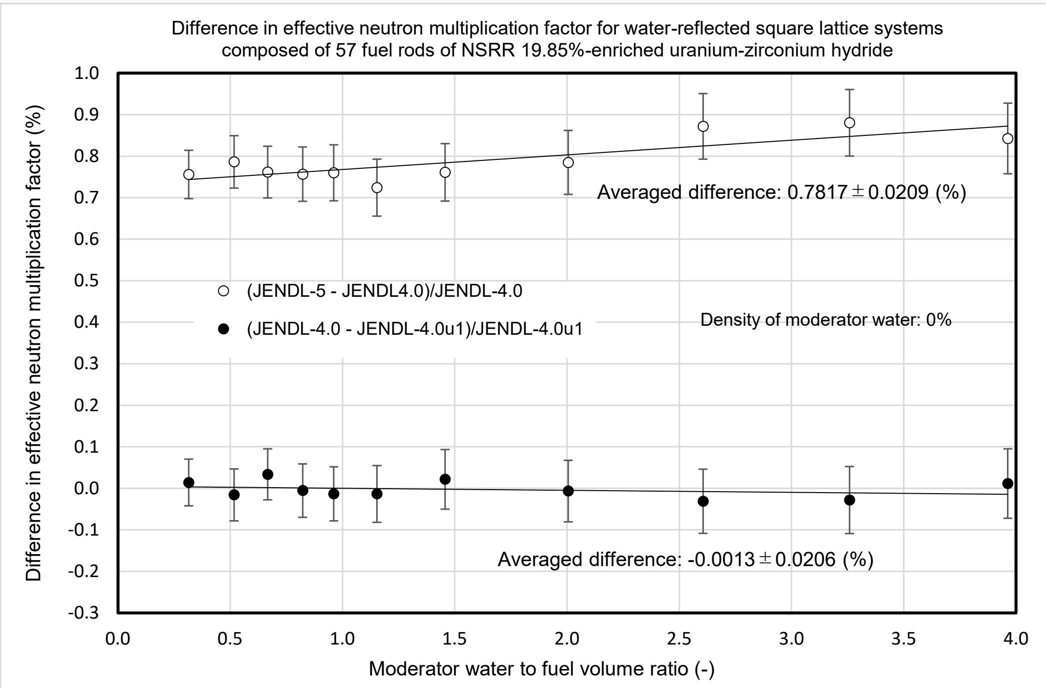

Fig.A.4.6(9) Difference in effective neutron multiplication factor
for water-reflected square lattice systems composed of 57 fuel rods
among different JENDL libraries, density of moderator water: 0 %.

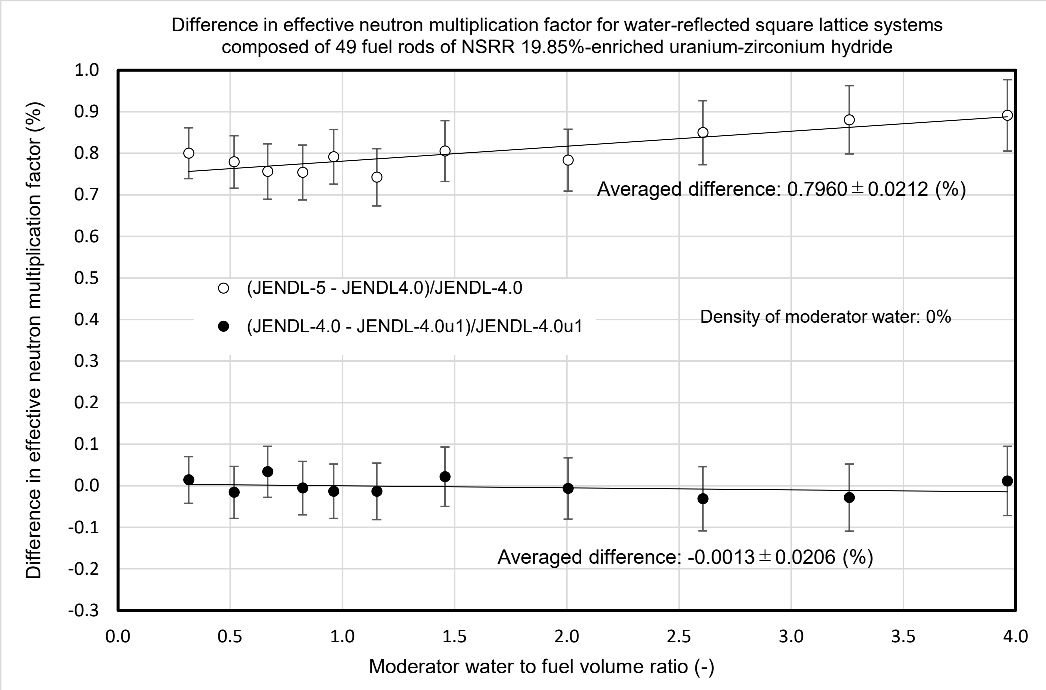

Fig.A.4.6(10) Difference in effective neutron multiplication factor for water-reflected square lattice systems composed of 49 fuel rods among different JENDL libraries, density of moderator water: 0 %.

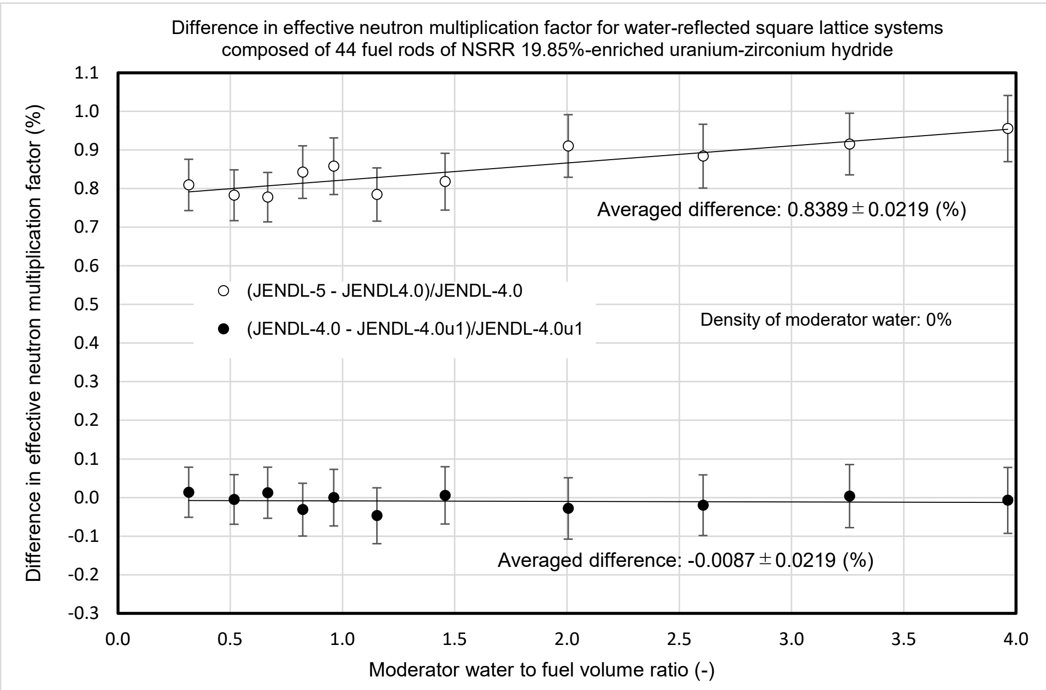

Fig.A.4.6(11) Difference in effective neutron multiplication factor for water-reflected square lattice systems composed of 44 fuel rods among different JENDL libraries, density of moderator water: 0 %.

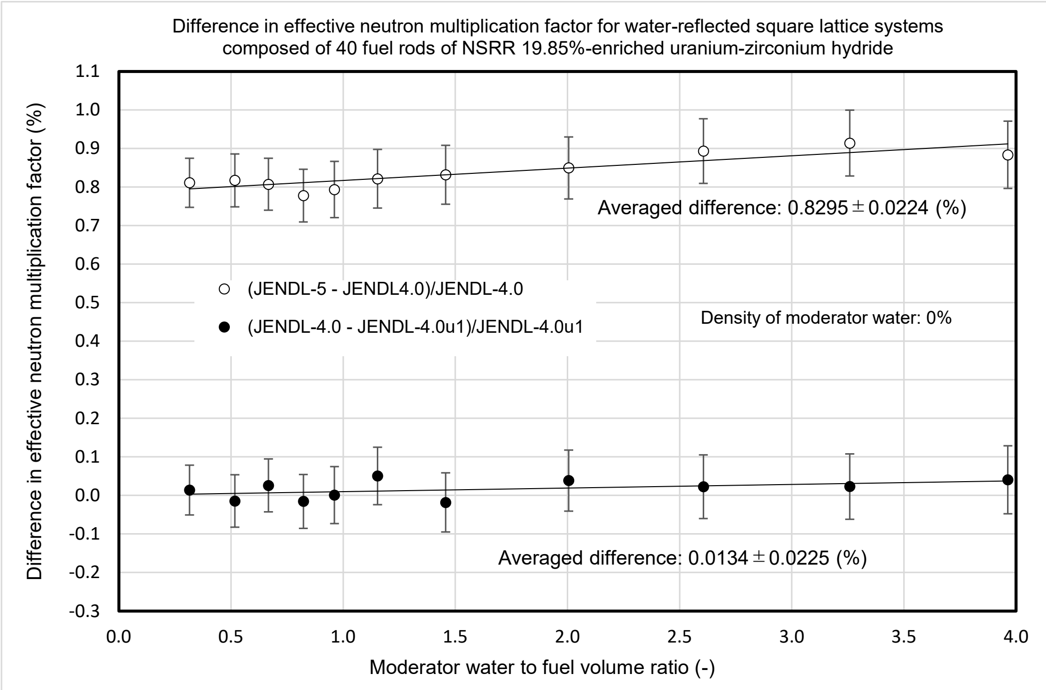

Fig.A.4.6(12) Difference in effective neutron multiplication factor for water-reflected square lattice systems composed of 40 fuel rods among different JENDL libraries, density of moderator water: 0 %.

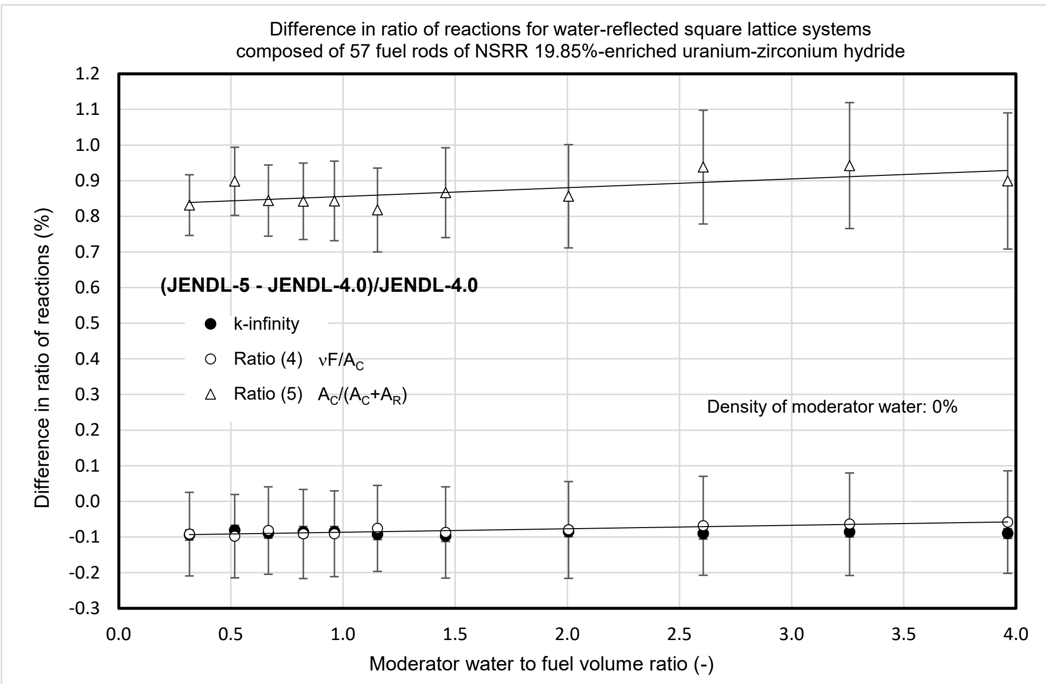

Fig.A.4.6(13) Difference in ratio of reactions for water-reflected square lattice systems composed of 57 fuel rods among different JENDL libraries, density of moderator water: 0 %.

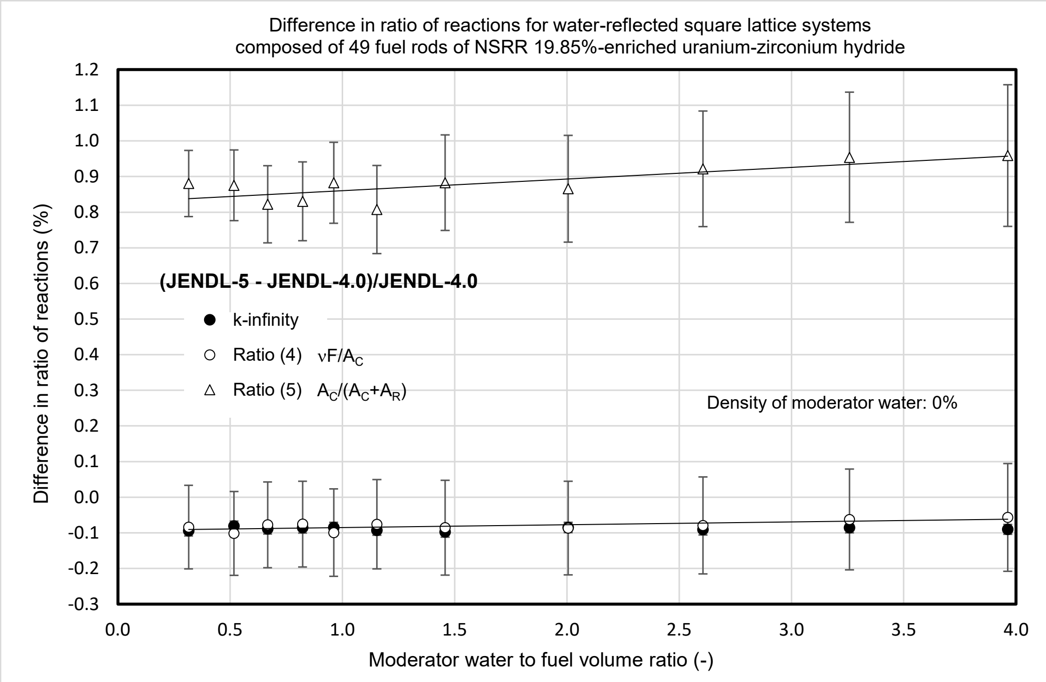

Fig.A.4.6(14) Difference in ratio of reactions
for water-reflected square lattice systems composed of 49 fuel rods
among different JENDL libraries, density of moderator water: 0 %.

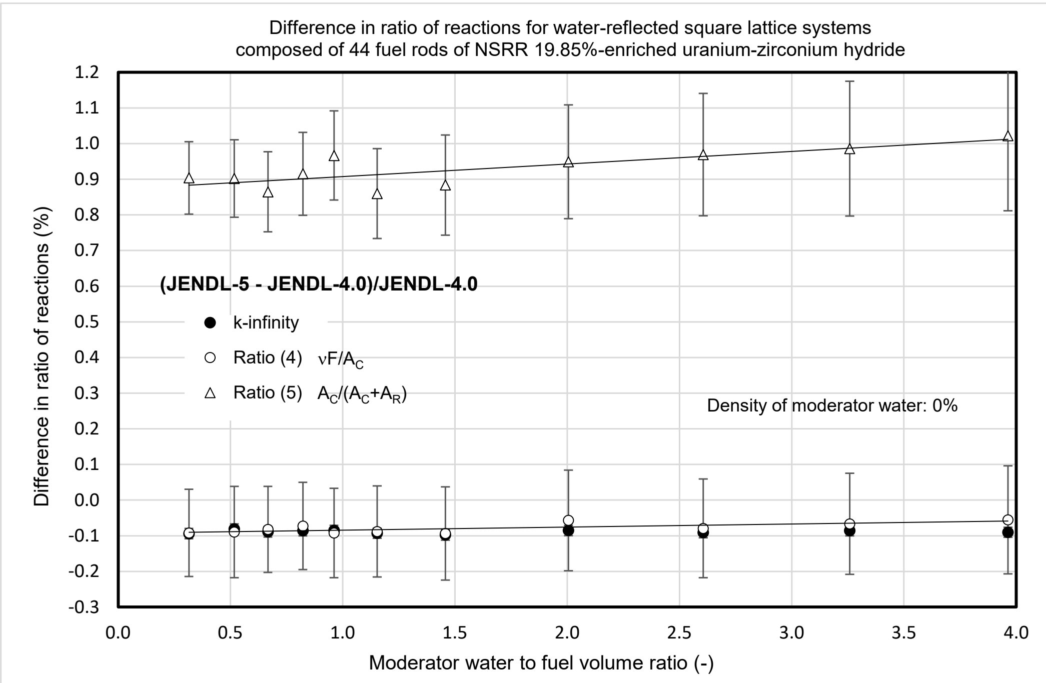

Fig.A.4.6(15) Difference in ratio of reactions
for water-reflected square lattice systems composed of 44 fuel rods
among different JENDL libraries, density of moderator water: 0 %.

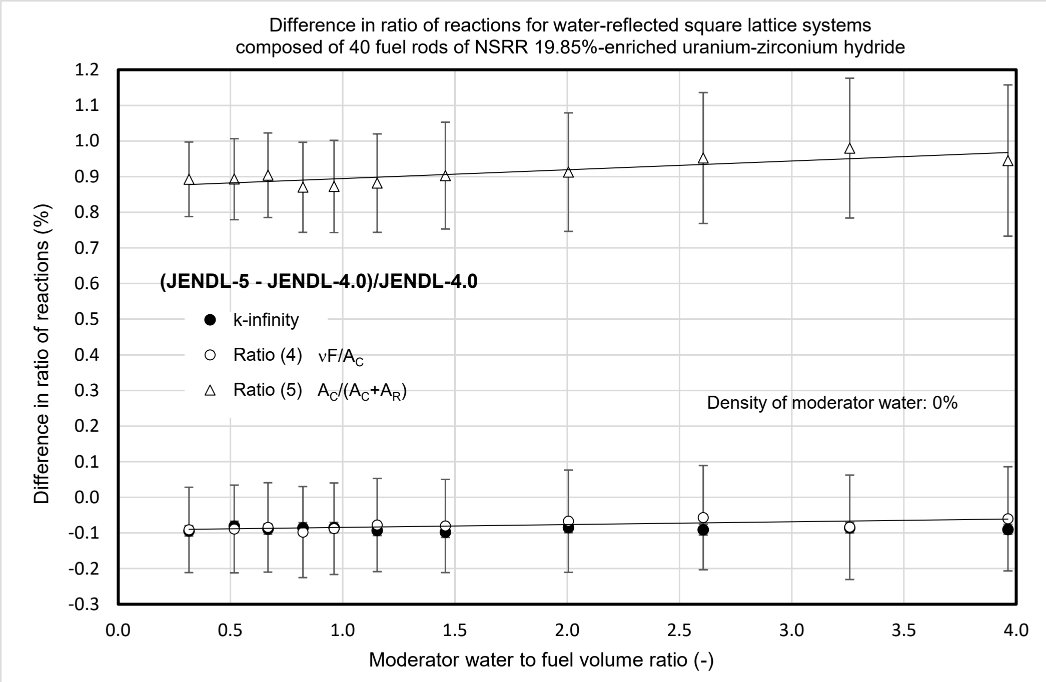

Fig.A.4.6(16) Difference in ratio of reactions
for water-reflected square lattice systems composed of 40 fuel rods
among different JENDL libraries, density of moderator water: 0 %.

(3) Effective neutron multiplication factor and ratio of reactions for hexagonal lattice systems containing no moderator water composed of 61 to 217 fuel rods

For the hexagonal lattice systems containing no moderator water, the differences in k_{eff} among the different JENDL libraries are shown in Figs.A.4.7(1) and A.4.7(2), and the differences in related ratios of reactions are also shown in Figs.A.4.7(3) and A.4.7(4).

For the water-reflected condition, it is shown in Fig.A.4.7(1) that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries decrease gradually as the number of fuel rods increases. This means that the smaller difference in k_{eff} occurs in the case of the smaller geometrical buckling for the horizontal direction and less neutron leakage from the system. It is also confirmed that the differences between the JENDL-4.0 and JENDL-4.0u1 libraries are smaller than three times their σ's, similar to the results shown in Sec.(2). As seen in the differences between the JENDL-5 and JENDL-4.0 libraries of Fig.A.4.7(3), it is confirmed that the differences in Ratio(4) are nearly constant in the full range of the number of fuel rods, which are the same values as those in k_{inf}. It is also confirmed that the differences in Ratio(5) decrease gradually as the number of fuel rods increases like the differences in k_{eff}. In addition, the differences in

Ratio(5) are larger than those in Ratio(4). Therefore, it is seen that the differences in Ratio(5) between the JENDL-5 and JENDL-4.0 libraries largely affect those in k_{eff}, similar to the results shown in Sec.(2) under the condition that the density of the moderator water was 0 %.

For the no-water-reflected condition, it is also shown in Fig.A.4.7(2) that the differences in k_{eff} between the JENDL-5 and JENDL-4.0 libraries decrease gradually as the number of fuel rods increases, but the differences are larger than those of the water-reflected condition. It is considered that the larger difference in k_{eff} is brought by the larger neutron leakage from the system without the water reflector. As seen in the differences between the JENDL-5 and JENDL-4.0 libraries of Fig.A.4.7(4), it is confirmed that the differences in both Ratio(4) and Ratio(5) are nearly constant in the whole range of the number of fuel rods and quite small in comparison with the differences in k_{eff}. On the no-water-reflected condition, it is found that the differences in the neutron leakage from the system affect largely those in k_{eff} rather than Ratio(4) and Ratio(5).

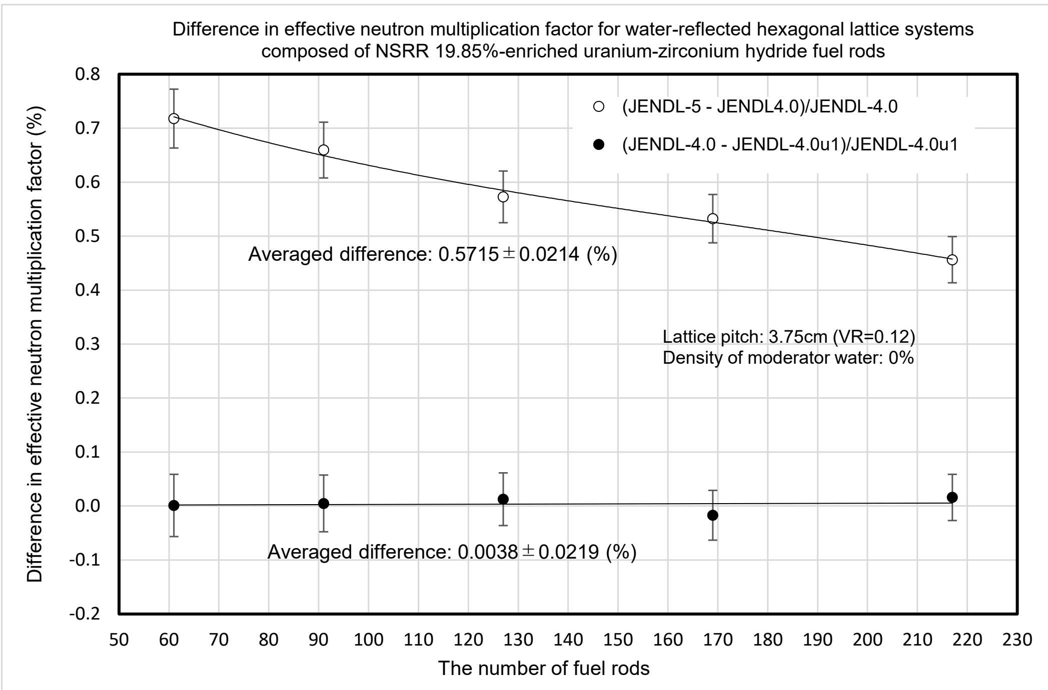

Fig.A.4.7(1) Difference in effective neutron multiplication factor as function of the number of fuel rods among different JENDL libraries, water-reflected hexagonal lattice systems containing no moderator water.

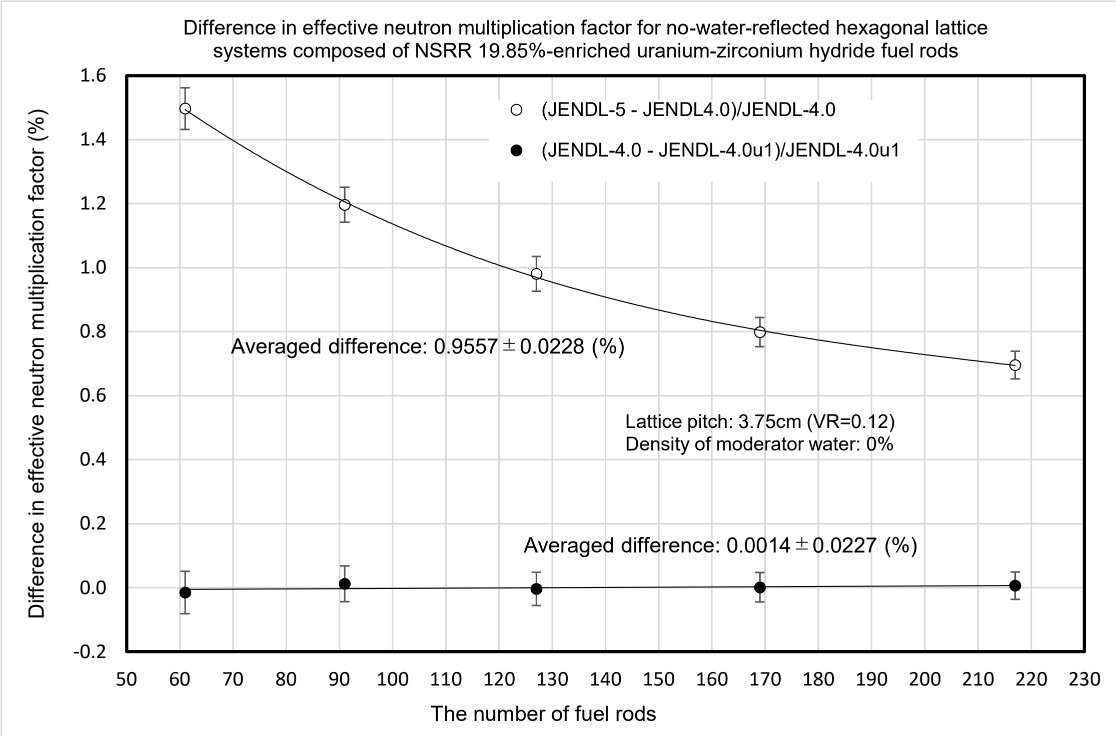

Fig.A.4.7(2) Difference in effective neutron multiplication factor as function of the number of fuel rods among different JENDL libraries, no-water-reflected hexagonal lattice systems containing no moderator water.

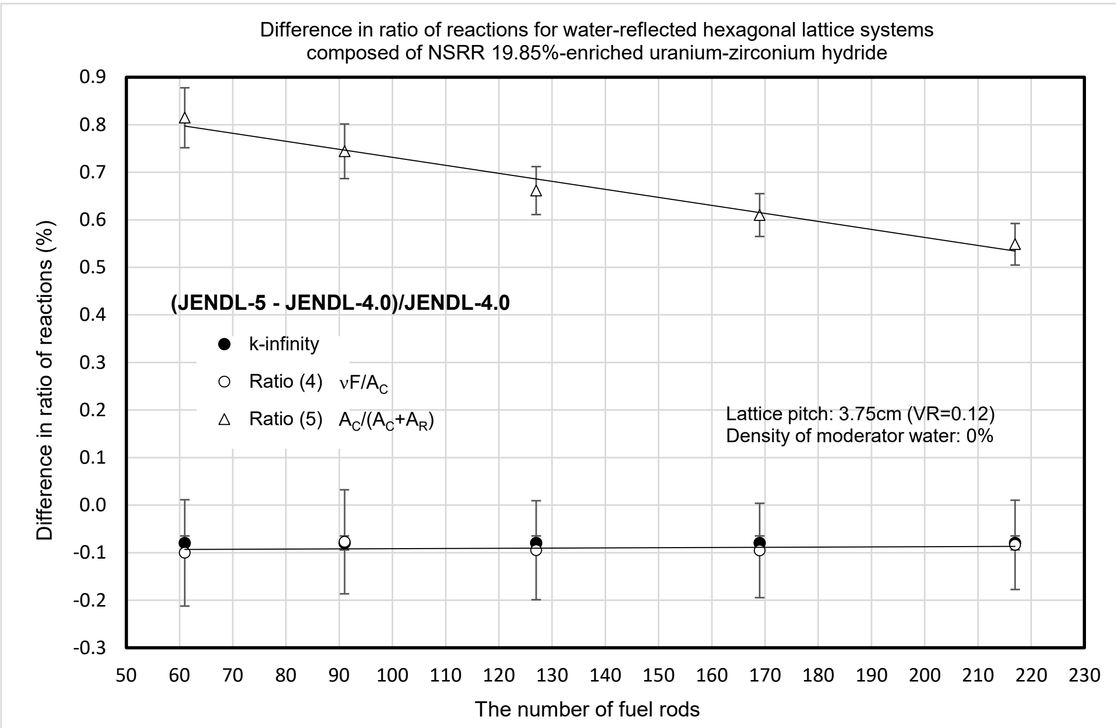

Fig.A.4.7(3) Difference in ratio of reactions as function of the number of fuel rods among different JENDL libraries, water-reflected hexagonal lattice systems containing no moderator water.

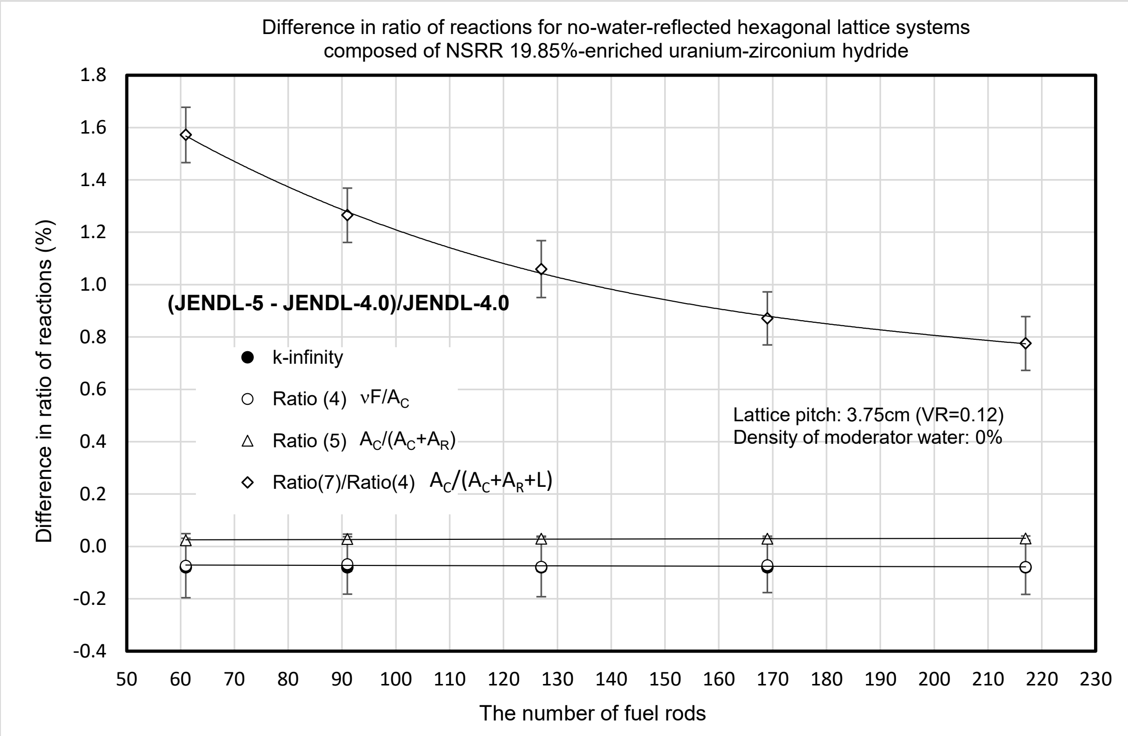

Fig.A.4.7(4) Difference in ratio of reactions
as function of the number of fuel rods among different JENDL libraries,
no-water-reflected hexagonal lattice systems containing no moderator water.

Appendix-5 Effect of Neutron Leakage from Water-reflected Finite Lattice Systems

As shown in Sec.2.3, the finite lattice systems have 30 cm thick reflector water surrounding the fuel rod lattice. On this condition, it is confirmed from the numerical data lists in Appendix-2 that there are differences not to be ignored between Ratio(6) defined by Eq.(3.2.3) and Ratio(7) defined by Eq.(3.2.4) in Sec.3.2. The differences are caused by the neutron leakage from the finite lattice systems. Hence, the results of additional calculations are shown hereafter on similar finite lattice systems, but they have twice as much as the thickness of the reflector water in Sec.2.3, i.e., 60 cm thick reflector water, as the conditions of the reflector water. It is considered that the effect of the neutron leakage to k_{eff} is examined by comparisons between results from the conditions of 30 and 60 cm thick reflector water. The additional calculations were conducted using the JENDL-5 library, and the densities of the moderator water were set to be 100 and 0 %.

(1) Finite hexagonal lattice system composed of 55, 49, 43 and 40 fuel rods

The numerical data calculated additionally for the finite hexagonal lattice systems composed of 55, 49, 43 and 40 fuel rods under the condition of 60 cm thick reflector water are listed in Tables A.5.1(1) and A.5.1(2), Tables A.5.2(1) and A.5.2(2), Tables A.5.3(1) and A.5.3(2), and Tables A.5.4(1) and A.5.4(2), respectively.

Figures A.5.1 to A.5.4 show the differences between Ratio(6) and Ratio(7) for the lattice systems of 30 cm thick reflector water. It is seen that the differences for 0 % of the density of the moderator water are larger than those for 100 % of the density, and the averaged differences for 100 and 0 % of the densities are in the range of 0.17 to 0.20 % and 0.27 to 0.34 %, respectively. On the other hand, it is found in Figs.A.5.5 to A.5.8 that the differences between Ratio(6) and Ratio(7) under the condition of 60 cm thick reflector water are smaller than three times their σ's, thus the effect of neutron leakage from the finite lattice systems is negligible.

It is, however, confirmed that the differences in k_{eff} between 30 and 60 cm thick reflector water are smaller than three times their σ's and not significant, as listed in Tables A.5.1(1) to A.5.4(2). Hence, it is concluded that the condition of 30 cm thick reflector water means sufficient thickness of the reflector water for the present lattice systems.

Table A.5.1(1) Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems, using JENDL-5, 55 fuel rods, 60 cm thick reflector water, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.12	1.00772 ± 0.00040	1.52022 ± 0.00118	0.66267 ± 0.00034	1.00741 ± 0.00077	1.00735 ± 0.00077	-0.00020 ± 0.00056
4.00	0.29	1.02635 ± 0.00041	1.50781 ± 0.00116	0.68052 ± 0.00034	1.02610 ± 0.00078	1.02605 ± 0.00078	0.00001 ± 0.00058
4.175	0.42	1.03437 ± 0.00037	1.49580 ± 0.00120	0.69132 ± 0.00033	1.03408 ± 0.00082	1.03403 ± 0.00082	-0.00035 ± 0.00052
4.35	0.56	1.03849 ± 0.00038	1.48119 ± 0.00114	0.70096 ± 0.00033	1.03825 ± 0.00080	1.03820 ± 0.00080	0.00013 ± 0.00053
4.50	0.68	1.03887 ± 0.00039	1.46653 ± 0.00107	0.70827 ± 0.00031	1.03870 ± 0.00076	1.03865 ± 0.00076	-0.00020 ± 0.00054
4.70	0.84	1.03636 ± 0.00039	1.44422 ± 0.00110	0.71749 ± 0.00031	1.03621 ± 0.00079	1.03616 ± 0.00079	0.00014 ± 0.00054
5.00	1.11	1.02527 ± 0.00039	1.40587 ± 0.00107	0.72916 ± 0.00033	1.02510 ± 0.00079	1.02506 ± 0.00079	-0.00012 ± 0.00053
5.50	1.58	0.99291 ± 0.00036	1.33190 ± 0.00102	0.74536 ± 0.00029	0.99275 ± 0.00075	0.99271 ± 0.00075	0.00004 ± 0.00051
6.00	2.10	0.94845 ± 0.00035	1.25041 ± 0.00090	0.75839 ± 0.00028	0.94830 ± 0.00069	0.94827 ± 0.00069	0.00006 ± 0.00050
6.50	2.67	0.89676 ± 0.00033	1.16578 ± 0.00091	0.76909 ± 0.00027	0.89659 ± 0.00069	0.89657 ± 0.00069	0.00003 ± 0.00046
7.00	3.28	0.84140 ± 0.00032	1.08147 ± 0.00084	0.77790 ± 0.00027	0.84127 ± 0.00065	0.84125 ± 0.00065	-0.00022 ± 0.00045

Table A.5.1(2) Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems, using JENDL-5, 55 fuel rods, 60 cm thick reflector water, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.12	0.95847 ± 0.00040	1.52897 ± 0.00124	0.62665 ± 0.00035	0.95814 ± 0.00075	0.95808 ± 0.00075	-0.00012 ± 0.00055
4.00	0.29	0.91706 ± 0.00038	1.53149 ± 0.00124	0.59861 ± 0.00036	0.91677 ± 0.00071	0.91671 ± 0.00071	-0.00001 ± 0.00055
4.175	0.42	0.88948 ± 0.00039	1.53361 ± 0.00124	0.57987 ± 0.00038	0.88930 ± 0.00070	0.88924 ± 0.00070	-0.00006 ± 0.00054
4.35	0.56	0.86402 ± 0.00038	1.53554 ± 0.00130	0.56254 ± 0.00039	0.86379 ± 0.00070	0.86374 ± 0.00070	-0.00007 ± 0.00055
4.50	0.68	0.84359 ± 0.00037	1.53716 ± 0.00131	0.54878 ± 0.00040	0.84357 ± 0.00068	0.84352 ± 0.00068	-0.00022 ± 0.00053
4.70	0.84	0.81859 ± 0.00039	1.53917 ± 0.00136	0.53172 ± 0.00040	0.81841 ± 0.00068	0.81836 ± 0.00068	-0.00024 ± 0.00055
5.00	1.11	0.78435 ± 0.00038	1.54224 ± 0.00142	0.50841 ± 0.00044	0.78409 ± 0.00068	0.78404 ± 0.00068	-0.00026 ± 0.00052
5.50	1.58	0.73510 ± 0.00038	1.54701 ± 0.00137	0.47518 ± 0.00045	0.73511 ± 0.00062	0.73506 ± 0.00062	-0.00001 ± 0.00053
6.00	2.10	0.69263 ± 0.00035	1.55142 ± 0.00149	0.44630 ± 0.00047	0.69239 ± 0.00062	0.69235 ± 0.00062	0.00004 ± 0.00050
6.50	2.67	0.65598 ± 0.00036	1.55586 ± 0.00150	0.42155 ± 0.00046	0.65588 ± 0.00058	0.65584 ± 0.00058	0.00025 ± 0.00049
7.00	3.28	0.62301 ± 0.00036	1.55992 ± 0.00156	0.39935 ± 0.00049	0.62295 ± 0.00057	0.62290 ± 0.00057	0.00005 ± 0.00051

Table A.5.2(1) Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems, using JENDL-5, 49 fuel rods, 60 cm thick reflector water, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.12	0.98564 ± 0.00038	1.52583 ± 0.00118	0.64582 ± 0.00036	0.98542 ± 0.00075	0.98536 ± 0.00075	0.00033 ± 0.00053
4.00	0.29	1.00255 ± 0.00038	1.51141 ± 0.00122	0.66316 ± 0.00033	1.00231 ± 0.00079	1.00226 ± 0.00079	-0.00001 ± 0.00054
4.175	0.42	1.00935 ± 0.00038	1.49872 ± 0.00111	0.67339 ± 0.00033	1.00922 ± 0.00074	1.00918 ± 0.00074	-0.00017 ± 0.00054
4.35	0.56	1.01313 ± 0.00037	1.48327 ± 0.00114	0.68287 ± 0.00031	1.01287 ± 0.00076	1.01283 ± 0.00076	-0.00011 ± 0.00054
4.50	0.68	1.01365 ± 0.00037	1.46812 ± 0.00108	0.69032 ± 0.00031	1.01348 ± 0.00073	1.01344 ± 0.00073	0.00027 ± 0.00054
4.70	0.84	1.01035 ± 0.00038	1.44511 ± 0.00106	0.69900 ± 0.00032	1.01013 ± 0.00073	1.01009 ± 0.00073	-0.00017 ± 0.00055
5.00	1.11	0.99928 ± 0.00037	1.40588 ± 0.00107	0.71061 ± 0.00030	0.99903 ± 0.00075	0.99899 ± 0.00075	-0.00019 ± 0.00051
5.50	1.58	0.96828 ± 0.00037	1.33137 ± 0.00101	0.72715 ± 0.00030	0.96811 ± 0.00073	0.96808 ± 0.00073	0.00013 ± 0.00050
6.00	2.10	0.92541 ± 0.00035	1.24956 ± 0.00094	0.74050 ± 0.00030	0.92530 ± 0.00070	0.92528 ± 0.00070	0.00007 ± 0.00049
6.50	2.67	0.87563 ± 0.00035	1.16497 ± 0.00091	0.75151 ± 0.00029	0.87549 ± 0.00068	0.87546 ± 0.00068	0.00011 ± 0.00049
7.00	3.28	0.82249 ± 0.00034	1.08067 ± 0.00090	0.76093 ± 0.00028	0.82232 ± 0.00069	0.82230 ± 0.00069	0.00001 ± 0.00048

Table A.5.2(2) Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems, using JENDL-5, 49 fuel rods, 60 cm thick reflector water, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.12	0.93945 ± 0.00039	1.53583 ± 0.00125	0.61161 ± 0.00037	0.93932 ± 0.00074	0.93927 ± 0.00074	0.00009 ± 0.00054
4.00	0.29	0.89977 ± 0.00037	1.53876 ± 0.00125	0.58469 ± 0.00037	0.89969 ± 0.00070	0.89964 ± 0.00070	-0.00018 ± 0.00053
4.175	0.42	0.87397 ± 0.00039	1.54089 ± 0.00125	0.56703 ± 0.00039	0.87374 ± 0.00069	0.87369 ± 0.00069	0.00006 ± 0.00055
4.35	0.56	0.84974 ± 0.00039	1.54303 ± 0.00126	0.55068 ± 0.00038	0.84972 ± 0.00066	0.84966 ± 0.00066	-0.00008 ± 0.00056
4.50	0.68	0.83036 ± 0.00038	1.54473 ± 0.00137	0.53735 ± 0.00040	0.83006 ± 0.00069	0.83001 ± 0.00069	-0.00004 ± 0.00055
4.70	0.84	0.80649 ± 0.00038	1.54676 ± 0.00137	0.52136 ± 0.00042	0.80641 ± 0.00068	0.80636 ± 0.00068	0.00053 ± 0.00054
5.00	1.11	0.77309 ± 0.00039	1.54983 ± 0.00143	0.49875 ± 0.00044	0.77298 ± 0.00067	0.77294 ± 0.00067	-0.00016 ± 0.00054
5.50	1.58	0.72486 ± 0.00036	1.55456 ± 0.00144	0.46613 ± 0.00043	0.72462 ± 0.00062	0.72458 ± 0.00062	-0.00006 ± 0.00053
6.00	2.10	0.68310 ± 0.00034	1.55919 ± 0.00150	0.43806 ± 0.00045	0.68302 ± 0.00060	0.68297 ± 0.00060	0.00011 ± 0.00050
6.50	2.67	0.64623 ± 0.00035	1.56337 ± 0.00145	0.41333 ± 0.00046	0.64619 ± 0.00055	0.64615 ± 0.00055	-0.00009 ± 0.00051
7.00	3.28	0.61337 ± 0.00036	1.56730 ± 0.00163	0.39138 ± 0.00051	0.61341 ± 0.00058	0.61337 ± 0.00058	-0.00006 ± 0.00051

Table A.5.3(1) Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems, using JENDL-5, 43 fuel rods, 60 cm thick reflector water, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.12	0.95453 ± 0.00038	1.52397 ± 0.00124	0.62618 ± 0.00035	0.95429 ± 0.00075	0.95424 ± 0.00075	0.00049 ± 0.00053
4.00	0.29	0.97365 ± 0.00040	1.51002 ± 0.00122	0.64462 ± 0.00035	0.97338 ± 0.00077	0.97334 ± 0.00077	-0.00002 ± 0.00054
4.175	0.42	0.98237 ± 0.00038	1.49751 ± 0.00116	0.65581 ± 0.00033	0.98208 ± 0.00074	0.98204 ± 0.00074	-0.00003 ± 0.00054
4.35	0.56	0.98767 ± 0.00037	1.48233 ± 0.00109	0.66616 ± 0.00032	0.98747 ± 0.00072	0.98743 ± 0.00072	0.00006 ± 0.00051
4.50	0.68	0.98919 ± 0.00038	1.46715 ± 0.00108	0.67408 ± 0.00033	0.98897 ± 0.00072	0.98893 ± 0.00072	0.00025 ± 0.00054
4.70	0.84	0.98787 ± 0.00040	1.44448 ± 0.00110	0.68372 ± 0.00034	0.98762 ± 0.00075	0.98758 ± 0.00075	-0.00012 ± 0.00054
5.00	1.11	0.97950 ± 0.00037	1.40564 ± 0.00107	0.69674 ± 0.00031	0.97936 ± 0.00074	0.97932 ± 0.00074	0.00020 ± 0.00053
5.50	1.58	0.95155 ± 0.00036	1.33138 ± 0.00097	0.71462 ± 0.00031	0.95143 ± 0.00069	0.95139 ± 0.00069	-0.00013 ± 0.00050
6.00	2.10	0.91159 ± 0.00034	1.24983 ± 0.00089	0.72936 ± 0.00030	0.91158 ± 0.00066	0.91155 ± 0.00066	-0.00020 ± 0.00049
6.50	2.67	0.86440 ± 0.00032	1.16532 ± 0.00088	0.74163 ± 0.00028	0.86423 ± 0.00065	0.86421 ± 0.00065	0.00019 ± 0.00047
7.00	3.28	0.81304 ± 0.00031	1.08113 ± 0.00080	0.75192 ± 0.00029	0.81292 ± 0.00061	0.81290 ± 0.00061	-0.00002 ± 0.00046

Table A.5.3(2) Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems, using JENDL-5, 43 fuel rods, 60 cm thick reflector water, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.12	0.90600 ± 0.00038	1.53388 ± 0.00125	0.59052 ± 0.00037	0.90579 ± 0.00071	0.90574 ± 0.00071	-0.00018 ± 0.00055
4.00	0.29	0.86661 ± 0.00038	1.53673 ± 0.00126	0.56381 ± 0.00039	0.86642 ± 0.00068	0.86637 ± 0.00068	-0.00026 ± 0.00056
4.175	0.42	0.84073 ± 0.00039	1.53878 ± 0.00131	0.54624 ± 0.00040	0.84054 ± 0.00068	0.84049 ± 0.00068	-0.00032 ± 0.00055
4.35	0.56	0.81684 ± 0.00037	1.54082 ± 0.00131	0.53011 ± 0.00041	0.81680 ± 0.00066	0.81675 ± 0.00066	-0.00049 ± 0.00053
4.50	0.68	0.79814 ± 0.00036	1.54246 ± 0.00137	0.51730 ± 0.00042	0.79791 ± 0.00067	0.79786 ± 0.00067	-0.00003 ± 0.00051
4.70	0.84	0.77472 ± 0.00037	1.54459 ± 0.00143	0.50149 ± 0.00045	0.77460 ± 0.00068	0.77456 ± 0.00068	-0.00020 ± 0.00054
5.00	1.11	0.74309 ± 0.00038	1.54774 ± 0.00143	0.48001 ± 0.00044	0.74294 ± 0.00064	0.74290 ± 0.00064	0.00040 ± 0.00052
5.50	1.58	0.69670 ± 0.00037	1.55250 ± 0.00149	0.44872 ± 0.00045	0.69663 ± 0.00062	0.69659 ± 0.00062	-0.00017 ± 0.00052
6.00	2.10	0.65688 ± 0.00034	1.55701 ± 0.00150	0.42176 ± 0.00046	0.65669 ± 0.00058	0.65665 ± 0.00058	-0.00045 ± 0.00051
6.50	2.67	0.62267 ± 0.00036	1.56120 ± 0.00156	0.39879 ± 0.00049	0.62259 ± 0.00057	0.62256 ± 0.00057	0.00024 ± 0.00051
7.00	3.28	0.59184 ± 0.00037	1.56533 ± 0.00162	0.37804 ± 0.00052	0.59176 ± 0.00056	0.59173 ± 0.00056	-0.00002 ± 0.00050

Table A.5.4(1) Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems, using JENDL-5, 40 fuel rods, 60 cm thick reflector water, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.12	0.93567 ± 0.00036	1.52327 ± 0.00118	0.61410 ± 0.00035	0.93544 ± 0.00070	0.93539 ± 0.00070	-0.00018 ± 0.00054
4.00	0.29	0.95606 ± 0.00036	1.50943 ± 0.00111	0.63327 ± 0.00034	0.95588 ± 0.00069	0.95583 ± 0.00069	-0.00010 ± 0.00054
4.175	0.42	0.96614 ± 0.00038	1.49695 ± 0.00116	0.64536 ± 0.00036	0.96607 ± 0.00074	0.96603 ± 0.00074	0.00043 ± 0.00053
4.35	0.56	0.97181 ± 0.00036	1.48161 ± 0.00109	0.65574 ± 0.00032	0.97156 ± 0.00070	0.97152 ± 0.00070	-0.00002 ± 0.00051
4.50	0.68	0.97402 ± 0.00038	1.46684 ± 0.00107	0.66391 ± 0.00034	0.97384 ± 0.00071	0.97380 ± 0.00071	-0.00001 ± 0.00054
4.70	0.84	0.97349 ± 0.00037	1.44425 ± 0.00106	0.67394 ± 0.00032	0.97333 ± 0.00071	0.97330 ± 0.00071	-0.00030 ± 0.00052
5.00	1.11	0.96656 ± 0.00036	1.40554 ± 0.00107	0.68760 ± 0.00032	0.96645 ± 0.00073	0.96642 ± 0.00073	0.00002 ± 0.00050
5.50	1.58	0.94075 ± 0.00036	1.33150 ± 0.00096	0.70639 ± 0.00031	0.94056 ± 0.00068	0.94053 ± 0.00068	0.00000 ± 0.00051
6.00	2.10	0.90234 ± 0.00034	1.24998 ± 0.00094	0.72178 ± 0.00030	0.90221 ± 0.00067	0.90218 ± 0.00067	0.00034 ± 0.00049
6.50	2.67	0.85674 ± 0.00037	1.16580 ± 0.00094	0.73481 ± 0.00031	0.85664 ± 0.00069	0.85662 ± 0.00069	0.00031 ± 0.00051
7.00	3.28	0.80674 ± 0.00035	1.08177 ± 0.00087	0.74564 ± 0.00029	0.80662 ± 0.00065	0.80660 ± 0.00065	0.00047 ± 0.00048

Table A.5.4(2) Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems, using JENDL-5, 40 fuel rods, 60 cm thick reflector water, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.12	0.88693 ± 0.00040	1.53289 ± 0.00124	0.57845 ± 0.00038	0.88670 ± 0.00070	0.88665 ± 0.00070	0.00024 ± 0.00055
4.00	0.29	0.84746 ± 0.00039	1.53587 ± 0.00131	0.55169 ± 0.00039	0.84732 ± 0.00069	0.84728 ± 0.00069	-0.00011 ± 0.00053
4.175	0.42	0.82246 ± 0.00038	1.53816 ± 0.00136	0.53463 ± 0.00040	0.82235 ± 0.00069	0.82231 ± 0.00069	0.00024 ± 0.00054
4.35	0.56	0.79867 ± 0.00037	1.54003 ± 0.00142	0.51851 ± 0.00042	0.79852 ± 0.00069	0.79847 ± 0.00069	-0.00011 ± 0.00054
4.50	0.68	0.78024 ± 0.00038	1.54167 ± 0.00137	0.50597 ± 0.00041	0.78004 ± 0.00065	0.78000 ± 0.00065	-0.00017 ± 0.00054
4.70	0.84	0.75705 ± 0.00039	1.54376 ± 0.00148	0.49033 ± 0.00045	0.75695 ± 0.00068	0.75690 ± 0.00068	-0.00041 ± 0.00054
5.00	1.11	0.72651 ± 0.00036	1.54684 ± 0.00149	0.46952 ± 0.00044	0.72628 ± 0.00064	0.72624 ± 0.00064	0.00024 ± 0.00051
5.50	1.58	0.68155 ± 0.00036	1.55188 ± 0.00150	0.43909 ± 0.00045	0.68142 ± 0.00060	0.68138 ± 0.00060	0.00006 ± 0.00052
6.00	2.10	0.64334 ± 0.00036	1.55636 ± 0.00155	0.41327 ± 0.00049	0.64319 ± 0.00059	0.64316 ± 0.00059	-0.00013 ± 0.00051
6.50	2.67	0.61026 ± 0.00036	1.56088 ± 0.00156	0.39092 ± 0.00050	0.61019 ± 0.00056	0.61015 ± 0.00056	0.00017 ± 0.00050
7.00	3.28	0.58085 ± 0.00034	1.56489 ± 0.00156	0.37111 ± 0.00051	0.58074 ± 0.00053	0.58071 ± 0.00053	0.00003 ± 0.00049

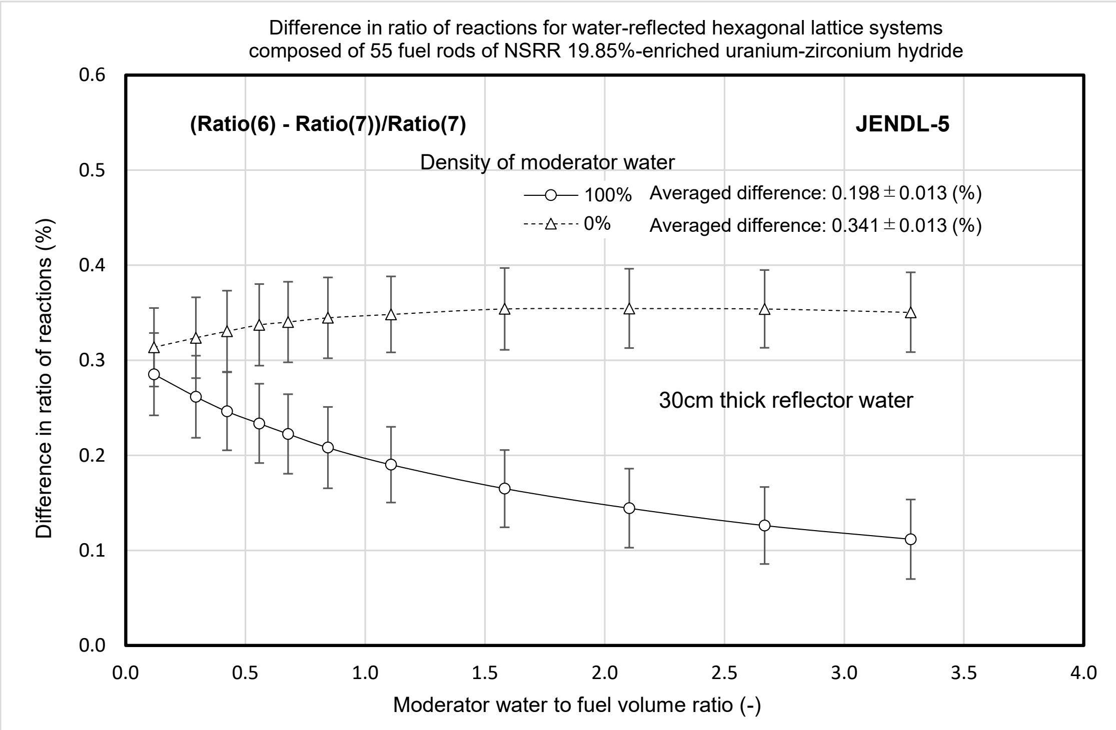

Fig.A.5.1 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems composed of 55 fuel rods, using JENDL-5, 30 cm thick reflector water.

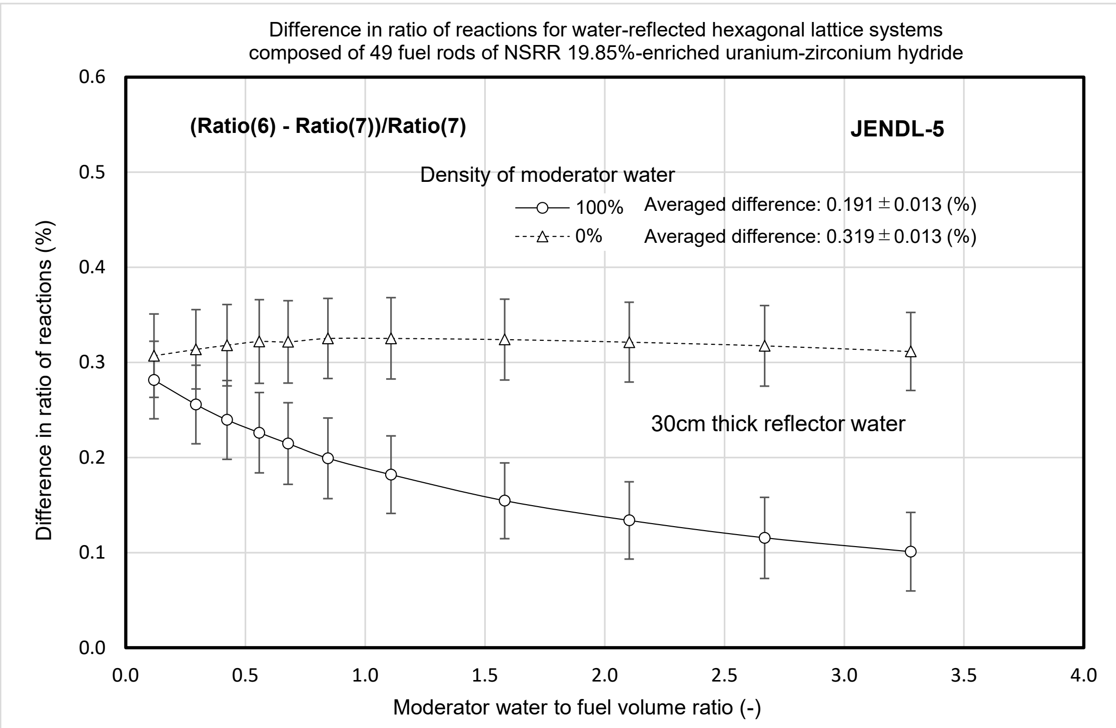

Fig.A.5.2 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems composed of 49 fuel rods, using JENDL-5, 30 cm thick reflector water.

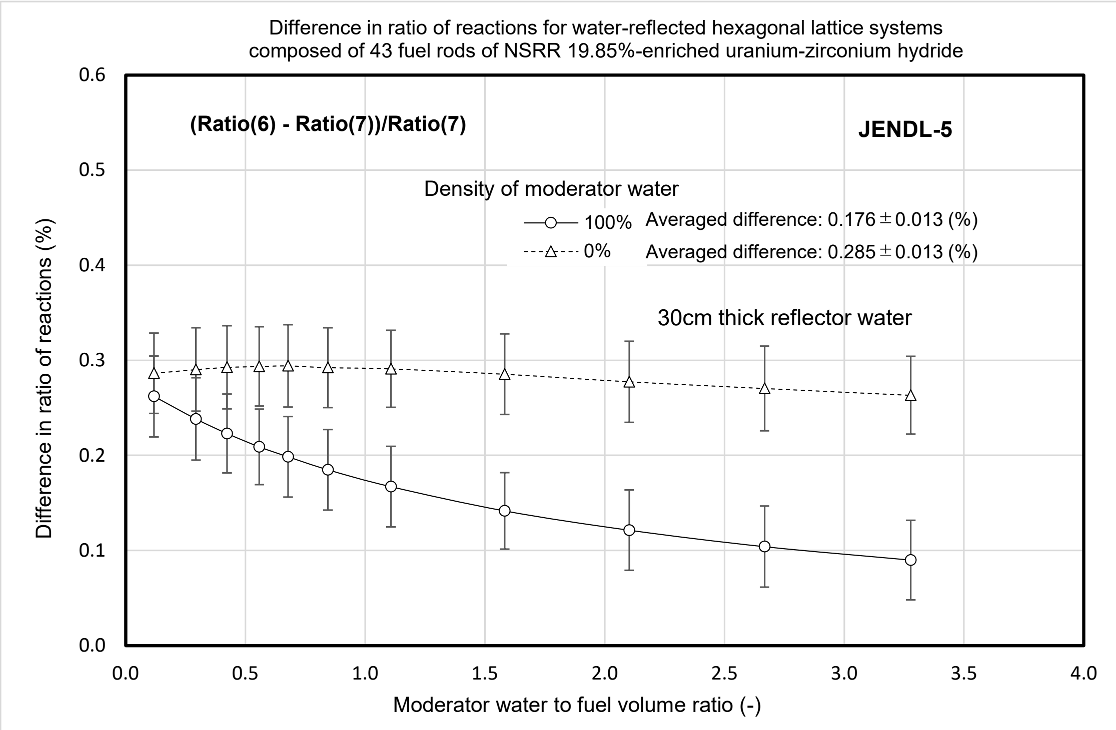

Fig.A.5.3 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems composed of 43 fuel rods, using JENDL-5, 30 cm thick reflector water.

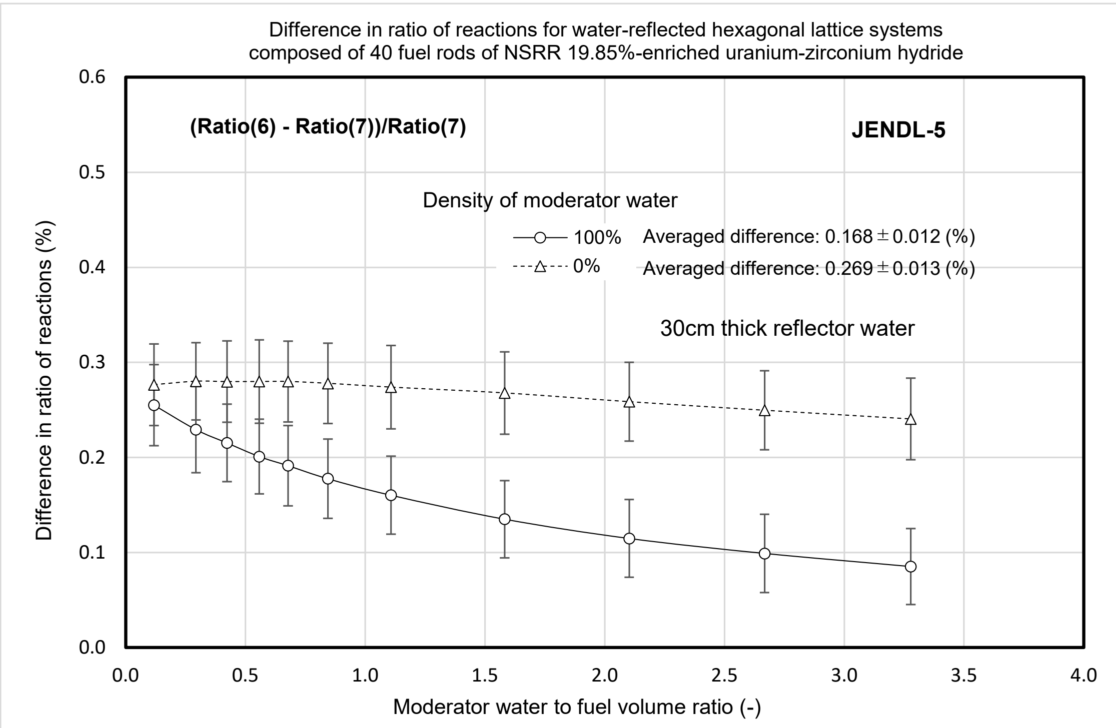

Fig.A.5.4 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems composed of 40 fuel rods, using JENDL-5, 30 cm thick reflector water.

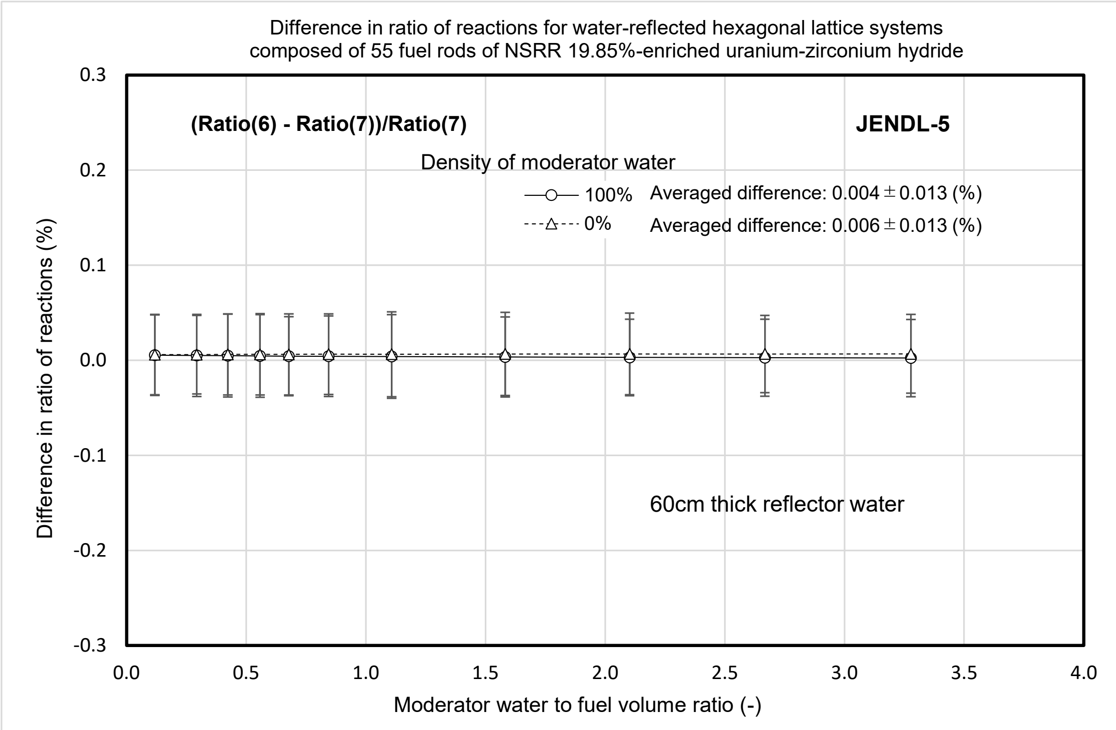

Fig.A.5.5 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems composed of 55 fuel rods, using JENDL-5, 60 cm thick reflector water.

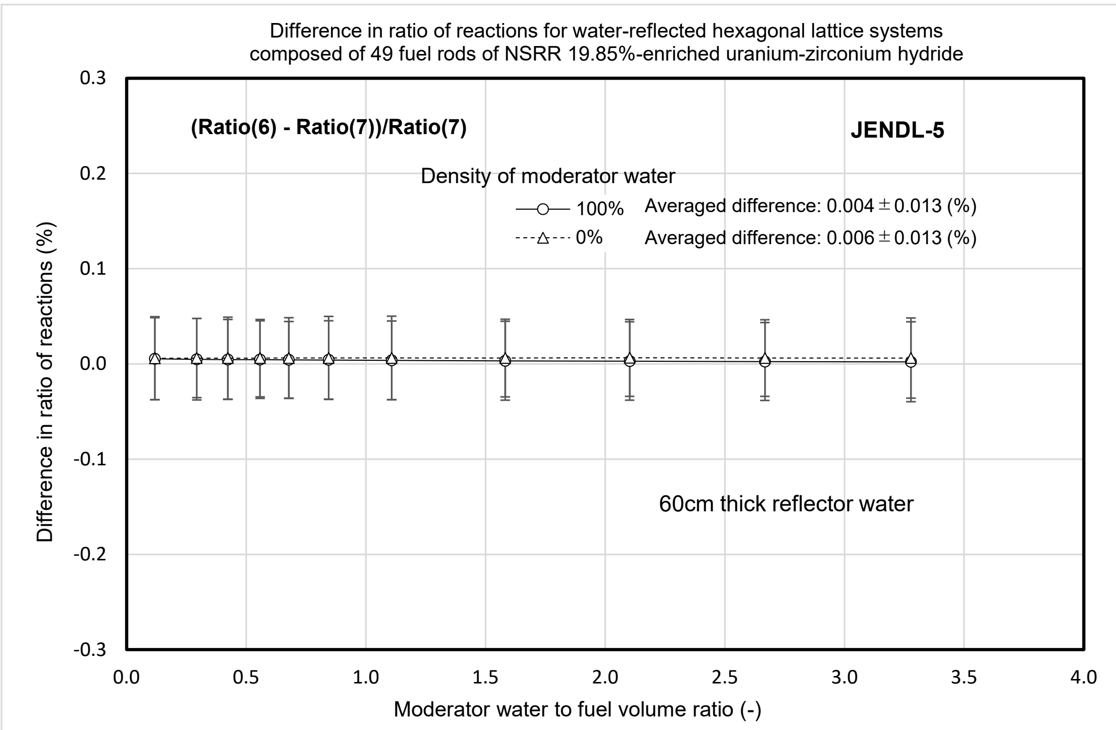

Fig.A.5.6 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems composed of 49 fuel rods, using JENDL-5, 60 cm thick reflector water.

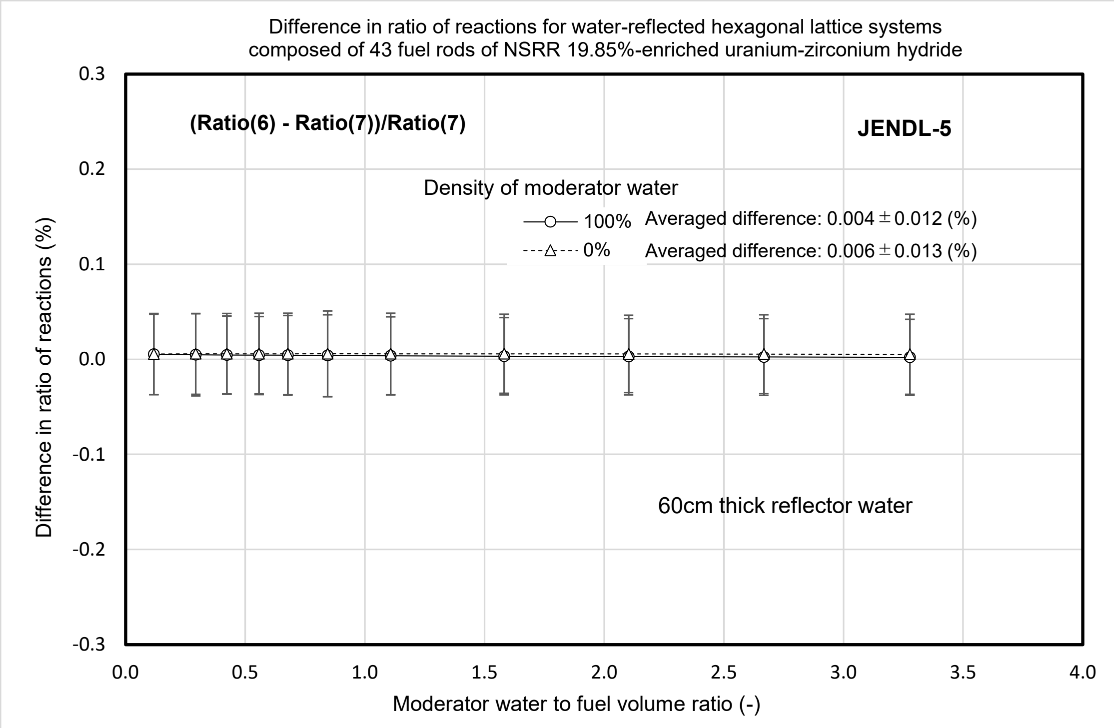

Fig.A.5.7 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems composed of 43 fuel rods, using JENDL-5, 60 cm thick reflector water.

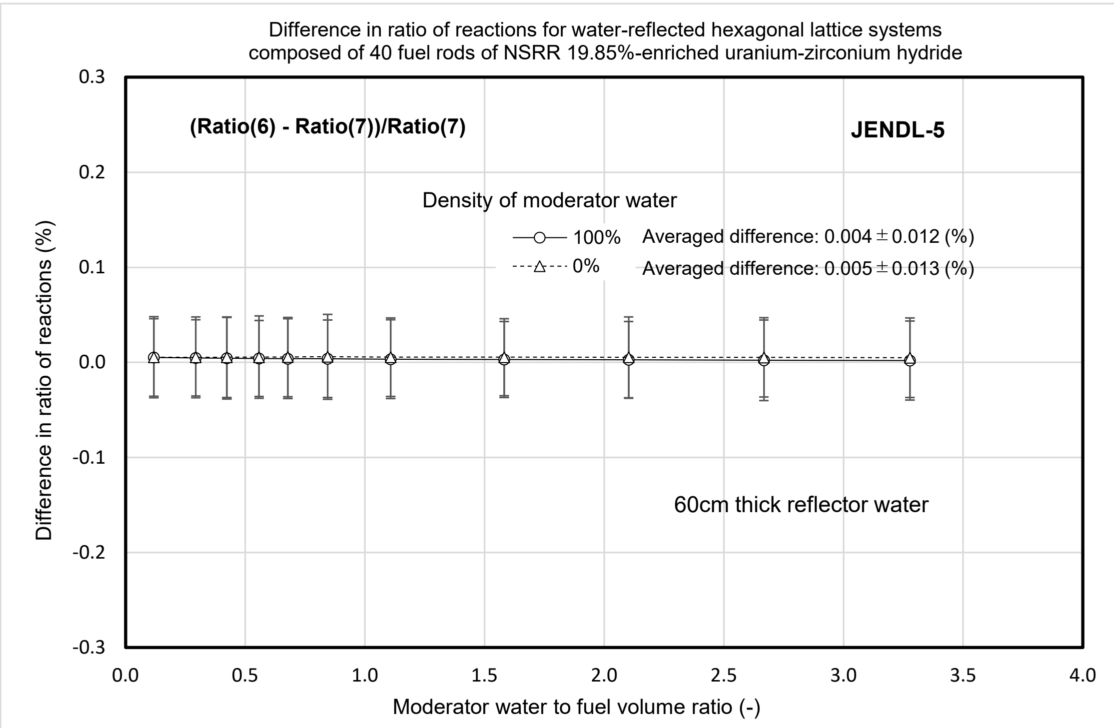

Fig.A.5.8 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems composed of 40 fuel rods, using JENDL-5, 60 cm thick reflector water.

(2) Finite square lattice system composed of 57, 49, 44 and 40 fuel rods

The numerical data calculated additionally for the finite square lattice systems composed of 57, 49, 44 and 40 fuel rods under the condition of 60 cm thick reflector water are listed in Tables A.5.5(1) and A.5.5(2), Tables A.5.6(1) and A.5.6(2), Tables A.5.7(1) and A.5.7(2), and Tables A.5.8(1) and A.5.8(2), respectively.

Figures A.5.9 to A.5.12 show the differences between Ratio(6) and Ratio(7) for the lattice systems of 30 cm thick reflector water. It is seen that the averaged differences for 100 and 0 % of the densities of the moderator water are in the range of 0.12 to 0.15 % and 0.22 to 0.28 %, respectively, and the latter is larger than the former like the results from the hexagonal lattice systems. It is also seen in Figs.A.5.13 to A.5.16 that the differences between Ratio(6) and Ratio(7) under the condition of 60 cm thick reflector water are smaller than three times their σ's like the results from the hexagonal lattice systems.

In addition, it is confirmed that the differences in k_{eff} between 30 and 60 cm thick reflector water are smaller than three times their σ's and not significant, as listed in Tables A.5.5(1) to A.5.8(2), thus the same conclusion is reached as mentioned for the results from the hexagonal lattice systems as mentioned above Sec.(1).

(3) Finite hexagonal lattice systems containing no moderator water composed of 61 to 217 fuel rods

The numerical data calculated additionally for the finite hexagonal lattice systems containing no moderator water composed of 61 to 217 fuel rods under the condition of 60 cm thick reflector water are listed in Table A.5.9.

Figure A.5.17 shows the differences between Ratio(6) and Ratio(7) for the lattice systems of 30 cm thick reflector water. It is seen that the difference decreases as the number of fuel rods and the averaged difference is 0.22 %. It is also seen in Fig.A.5.18 that the differences between Ratio(6) and Ratio(7) under the condition of 60 cm thick reflector water are smaller than three times their σ's like the results from the hexagonal and square lattice systems as mentioned above (1) and (2).

In addition, it is confirmed that the differences in k_{eff} between 30 and 60 cm thick reflector water are smaller than three times their σ's and not significant, as listed in Tables A.5.9, thus the same conclusion is reached as mentioned for the results from the hexagonal lattice systems as mentioned above Sec.(1).

Table A.5.5(1) Effective neutron multiplication factor and ratio of reactions for water-reflected square lattice systems, using JENDL-5, 57 fuel rods, 60 cm thick reflector water, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.32	1.03049 ± 0.00039	1.50302 ± 0.00110	0.68546 ± 0.00033	1.03026 ± 0.00075	1.03022 ± 0.00075	0.00012 ± 0.00054
4.00	0.52	1.03915 ± 0.00037	1.48175 ± 0.00116	0.70115 ± 0.00032	1.03893 ± 0.00079	1.03890 ± 0.00079	0.00001 ± 0.00053
4.175	0.67	1.04018 ± 0.00037	1.46376 ± 0.00107	0.71048 ± 0.00030	1.03998 ± 0.00075	1.03994 ± 0.00075	-0.00005 ± 0.00053
4.35	0.82	1.03729 ± 0.00039	1.44255 ± 0.00110	0.71887 ± 0.00030	1.03700 ± 0.00078	1.03697 ± 0.00078	-0.00010 ± 0.00055
4.50	0.96	1.03235 ± 0.00036	1.42293 ± 0.00099	0.72539 ± 0.00031	1.03218 ± 0.00072	1.03215 ± 0.00072	0.00022 ± 0.00053
4.70	1.15	1.02298 ± 0.00036	1.39424 ± 0.00101	0.73361 ± 0.00030	1.02283 ± 0.00074	1.02280 ± 0.00074	0.00024 ± 0.00051
5.00	1.46	1.00223 ± 0.00035	1.34679 ± 0.00097	0.74393 ± 0.00029	1.00192 ± 0.00072	1.00189 ± 0.00072	0.00041 ± 0.00051
5.50	2.01	0.95598 ± 0.00034	1.26082 ± 0.00095	0.75813 ± 0.00029	0.95586 ± 0.00072	0.95584 ± 0.00072	-0.00008 ± 0.00048
6.00	2.61	0.90125 ± 0.00034	1.17046 ± 0.00087	0.76991 ± 0.00028	0.90115 ± 0.00067	0.90113 ± 0.00067	0.00016 ± 0.00048
6.50	3.26	0.84192 ± 0.00034	1.08012 ± 0.00081	0.77936 ± 0.00029	0.84180 ± 0.00063	0.84179 ± 0.00063	0.00014 ± 0.00047
7.00	3.96	0.78179 ± 0.00032	0.99303 ± 0.00080	0.78714 ± 0.00029	0.78165 ± 0.00063	0.78164 ± 0.00063	0.00012 ± 0.00045

Table A.5.5(2) Effective neutron multiplication factor and ratio of reactions for water-reflected square lattice systems, using JENDL-5, 57 fuel rods, 60 cm thick reflector water, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.32	0.91760 ± 0.00039	1.53192 ± 0.00125	0.59880 ± 0.00037	0.91732 ± 0.00072	0.91728 ± 0.00072	-0.00043 ± 0.00054
4.00	0.52	0.87808 ± 0.00037	1.53475 ± 0.00125	0.57190 ± 0.00036	0.87772 ± 0.00068	0.87768 ± 0.00068	0.00013 ± 0.00054
4.175	0.67	0.85225 ± 0.00040	1.53684 ± 0.00131	0.55450 ± 0.00040	0.85217 ± 0.00069	0.85213 ± 0.00069	0.00004 ± 0.00054
4.35	0.82	0.82846 ± 0.00038	1.53868 ± 0.00136	0.53832 ± 0.00040	0.82831 ± 0.00069	0.82827 ± 0.00069	0.00030 ± 0.00053
4.50	0.96	0.80916 ± 0.00038	1.54032 ± 0.00131	0.52523 ± 0.00040	0.80902 ± 0.00065	0.80898 ± 0.00065	0.00015 ± 0.00054
4.70	1.15	0.78508 ± 0.00039	1.54257 ± 0.00142	0.50896 ± 0.00043	0.78511 ± 0.00068	0.78507 ± 0.00068	0.00021 ± 0.00054
5.00	1.46	0.75240 ± 0.00038	1.54571 ± 0.00143	0.48667 ± 0.00045	0.75225 ± 0.00065	0.75222 ± 0.00065	0.00007 ± 0.00052
5.50	2.01	0.70513 ± 0.00035	1.55061 ± 0.00144	0.45467 ± 0.00045	0.70502 ± 0.00061	0.70498 ± 0.00061	0.00014 ± 0.00052
6.00	2.61	0.66431 ± 0.00036	1.55506 ± 0.00155	0.42723 ± 0.00047	0.66437 ± 0.00060	0.66434 ± 0.00060	-0.00029 ± 0.00051
6.50	3.26	0.62917 ± 0.00035	1.55937 ± 0.00162	0.40339 ± 0.00051	0.62903 ± 0.00059	0.62900 ± 0.00059	0.00012 ± 0.00049
7.00	3.96	0.59776 ± 0.00035	1.56339 ± 0.00156	0.38230 ± 0.00050	0.59768 ± 0.00054	0.59766 ± 0.00054	0.00016 ± 0.00049

Table A.5.6(1) Effective neutron multiplication factor and ratio of reactions for water-reflected square lattice systems, using JENDL-5, 49 fuel rods, 60 cm thick reflector water, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.32	1.00085 ± 0.00037	1.50425 ± 0.00121	0.66514 ± 0.00032	1.00053 ± 0.00078	1.00050 ± 0.00078	0.00019 ± 0.00052
4.00	0.52	1.01060 ± 0.00039	1.48261 ± 0.00114	0.68147 ± 0.00033	1.01036 ± 0.00077	1.01032 ± 0.00077	0.00011 ± 0.00056
4.175	0.67	1.01234 ± 0.00036	1.46401 ± 0.00107	0.69137 ± 0.00031	1.01217 ± 0.00073	1.01214 ± 0.00073	-0.00003 ± 0.00054
4.35	0.82	1.01036 ± 0.00036	1.44298 ± 0.00106	0.70013 ± 0.00031	1.01028 ± 0.00073	1.01025 ± 0.00073	-0.00009 ± 0.00052
4.50	0.96	1.00632 ± 0.00038	1.42294 ± 0.00104	0.70715 ± 0.00032	1.00623 ± 0.00074	1.00620 ± 0.00074	-0.00049 ± 0.00053
4.70	1.15	0.99767 ± 0.00036	1.39402 ± 0.00106	0.71550 ± 0.00031	0.99742 ± 0.00075	0.99739 ± 0.00075	-0.00005 ± 0.00052
5.00	1.46	0.97885 ± 0.00036	1.34663 ± 0.00097	0.72668 ± 0.00031	0.97857 ± 0.00071	0.97855 ± 0.00071	-0.00008 ± 0.00050
5.50	2.01	0.93564 ± 0.00036	1.26048 ± 0.00095	0.74219 ± 0.00031	0.93552 ± 0.00071	0.93550 ± 0.00071	-0.00020 ± 0.00051
6.00	2.61	0.88368 ± 0.00033	1.17025 ± 0.00087	0.75499 ± 0.00027	0.88352 ± 0.00066	0.88351 ± 0.00066	0.00029 ± 0.00048
6.50	3.26	0.82646 ± 0.00031	1.07987 ± 0.00084	0.76521 ± 0.00028	0.82633 ± 0.00064	0.82631 ± 0.00064	-0.00004 ± 0.00045
7.00	3.96	0.76875 ± 0.00034	0.99277 ± 0.00080	0.77418 ± 0.00029	0.76858 ± 0.00062	0.76857 ± 0.00062	0.00000 ± 0.00046

Table A.5.6(2) Effective neutron multiplication factor and ratio of reactions for water-reflected square lattice systems, using JENDL-5, 49 fuel rods, 60 cm thick reflector water, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.32	0.88950 ± 0.00036	1.53520 ± 0.00119	0.57925 ± 0.00037	0.88926 ± 0.00067	0.88923 ± 0.00067	-0.00015 ± 0.00052
4.00	0.52	0.85083 ± 0.00039	1.53797 ± 0.00136	0.55318 ± 0.00040	0.85078 ± 0.00071	0.85074 ± 0.00071	-0.00009 ± 0.00053
4.175	0.67	0.82588 ± 0.00037	1.53989 ± 0.00131	0.53626 ± 0.00040	0.82579 ± 0.00067	0.82575 ± 0.00067	-0.00017 ± 0.00054
4.35	0.82	0.80344 ± 0.00038	1.54192 ± 0.00137	0.52093 ± 0.00041	0.80324 ± 0.00067	0.80320 ± 0.00067	0.00031 ± 0.00053
4.50	0.96	0.78468 ± 0.00036	1.54361 ± 0.00133	0.50826 ± 0.00042	0.78455 ± 0.00064	0.78452 ± 0.00064	-0.00015 ± 0.00051
4.70	1.15	0.76168 ± 0.00037	1.54573 ± 0.00137	0.49267 ± 0.00043	0.76153 ± 0.00064	0.76150 ± 0.00064	0.00000 ± 0.00052
5.00	1.46	0.73046 ± 0.00037	1.54917 ± 0.00143	0.47138 ± 0.00044	0.73024 ± 0.00063	0.73021 ± 0.00063	-0.00014 ± 0.00052
5.50	2.01	0.68480 ± 0.00037	1.55414 ± 0.00155	0.44053 ± 0.00047	0.68465 ± 0.00063	0.68462 ± 0.00063	0.00008 ± 0.00052
6.00	2.61	0.64555 ± 0.00035	1.55857 ± 0.00155	0.41414 ± 0.00048	0.64547 ± 0.00059	0.64545 ± 0.00059	-0.00037 ± 0.00050
6.50	3.26	0.61137 ± 0.00034	1.56263 ± 0.00158	0.39117 ± 0.00051	0.61125 ± 0.00056	0.61122 ± 0.00056	-0.00003 ± 0.00049
7.00	3.96	0.58109 ± 0.00034	1.56643 ± 0.00162	0.37086 ± 0.00054	0.58093 ± 0.00055	0.58091 ± 0.00055	0.00018 ± 0.00049

Table A.5.7(1) Effective neutron multiplication factor and ratio of reactions for water-reflected square lattice systems, using JENDL-5, 44 fuel rods, 60 cm thick reflector water, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.32	0.97674 ± 0.00038	1.50453 ± 0.00116	0.64911 ± 0.00033	0.97660 ± 0.00074	0.97656 ± 0.00074	0.00016 ± 0.00053
4.00	0.52	0.98717 ± 0.00040	1.48262 ± 0.00119	0.66574 ± 0.00034	0.98704 ± 0.00078	0.98701 ± 0.00078	-0.00022 ± 0.00055
4.175	0.67	0.98957 ± 0.00039	1.46398 ± 0.00112	0.67583 ± 0.00033	0.98940 ± 0.00075	0.98936 ± 0.00075	-0.00011 ± 0.00053
4.35	0.82	0.98868 ± 0.00036	1.44293 ± 0.00106	0.68507 ± 0.00031	0.98851 ± 0.00071	0.98848 ± 0.00071	0.00011 ± 0.00052
4.50	0.96	0.98547 ± 0.00038	1.42290 ± 0.00109	0.69239 ± 0.00032	0.98520 ± 0.00075	0.98516 ± 0.00075	0.00014 ± 0.00054
4.70	1.15	0.97756 ± 0.00037	1.39383 ± 0.00102	0.70124 ± 0.00033	0.97742 ± 0.00072	0.97739 ± 0.00072	-0.00011 ± 0.00051
5.00	1.46	0.96005 ± 0.00037	1.34647 ± 0.00102	0.71287 ± 0.00031	0.95985 ± 0.00072	0.95983 ± 0.00072	0.00011 ± 0.00050
5.50	2.01	0.91930 ± 0.00036	1.26030 ± 0.00095	0.72931 ± 0.00030	0.91914 ± 0.00069	0.91912 ± 0.00069	0.00004 ± 0.00052
6.00	2.61	0.86913 ± 0.00032	1.17017 ± 0.00091	0.74272 ± 0.00028	0.86911 ± 0.00067	0.86909 ± 0.00067	0.00013 ± 0.00046
6.50	3.26	0.81424 ± 0.00035	1.08001 ± 0.00083	0.75384 ± 0.00030	0.81415 ± 0.00063	0.81413 ± 0.00063	-0.00016 ± 0.00048
7.00	3.96	0.75806 ± 0.00033	0.99284 ± 0.00079	0.76337 ± 0.00029	0.75790 ± 0.00061	0.75789 ± 0.00061	-0.00010 ± 0.00046

Table A.5.7(2) Effective neutron multiplication factor and ratio of reactions for water-reflected square lattice systems, using JENDL-5, 44 fuel rods, 60 cm thick reflector water, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.32	0.86528 ± 0.00038	1.53611 ± 0.00136	0.56310 ± 0.00040	0.86498 ± 0.00073	0.86494 ± 0.00073	-0.00014 ± 0.00055
4.00	0.52	0.82759 ± 0.00037	1.53906 ± 0.00142	0.53759 ± 0.00039	0.82738 ± 0.00071	0.82734 ± 0.00071	0.00018 ± 0.00053
4.175	0.67	0.80347 ± 0.00039	1.54112 ± 0.00148	0.52126 ± 0.00044	0.80332 ± 0.00072	0.80328 ± 0.00072	0.00004 ± 0.00053
4.35	0.82	0.78105 ± 0.00038	1.54301 ± 0.00142	0.50603 ± 0.00043	0.78080 ± 0.00068	0.78076 ± 0.00068	-0.00027 ± 0.00054
4.50	0.96	0.76348 ± 0.00039	1.54489 ± 0.00137	0.49411 ± 0.00043	0.76335 ± 0.00064	0.76331 ± 0.00064	0.00002 ± 0.00055
4.70	1.15	0.74106 ± 0.00037	1.54695 ± 0.00138	0.47891 ± 0.00044	0.74085 ± 0.00062	0.74081 ± 0.00062	0.00034 ± 0.00050
5.00	1.46	0.71055 ± 0.00036	1.55021 ± 0.00154	0.45825 ± 0.00045	0.71039 ± 0.00065	0.71035 ± 0.00065	0.00018 ± 0.00052
5.50	2.01	0.66629 ± 0.00037	1.55517 ± 0.00161	0.42831 ± 0.00049	0.66609 ± 0.00063	0.66605 ± 0.00063	-0.00015 ± 0.00052
6.00	2.61	0.62842 ± 0.00035	1.55960 ± 0.00155	0.40286 ± 0.00049	0.62831 ± 0.00057	0.62827 ± 0.00057	0.00017 ± 0.00051
6.50	3.26	0.59519 ± 0.00034	1.56402 ± 0.00162	0.38051 ± 0.00050	0.59512 ± 0.00056	0.59509 ± 0.00056	-0.00007 ± 0.00047
7.00	3.96	0.56585 ± 0.00034	1.56779 ± 0.00163	0.36084 ± 0.00051	0.56573 ± 0.00052	0.56570 ± 0.00052	-0.00002 ± 0.00048

Table A.5.8(1) Effective neutron multiplication factor and ratio of reactions for water-reflected square lattice systems, using JENDL-5, 40 fuel rods, 60 cm thick reflector water, density of moderator water: 100 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.32	0.95335 ± 0.00039	1.50490 ± 0.00116	0.63333 ± 0.00037	0.95310 ± 0.00073	0.95307 ± 0.00073	0.00019 ± 0.00054
4.00	0.52	0.96479 ± 0.00039	1.48279 ± 0.00114	0.65055 ± 0.00035	0.96463 ± 0.00073	0.96459 ± 0.00073	0.00009 ± 0.00056
4.175	0.67	0.96831 ± 0.00039	1.46425 ± 0.00112	0.66118 ± 0.00035	0.96813 ± 0.00074	0.96810 ± 0.00074	0.00001 ± 0.00055
4.35	0.82	0.96781 ± 0.00036	1.44294 ± 0.00111	0.67055 ± 0.00031	0.96757 ± 0.00072	0.96754 ± 0.00072	-0.00007 ± 0.00051
4.50	0.96	0.96493 ± 0.00036	1.42301 ± 0.00099	0.67793 ± 0.00033	0.96470 ± 0.00067	0.96467 ± 0.00067	0.00002 ± 0.00052
4.70	1.15	0.95811 ± 0.00036	1.39398 ± 0.00106	0.68721 ± 0.00031	0.95796 ± 0.00072	0.95793 ± 0.00072	0.00026 ± 0.00051
5.00	1.46	0.94194 ± 0.00035	1.34643 ± 0.00097	0.69949 ± 0.00030	0.94181 ± 0.00068	0.94179 ± 0.00068	-0.00011 ± 0.00051
5.50	2.01	0.90359 ± 0.00035	1.26041 ± 0.00095	0.71666 ± 0.00031	0.90328 ± 0.00068	0.90326 ± 0.00068	0.00014 ± 0.00050
6.00	2.61	0.85532 ± 0.00033	1.17016 ± 0.00087	0.73078 ± 0.00030	0.85513 ± 0.00064	0.85512 ± 0.00064	-0.00017 ± 0.00048
6.50	3.26	0.80228 ± 0.00034	1.08016 ± 0.00084	0.74263 ± 0.00029	0.80216 ± 0.00062	0.80215 ± 0.00062	-0.00026 ± 0.00047
7.00	3.96	0.74784 ± 0.00032	0.99314 ± 0.00080	0.75285 ± 0.00029	0.74769 ± 0.00060	0.74767 ± 0.00060	-0.00023 ± 0.00046

Table A.5.8(2) Effective neutron multiplication factor and ratio of reactions for water-reflected square lattice systems, using JENDL-5, 40 fuel rods, 60 cm thick reflector water, density of moderator water: 0 %.

Lattice pitch (cm)	Volume ratio	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	0.32	0.84189 ± 0.00039	1.53682 ± 0.00136	0.54762 ± 0.00040	0.84160 ± 0.00071	0.84156 ± 0.00071	-0.00008 ± 0.00054
4.00	0.52	0.80520 ± 0.00037	1.53963 ± 0.00125	0.52288 ± 0.00040	0.80504 ± 0.00063	0.80500 ± 0.00063	-0.00004 ± 0.00053
4.175	0.67	0.78194 ± 0.00037	1.54172 ± 0.00137	0.50708 ± 0.00043	0.78178 ± 0.00066	0.78174 ± 0.00066	0.00004 ± 0.00052
4.35	0.82	0.76034 ± 0.00035	1.54390 ± 0.00137	0.49231 ± 0.00042	0.76007 ± 0.00063	0.76004 ± 0.00063	0.00042 ± 0.00051
4.50	0.96	0.74279 ± 0.00036	1.54553 ± 0.00143	0.48053 ± 0.00043	0.74267 ± 0.00064	0.74264 ± 0.00064	-0.00014 ± 0.00051
4.70	1.15	0.72148 ± 0.00036	1.54780 ± 0.00143	0.46608 ± 0.00043	0.72140 ± 0.00062	0.72136 ± 0.00062	-0.00021 ± 0.00052
5.00	1.46	0.69206 ± 0.00036	1.55106 ± 0.00143	0.44607 ± 0.00047	0.69189 ± 0.00060	0.69186 ± 0.00060	-0.00001 ± 0.00051
5.50	2.01	0.64983 ± 0.00035	1.55612 ± 0.00150	0.41761 ± 0.00047	0.64985 ± 0.00057	0.64982 ± 0.00057	-0.00026 ± 0.00051
6.00	2.61	0.61381 ± 0.00037	1.56069 ± 0.00167	0.39308 ± 0.00051	0.61348 ± 0.00059	0.61345 ± 0.00059	-0.00023 ± 0.00051
6.50	3.26	0.58217 ± 0.00034	1.56496 ± 0.00162	0.37196 ± 0.00051	0.58210 ± 0.00054	0.58207 ± 0.00054	-0.00033 ± 0.00049
7.00	3.96	0.55399 ± 0.00036	1.56880 ± 0.00163	0.35309 ± 0.00054	0.55392 ± 0.00052	0.55389 ± 0.00052	-0.00031 ± 0.00049

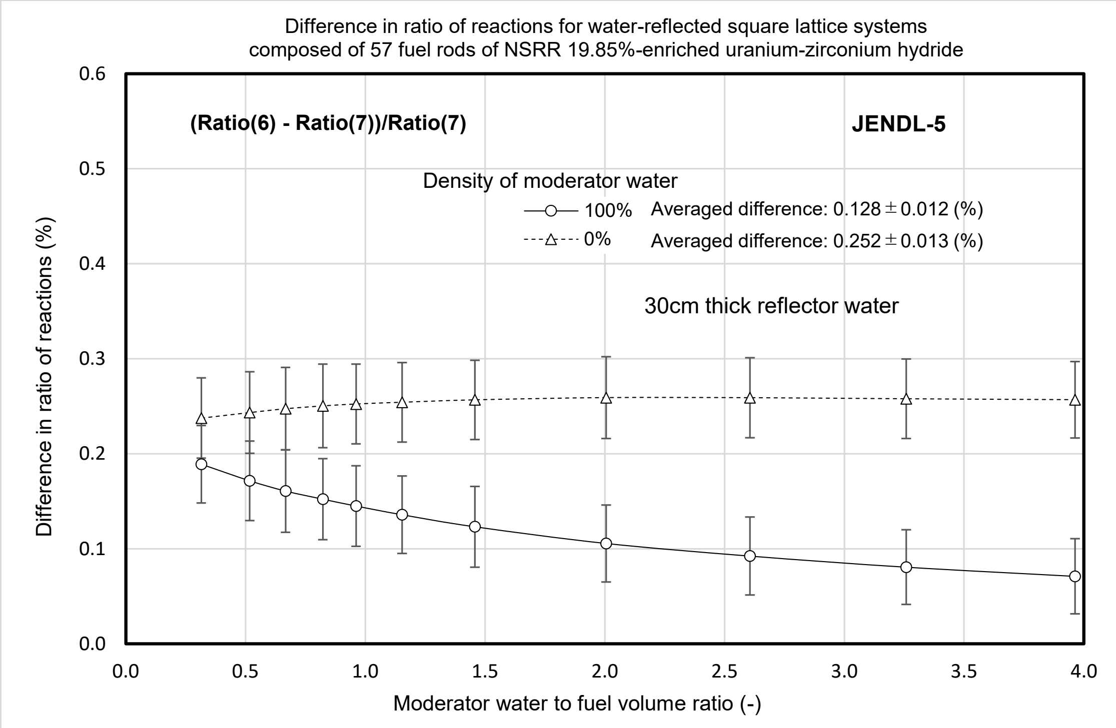

Fig.A.5.9 Difference between Ratio(6) and Ratio(7) for water-reflected square lattice systems composed of 57 fuel rods, using JENDL-5, 30 cm thick reflector water.

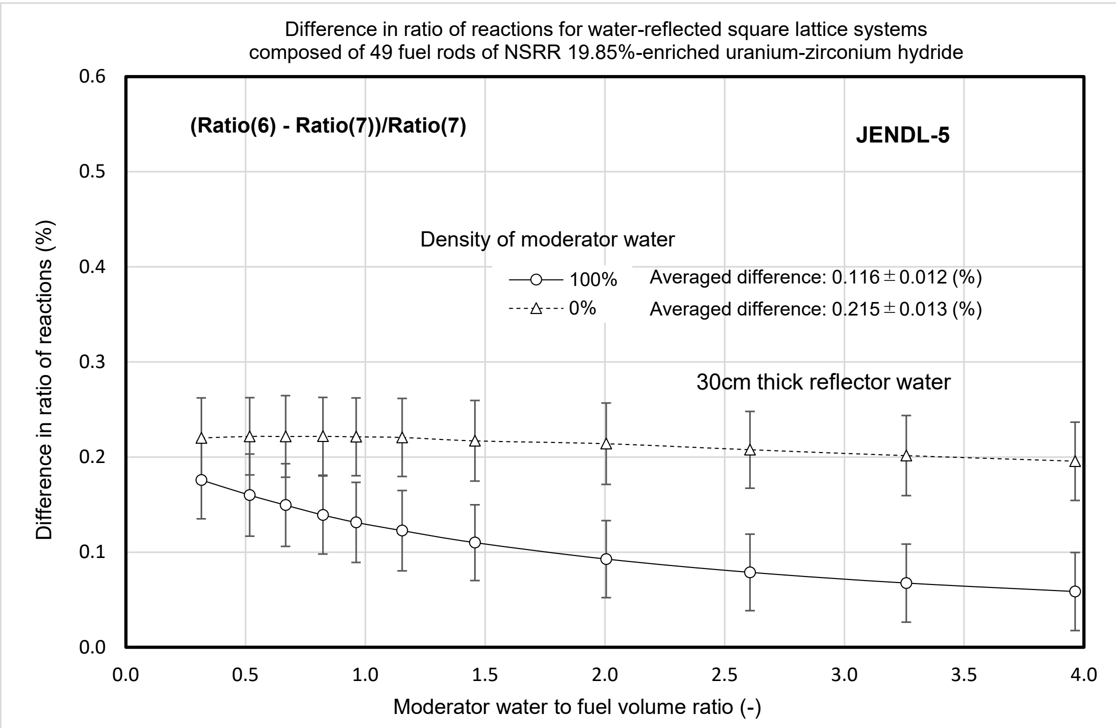

Fig.A.5.10 Difference between Ratio(6) and Ratio(7) for water-reflected square lattice systems composed of 49 fuel rods, using JENDL-5, 30 cm thick reflector water.

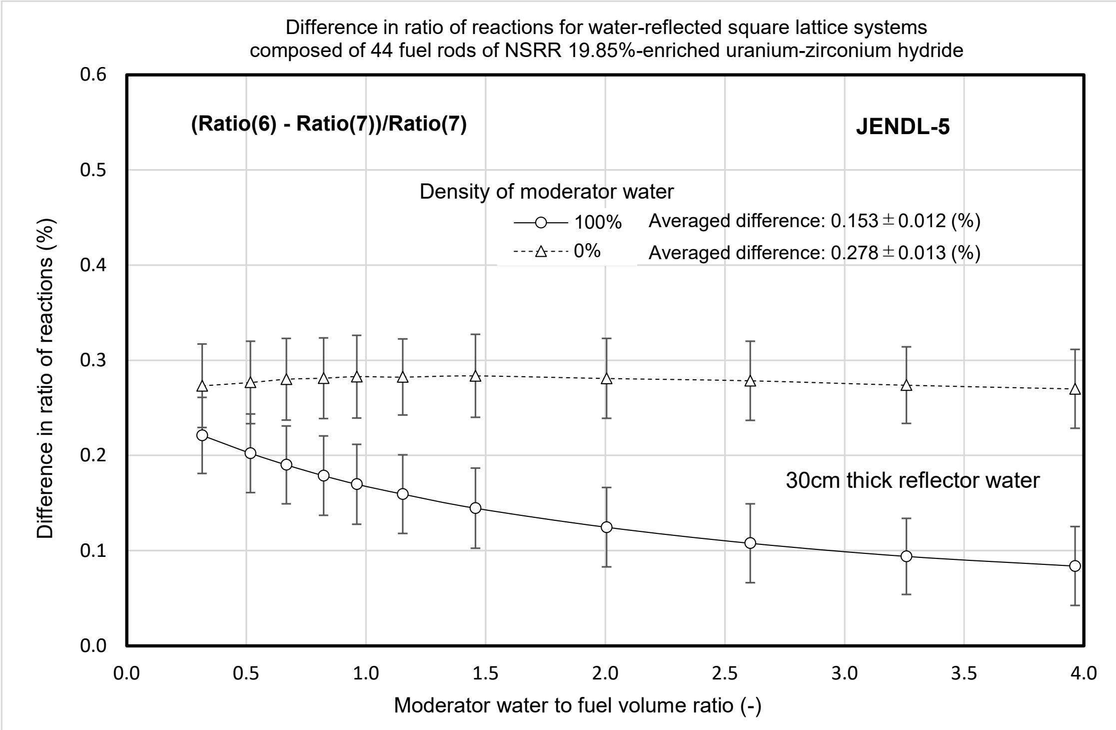

Fig.A.5.11 Difference between Ratio(6) and Ratio(7) for water-reflected square lattice systems composed of 44 fuel rods, using JENDL-5, 30 cm thick reflector water.

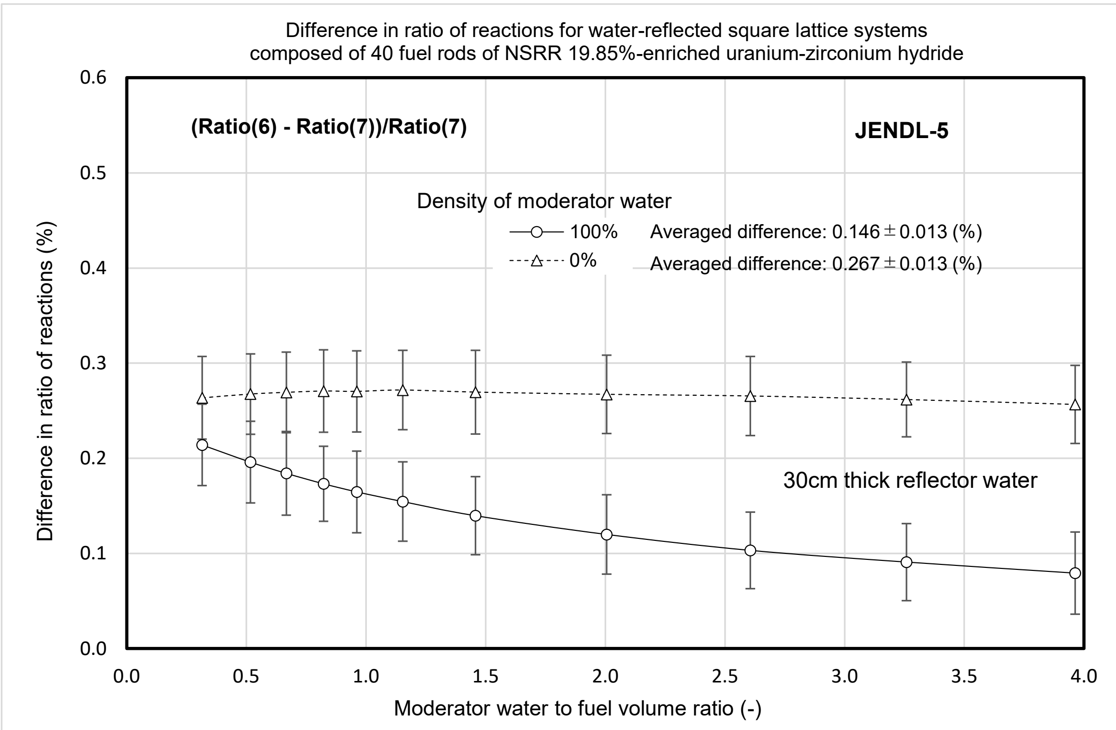

Fig.A.5.12 Difference between Ratio(6) and Ratio(7) for water-reflected square lattice systems composed of 40 fuel rods, using JENDL-5, 30 cm thick reflector water.

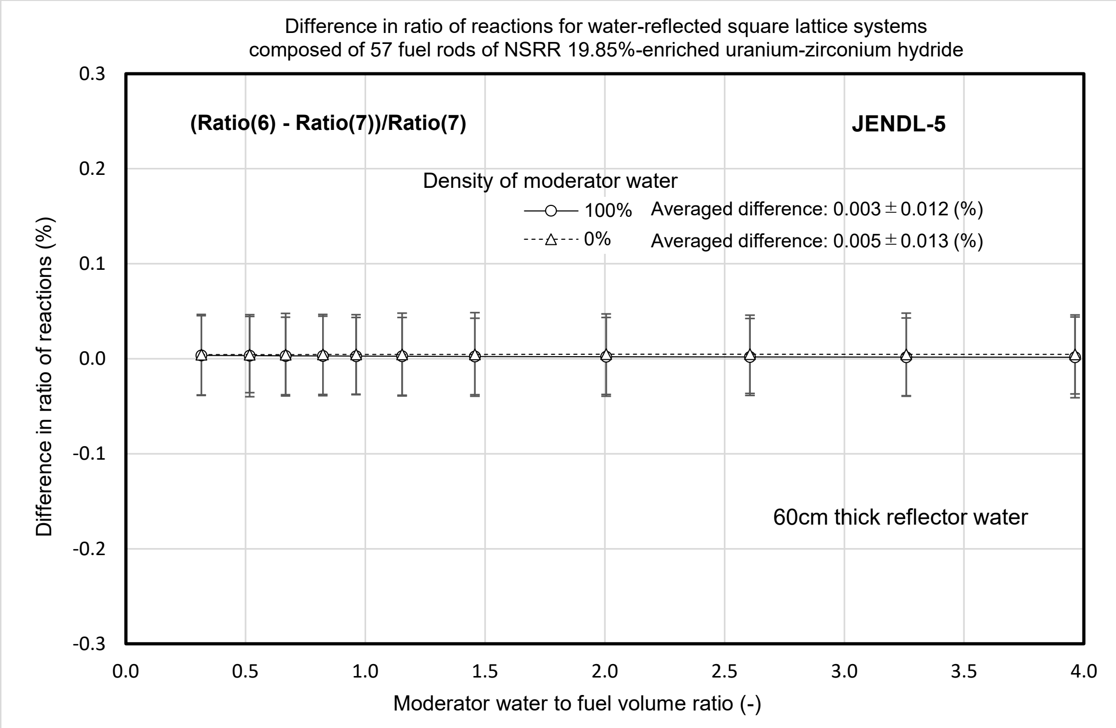

Fig.A.5.13 Difference between Ratio(6) and Ratio(7) for water-reflected square lattice systems composed of 57 fuel rods, using JENDL-5, 60 cm thick reflector water.

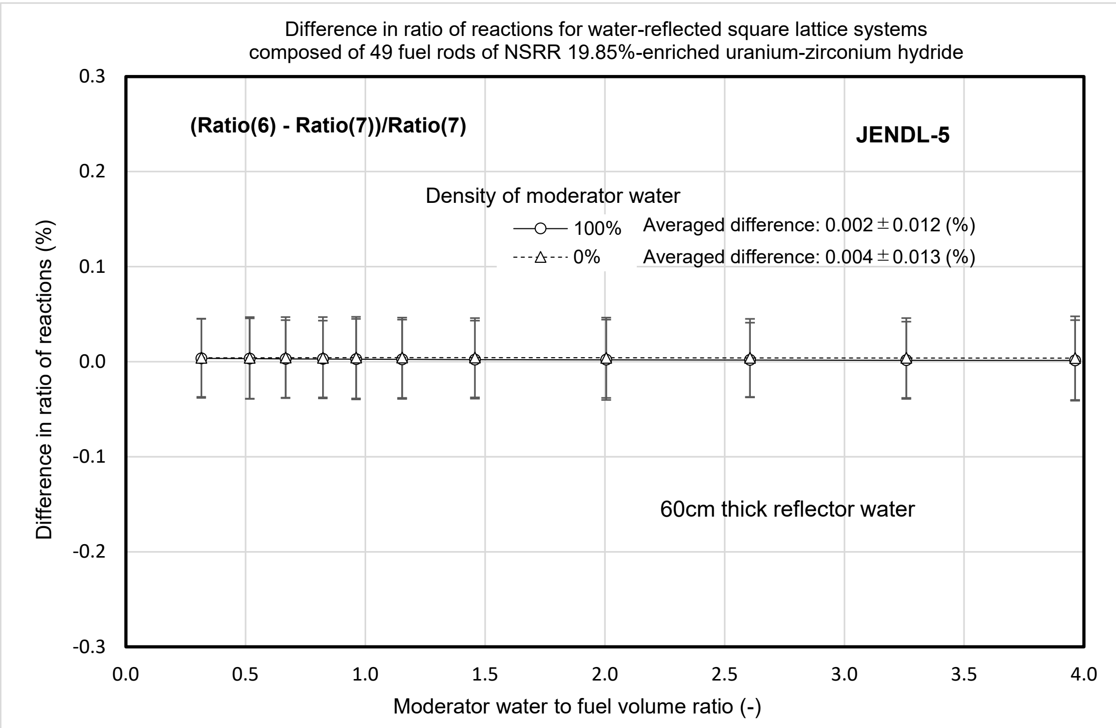

Fig.A.5.14 Difference between Ratio(6) and Ratio(7) for water-reflected square lattice systems composed of 49 fuel rods, using JENDL-5, 60 cm thick reflector water.

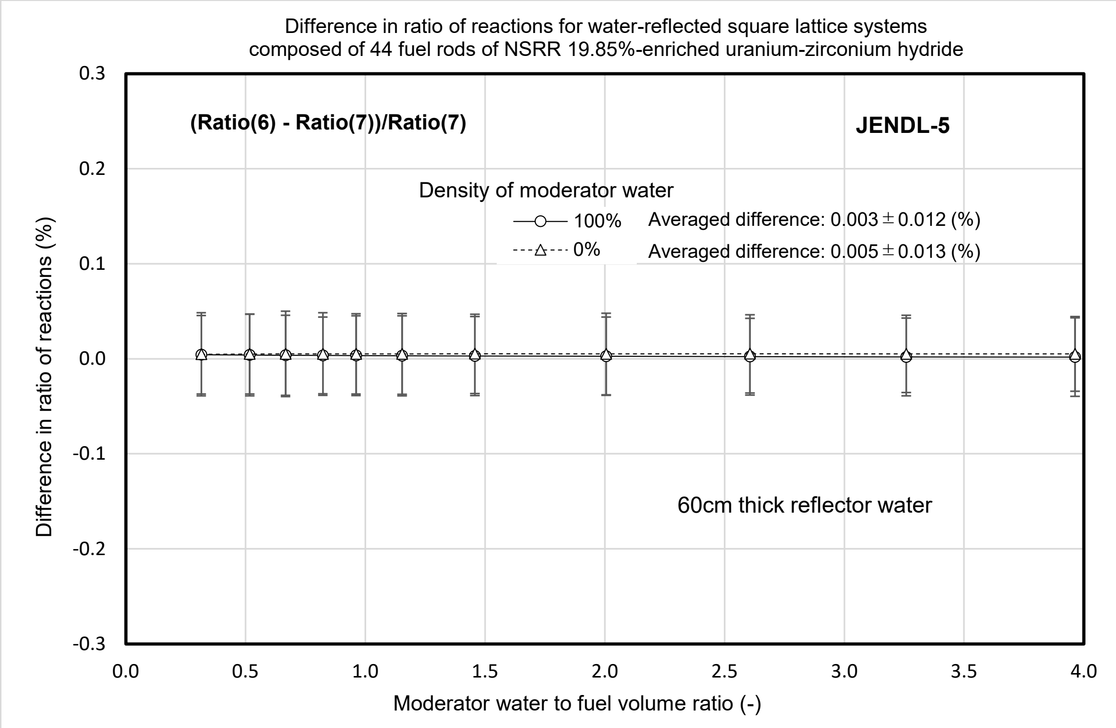

Fig.A.5.15 Difference between Ratio(6) and Ratio(7) for water-reflected square lattice systems composed of 44 fuel rods, using JENDL-5, 60 cm thick reflector water.

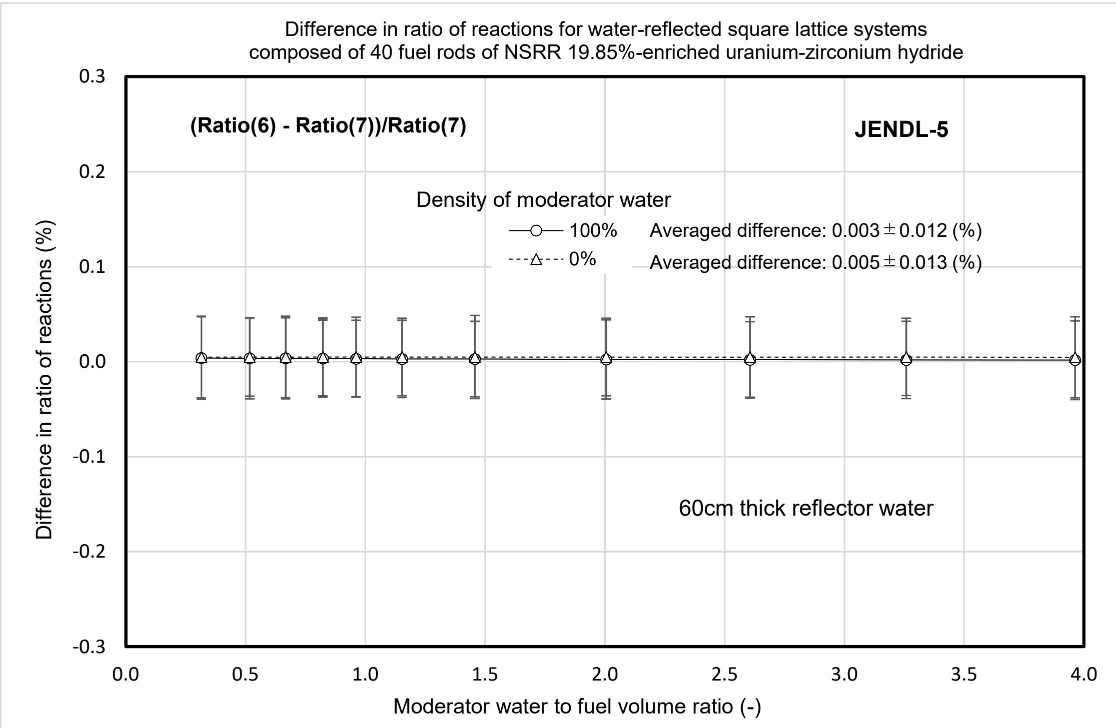

Fig.A.5.16 Difference between Ratio(6) and Ratio(7) for water-reflected square lattice systems composed of 40 fuel rods, using JENDL-5, 60 cm thick reflector water.

Table A.5.9 Effective neutron multiplication factor and ratio of reactions for water-reflected hexagonal lattice systems under no moderator water condition, using JENDL-5, 60 cm thick reflector water.

Lattice pitch (cm)	The number of fuel rods	k-effective ± 3σ	Ratio (4): $\nu F/A_C$ ± 3σ	Ratio (5): $A_C/(A_C+A_R)$ ± 3σ	Ratio (6)=(4)*(5): $\nu F/(A_C+A_R)$ ± 3σ	Ratio (7): $\nu F/(A_C+A_R+L)$ ± 3σ	60-30cmT reflector: Δk_{eff} ± 3σ
3.75	61	0.97878 ± 0.00038	1.52727 ± 0.00113	0.64069 ± 0.00035	0.97850 ± 0.00072	0.97844 ± 0.00072	0.00016 ± 0.00053
3.75	91	1.05925 ± 0.00039	1.52426 ± 0.00114	0.69466 ± 0.00033	1.05885 ± 0.00078	1.05880 ± 0.00078	0.00003 ± 0.00055
3.75	127	1.11879 ± 0.00039	1.52223 ± 0.00113	0.73473 ± 0.00030	1.11843 ± 0.00082	1.11839 ± 0.00082	0.00013 ± 0.00055
3.75	169	1.16354 ± 0.00035	1.52083 ± 0.00101	0.76475 ± 0.00027	1.16305 ± 0.00078	1.16302 ± 0.00078	0.00001 ± 0.00050
3.75	217	1.19805 ± 0.00037	1.51995 ± 0.00103	0.78794 ± 0.00028	1.19763 ± 0.00082	1.19760 ± 0.00082	0.00021 ± 0.00052

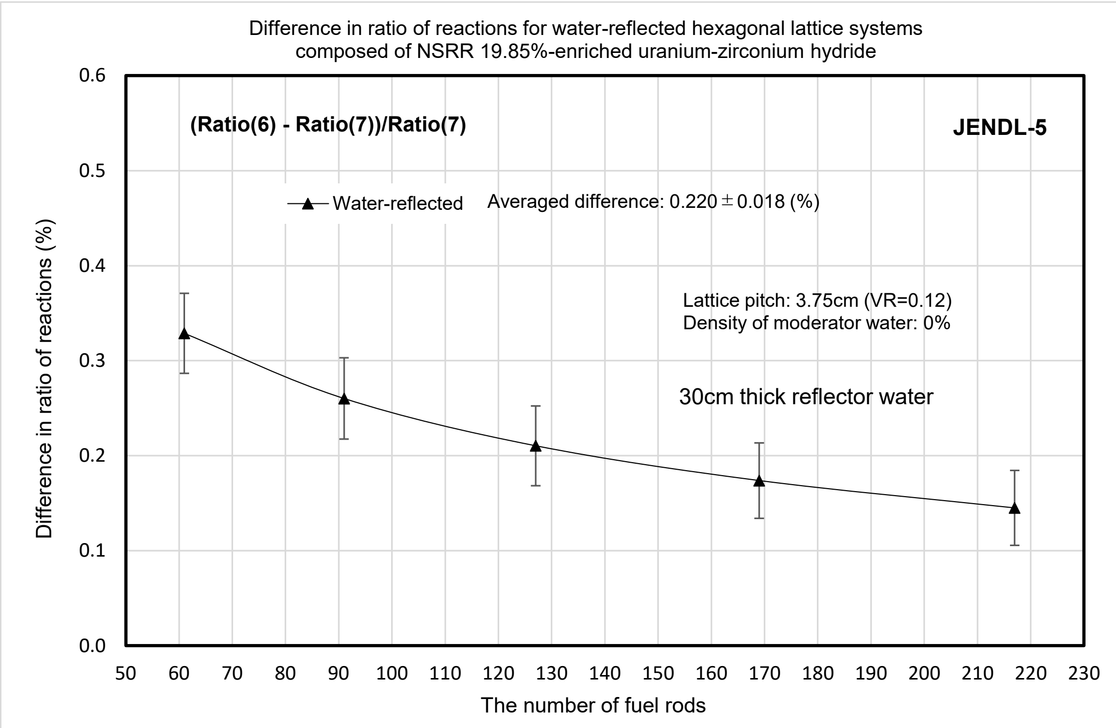

Fig.A.5.17 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems under no moderator water condition, using JENDL-5, 30 cm thick reflector water.

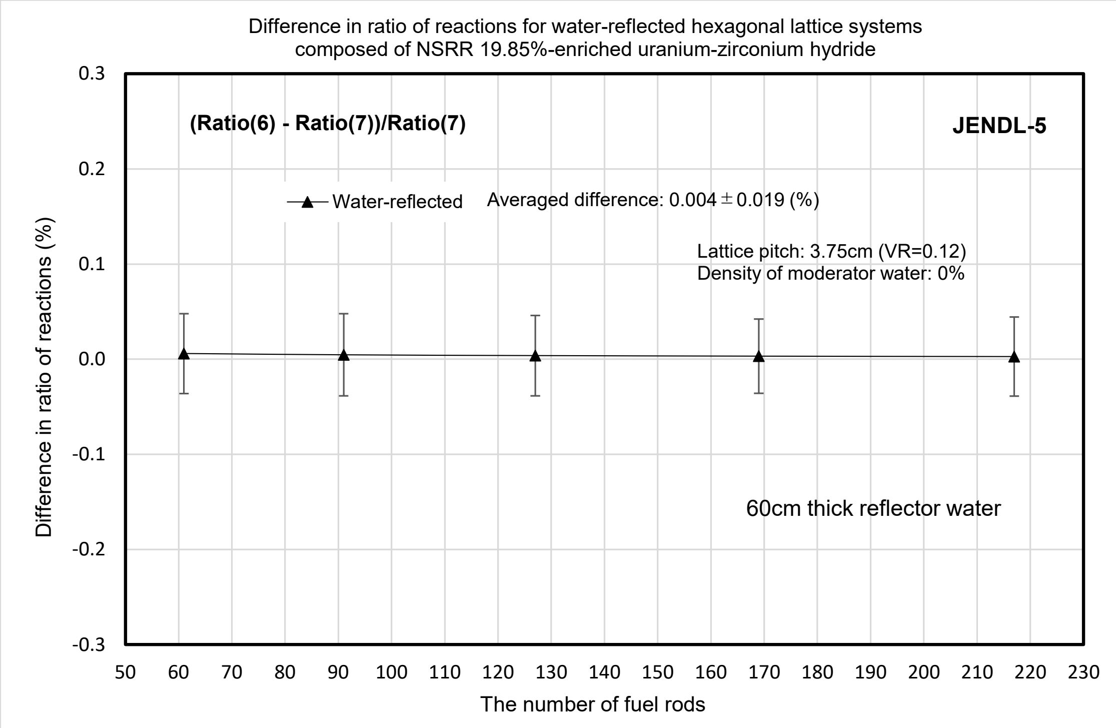

Fig.A.5.18 Difference between Ratio(6) and Ratio(7) for water-reflected hexagonal lattice systems under no moderator water condition, using JENDL-5, 60 cm thick reflector water.

Appendix-6 Evaluation of Criticality Biases

The criticality biases were evaluated by using the calculated results on the detailed models of NSRR as benchmarking cited from the earlier study [6]. The detailed benchmark models are annular shaped cores configured with the hexagonal lattice, of which pitch is 4.175 cm (VR=0.42). There are 37 sorts of benchmark cases including the minimum (113 fuel rods), intermediate (114 to 148 fuel rods) and standard (149 fuel rods) cores of NSRR [6]. Table A.6.1 lists values of C/E of effective neutron multiplication factor (k_{eff}) using the JENDL-5, JENDL-4.0 and JENDL-4.0u1 libraries.

In order to determine the most probable value of the criticality bias, the least square technique was applied to the following zeroth-degree expression for C/E's of k_{eff} in those benchmark cases.

$$y = C, \qquad \text{(A.6.1)}$$

where,

y: C/E of k_{eff}, and

C: criticality bias, i.e., an unknown parameter to be evaluated by the least square technique, respectively.

For this expression, the normal equation derived by the condition of the least squares is expressed as,

$$\left({}^{t}\boldsymbol{A} \cdot \boldsymbol{W} \cdot \boldsymbol{A} \right) C = {}^{t}\boldsymbol{A} \cdot \boldsymbol{W} \cdot \boldsymbol{y}, \qquad \text{(A.6.2)}$$

where,

$\boldsymbol{A}$: Jacobian vector with n elements,

$\boldsymbol{W}$: diagonal matrix with n rows and n columns, and

$\boldsymbol{y}$: vector of C/E values with n elements, respectively.

Here, the symbol: n means the number of benchmark cases.

Since the first order derivation of y by the unknown parameter: C becomes unity in Eq.(A.6.1), all elements in the Jacobian vector are unity. The diagonal element of i-th row and i-th column in $\boldsymbol{W}$ is expressed with inverse of the error variance of the i-th C/E value, as follows.

$$W_{ii} = \frac{1}{\sigma_i^2},$$

$$\text{(A.6.3)}$$

where,

W_{ii}: diagonal element of i-th row and i-th column in $\boldsymbol{W}$, and

σ_i^2: error variance of the i-th C/E value, respectively.

In addition, error variance of C: $Var(C)$ propagated from the error variance of the C/E value is expressed as,

$$Var(C) = \left({}^t\boldsymbol{A} \cdot \boldsymbol{W} \cdot \boldsymbol{A} \right)^{-1}, \quad \text{(A.6.4)}$$

Using Eqs.(A.6.2) to (A.6.4), the most probable value of the criticality bias and its error are possible to be evaluated by the following equations.

$$\langle C \rangle = \sum_{i=1}^{n} \frac{y_i}{\sigma_i^2} \Big/ \sum_{i=1}^{n} \frac{1}{\sigma_i^2}, \quad \text{(A.6.5)}$$

$$\sigma_C = \sqrt{Var(C)} = 1 \Big/ \sqrt{\sum_{i=1}^{n} \frac{1}{\sigma_i^2}}, \quad \text{(A.6.6)}$$

where,

$\langle C \rangle$: the most probable value of criticality bias, and

σ_c: error of $\langle C \rangle$, respectively.

The criticality biases and their errors were evaluated with two sorts of the different number of benchmark cases accounted for. One is all cases, i.e., 37 benchmark cases including the minimum, intermediate and standard cores of NSRR, and the other is 2 benchmark cases including the minimum and standard cores. It is foreseen from Eq.(A.6.6) that the fewer benchmark case tends to make lager σ_c. The evaluated criticality biases and their errors are listed in Table A.6.2 and shown with the values of C/E of k_{eff} in Figs.A.6.1 to A.6.6.

Table A.6.1 C/E of effective neutron multiplication factor for NSRR detailed benchmark models.

Benchmark case	The number of fuel rods	C/E of k_{eff} Using JENDL-5	C/E of k_{eff} Using JENDL-4.0	C/E of k_{eff} Using JENDL-4.0u1	C: MVP3 Calc. Using JENDL-5	C: MVP3 Calc. Using JENDL-4.0	C: MVP3 Calc. Using JENDL-4.0u1	E: benchmark model
		C/E ± 3σ			k_{eff} ± 3σ			k_{eff} ± 3σ
1	113	1.00535 ± 0.00844	0.99969 ± 0.00840	0.99984 ± 0.00840	1.00535 ± 0.00039	0.99969 ± 0.00038	0.99984 ± 0.00038	1.00000 ± 0.00840
2	114	1.00495 ± 0.00874	0.99986 ± 0.00870	0.99968 ± 0.00870	1.00495 ± 0.00037	0.99986 ± 0.00038	0.99968 ± 0.00040	1.00000 ± 0.00870
3	115	1.00505 ± 0.00874	0.99966 ± 0.00870	0.99964 ± 0.00870	1.00505 ± 0.00036	0.99966 ± 0.00040	0.99964 ± 0.00040	1.00000 ± 0.00870
4	116	1.00503 ± 0.00874	0.99993 ± 0.00870	0.99978 ± 0.00870	1.00503 ± 0.00036	0.99993 ± 0.00038	0.99978 ± 0.00037	1.00000 ± 0.00870
5	117	1.00486 ± 0.00874	1.00012 ± 0.00870	1.00013 ± 0.00870	1.00486 ± 0.00039	1.00012 ± 0.00038	1.00013 ± 0.00039	1.00000 ± 0.00870
6	118	1.00504 ± 0.00874	0.99993 ± 0.00870	1.00008 ± 0.00870	1.00504 ± 0.00037	0.99993 ± 0.00037	1.00008 ± 0.00038	1.00000 ± 0.00870
7	119	1.00517 ± 0.00874	1.00007 ± 0.00870	1.00022 ± 0.00870	1.00517 ± 0.00037	1.00007 ± 0.00037	1.00022 ± 0.00037	1.00000 ± 0.00870
8	120	1.00503 ± 0.00874	1.00012 ± 0.00870	1.00018 ± 0.00870	1.00503 ± 0.00038	1.00012 ± 0.00038	1.00018 ± 0.00035	1.00000 ± 0.00870
9	121	1.00512 ± 0.00874	1.00013 ± 0.00870	0.99999 ± 0.00870	1.00512 ± 0.00036	1.00013 ± 0.00038	0.99999 ± 0.00038	1.00000 ± 0.00870
10	122	1.00480 ± 0.00874	1.00009 ± 0.00870	1.00016 ± 0.00870	1.00480 ± 0.00037	1.00009 ± 0.00037	1.00016 ± 0.00036	1.00000 ± 0.00870
11	123	1.00483 ± 0.00874	1.00003 ± 0.00870	0.99997 ± 0.00870	1.00483 ± 0.00037	1.00003 ± 0.00036	0.99997 ± 0.00036	1.00000 ± 0.00870
12	124	1.00468 ± 0.00874	1.00019 ± 0.00870	1.00018 ± 0.00870	1.00468 ± 0.00038	1.00019 ± 0.00037	1.00018 ± 0.00040	1.00000 ± 0.00870
13	125	1.00475 ± 0.00874	1.00041 ± 0.00870	1.00034 ± 0.00870	1.00475 ± 0.00038	1.00041 ± 0.00038	1.00034 ± 0.00038	1.00000 ± 0.00870
14	126	1.00490 ± 0.00874	1.00028 ± 0.00870	1.00043 ± 0.00870	1.00490 ± 0.00037	1.00028 ± 0.00037	1.00043 ± 0.00039	1.00000 ± 0.00870
15	127	1.00511 ± 0.00874	1.00056 ± 0.00870	1.00039 ± 0.00870	1.00511 ± 0.00037	1.00056 ± 0.00040	1.00039 ± 0.00038	1.00000 ± 0.00870
16	128	1.00492 ± 0.00874	1.00029 ± 0.00870	1.00041 ± 0.00870	1.00492 ± 0.00036	1.00029 ± 0.00038	1.00041 ± 0.00038	1.00000 ± 0.00870
17	129	1.00506 ± 0.00874	1.00060 ± 0.00871	1.00044 ± 0.00870	1.00506 ± 0.00037	1.00060 ± 0.00039	1.00044 ± 0.00038	1.00000 ± 0.00870
18	130	1.00488 ± 0.00874	1.00047 ± 0.00870	1.00056 ± 0.00870	1.00488 ± 0.00036	1.00047 ± 0.00037	1.00056 ± 0.00036	1.00000 ± 0.00870
19	131	1.00498 ± 0.00874	1.00040 ± 0.00870	1.00042 ± 0.00870	1.00498 ± 0.00036	1.00040 ± 0.00036	1.00042 ± 0.00036	1.00000 ± 0.00870
20	132	1.00495 ± 0.00874	1.00044 ± 0.00870	1.00044 ± 0.00870	1.00495 ± 0.00038	1.00044 ± 0.00038	1.00044 ± 0.00040	1.00000 ± 0.00870
21	133	1.00488 ± 0.00874	1.00057 ± 0.00870	1.00068 ± 0.00871	1.00488 ± 0.00040	1.00057 ± 0.00037	1.00068 ± 0.00037	1.00000 ± 0.00870
22	134	1.00511 ± 0.00874	1.00045 ± 0.00870	1.00061 ± 0.00871	1.00511 ± 0.00036	1.00045 ± 0.00040	1.00061 ± 0.00037	1.00000 ± 0.00870
23	135	1.00472 ± 0.00874	1.00043 ± 0.00870	1.00048 ± 0.00870	1.00472 ± 0.00036	1.00043 ± 0.00037	1.00048 ± 0.00039	1.00000 ± 0.00870
24	136	1.00485 ± 0.00874	1.00038 ± 0.00870	1.00041 ± 0.00870	1.00485 ± 0.00036	1.00038 ± 0.00038	1.00041 ± 0.00038	1.00000 ± 0.00870
25	137	1.00478 ± 0.00874	1.00083 ± 0.00871	1.00078 ± 0.00871	1.00478 ± 0.00037	1.00083 ± 0.00037	1.00078 ± 0.00037	1.00000 ± 0.00870
26	138	1.00483 ± 0.00874	1.00071 ± 0.00871	1.00069 ± 0.00871	1.00483 ± 0.00036	1.00071 ± 0.00036	1.00069 ± 0.00037	1.00000 ± 0.00870
27	139	1.00526 ± 0.00875	1.00084 ± 0.00871	1.00086 ± 0.00871	1.00526 ± 0.00037	1.00084 ± 0.00038	1.00086 ± 0.00035	1.00000 ± 0.00870
28	140	1.00481 ± 0.00874	1.00057 ± 0.00870	1.00070 ± 0.00871	1.00481 ± 0.00036	1.00057 ± 0.00036	1.00070 ± 0.00038	1.00000 ± 0.00870
29	141	1.00460 ± 0.00874	1.00098 ± 0.00871	1.00081 ± 0.00871	1.00460 ± 0.00036	1.00098 ± 0.00035	1.00081 ± 0.00037	1.00000 ± 0.00870
30	142	1.00503 ± 0.00874	1.00090 ± 0.00871	1.00083 ± 0.00871	1.00503 ± 0.00038	1.00090 ± 0.00036	1.00083 ± 0.00038	1.00000 ± 0.00870
31	143	1.00465 ± 0.00874	1.00086 ± 0.00871	1.00077 ± 0.00871	1.00465 ± 0.00037	1.00086 ± 0.00037	1.00077 ± 0.00040	1.00000 ± 0.00870
32	144	1.00483 ± 0.00874	1.00088 ± 0.00871	1.00078 ± 0.00871	1.00483 ± 0.00039	1.00088 ± 0.00038	1.00078 ± 0.00037	1.00000 ± 0.00870
33	145	1.00465 ± 0.00874	1.00073 ± 0.00871	1.00070 ± 0.00871	1.00465 ± 0.00038	1.00073 ± 0.00035	1.00070 ± 0.00036	1.00000 ± 0.00870
34	146	1.00471 ± 0.00874	1.00083 ± 0.00871	1.00075 ± 0.00871	1.00471 ± 0.00038	1.00083 ± 0.00039	1.00075 ± 0.00040	1.00000 ± 0.00870
35	147	1.00448 ± 0.00874	1.00067 ± 0.00871	1.00067 ± 0.00871	1.00448 ± 0.00035	1.00067 ± 0.00036	1.00067 ± 0.00034	1.00000 ± 0.00870
36	148	1.00453 ± 0.00874	1.00060 ± 0.00871	1.00075 ± 0.00871	1.00453 ± 0.00036	1.00060 ± 0.00036	1.00075 ± 0.00038	1.00000 ± 0.00870
37	149	1.00492 ± 0.00814	1.00067 ± 0.00811	1.00065 ± 0.00811	1.00492 ± 0.00037	1.00067 ± 0.00036	1.00065 ± 0.00039	1.00000 ± 0.00810

Case 1: Minimum core.
Case 37: Standard core.
Case 2 to 36: Intermediate cores.

Table A.6.2 Evaluated criticality biases and their errors determined by using NSRR detailed benchmark models.

	<C> ± 3σ_c	
Library	37 benchmark cases*1	2 benchmark cases*2
JENDL-5	1.00490 ± 0.0143	1.00513 ± 0.0586
JENDL-4.0	1.00041 ± 0.0143	1.00020 ± 0.0583
JENDL-4.0u1	1.00041 ± 0.0143	1.00026 ± 0.0583

*1 Benchmark cases for the detailed models of the minimum, intermediate and standard cores.
*2 Benchmark cases for the detailed models of the minimum and standard cores.

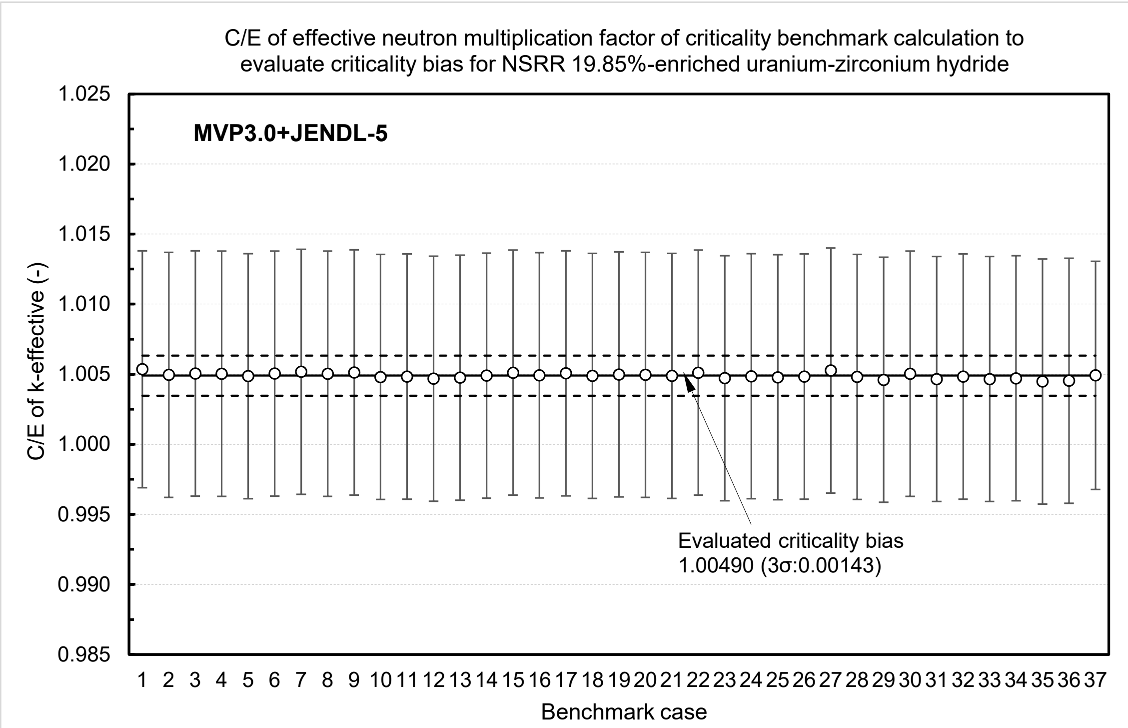

Fig.A.6.1 Evaluated criticality bias for 37 benchmark cases of NSRR detailed models, using JENDL-5.

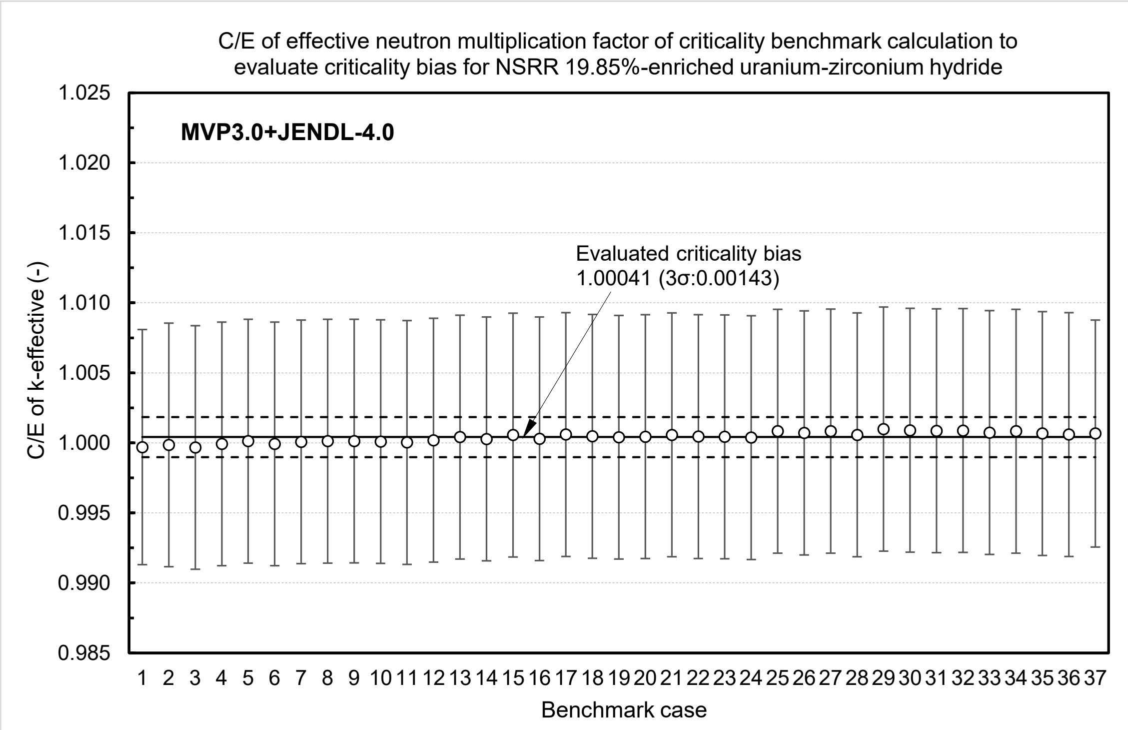

Fig.A.6.2 Evaluated criticality bias for 37 benchmark cases of NSRR detailed models, using JENDL-4.0.

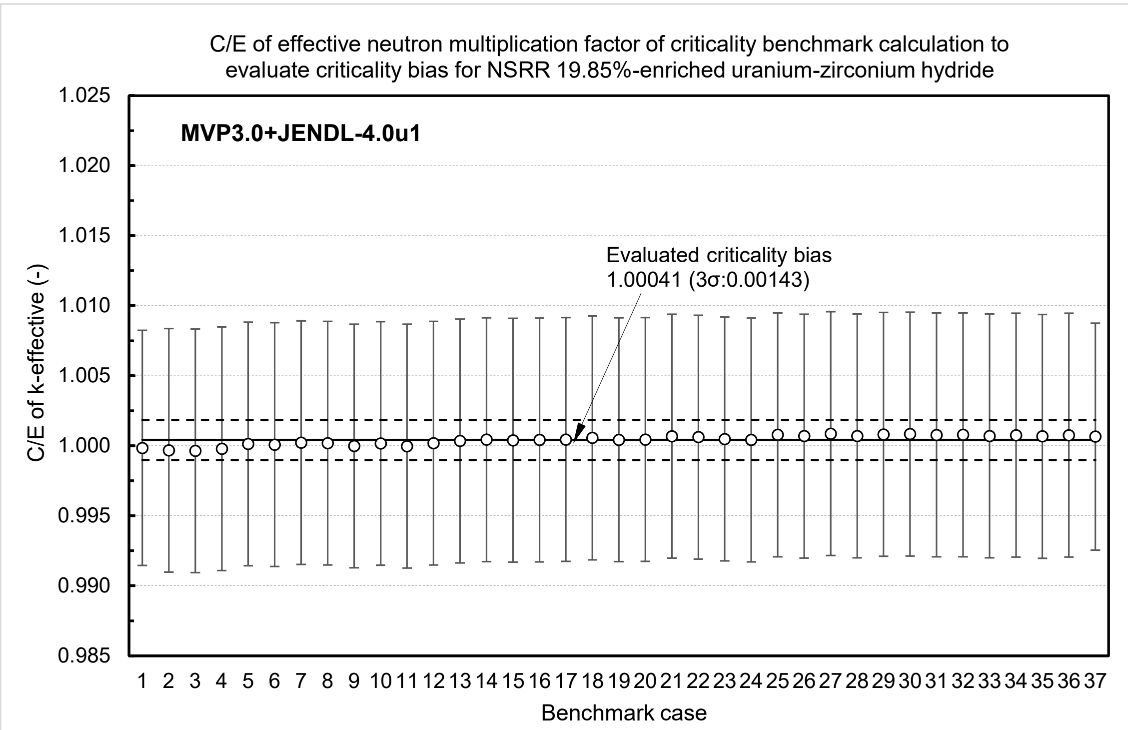

Fig.A.6.3 Evaluated criticality bias for 37 benchmark cases of NSRR detailed models, using JENDL-4.0u1.

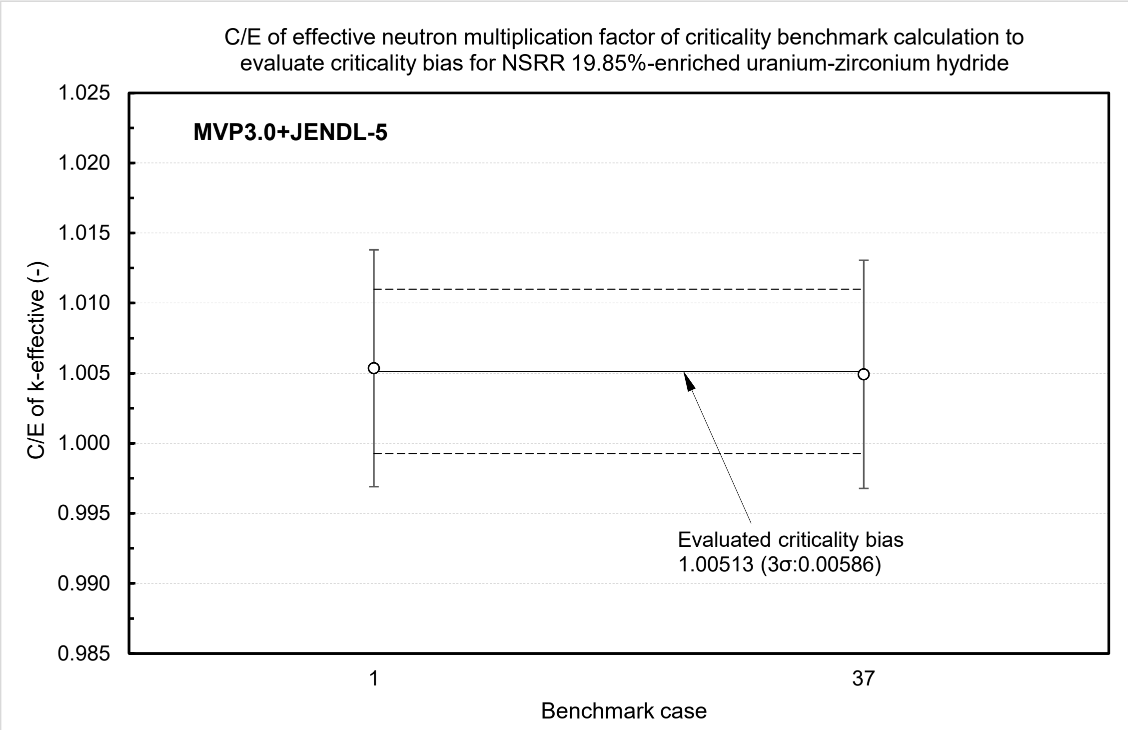

Fig.A.6.4 Evaluated criticality bias for 2 benchmark cases
of NSRR detailed models, using JENDL-5.

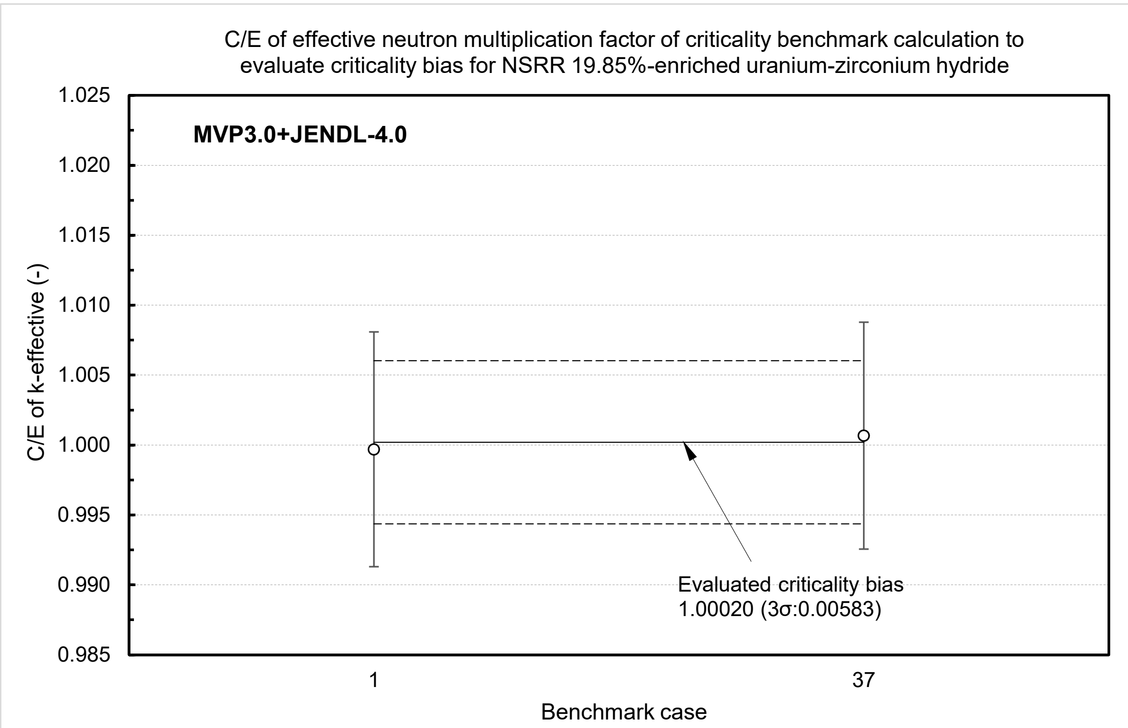

Fig.A.6.5 Evaluated criticality bias for 2 benchmark cases
of NSRR detailed models, using JENDL-4.0.

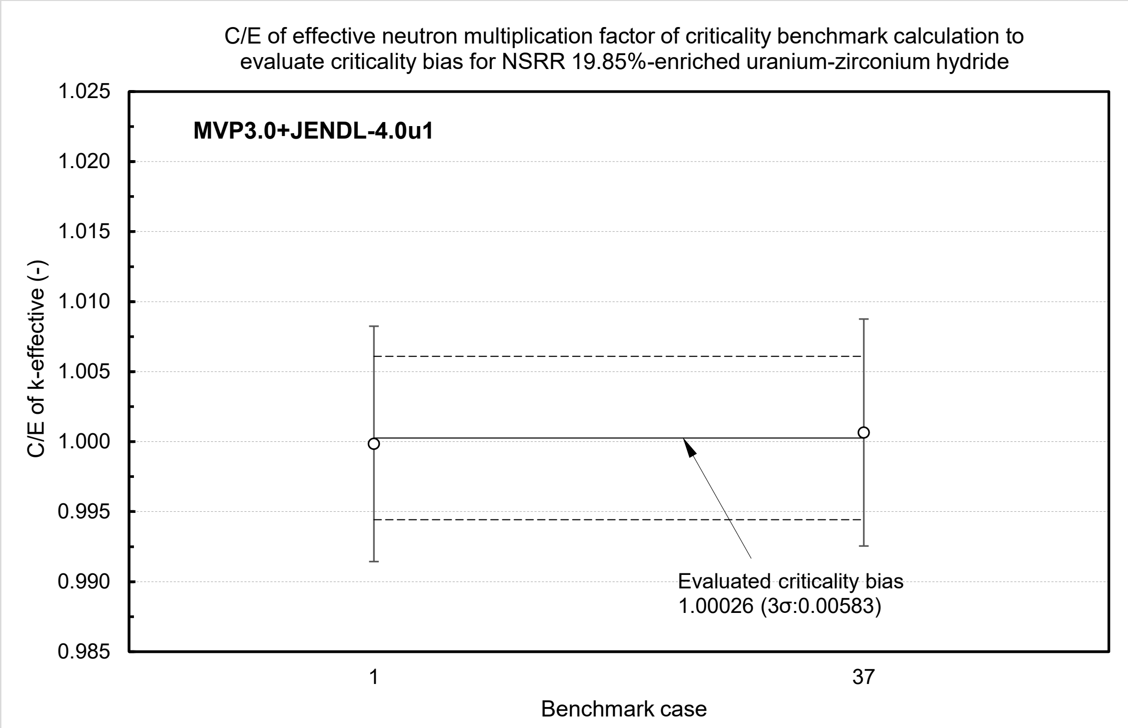

Fig.A.6.6 Evaluated criticality bias for 2 benchmark cases
of NSRR detailed models, using JENDL-4.0u1.

Appendix-7 Sample Input List for MVP

Samples of the input for the MVP version 3 code[7] are attached below. The samples were prepared for a part of the analyses on the infinite and finite lattice systems using the JENDL-5 library[8].

Infinite hexagonal lattice system

```
NSRR 19.85%EU infinite hexagonal lattice
50 million histories  JENDL-5
*
*--------+---------+---------+---------+---------+---------+---------+--
* OPTIONS
*--------+---------+---------+---------+---------+---------+---------+--
  BETA-EFFECTIVE DOPPLER-SCATTERING(EXACT)
  NEUTRON PERTURBATION DYNAMIC-MEMORY(550000000)
  EIGEN-VALUE FLUX-PRINT PRINT-SUPPRESS(6 7)

% NBT =   500  /* number of effective batches
% NSK =   200  /* number of skipped batches
% NHT = 100000  /* number of particles per batch
*
  NPART(<(NBT+NSK)*NHT>) /* total number of histories
  NHIST(<NHT>)          /* number of particles per batch
  NBANK(<NHT*2>)        /* length of particle bank
  NFBANK(<NHT*2>)       /* length of fission source bank
  NSKIP(<NSK>)          /* number of skipped batches
*
  NMEMO( 100 )          /* number of next-zone memory per zone
*  TCPU( 180 )            /* calculation CPU time limit (min)
  ETOP.N(2.0E7)         /* top of neutron energy (eV)
  EBOT.N(1.0E-5)        /* bottom of neutron energy (eV)
*
  NGROUP.N( 120 )
  ENGYB.N( 2.0000E+07 1.5795E+07 1.2474E+07 9.8515E+06 7.7803E+06
         6.1445E+06 4.8526E+06 3.8324E+06 3.0266E+06 2.3903E+06
         1.8877E+06 1.4909E+06 1.1774E+06 9.2986E+05 7.3436E+05
         5.7996E+05 4.5803E+05 3.6173E+05 2.8568E+05 2.2561E+05
         1.7818E+05 1.4072E+05 1.1113E+05 8.7767E+04 6.9315E+04
         5.4741E+04 4.3232E+04 3.4143E+04 2.6964E+04 2.1295E+04
         1.6818E+04 1.3282E+04 1.0490E+04 8.2841E+03 6.5424E+03
         5.1669E+03 4.0806E+03 3.2226E+03 2.5451E+03 2.0100E+03
         1.5874E+03 1.2537E+03 9.9008E+02 7.8192E+02 6.1752E+02
         4.8769E+02 3.8516E+02 3.0418E+02 2.4023E+02 1.8972E+02
         1.4983E+02 1.1833E+02 9.3451E+01 7.3803E+01 5.8286E+01
         4.6032E+01 3.6354E+01 2.8711E+01 2.2674E+01 1.7907E+01
         1.4142E+01 1.1169E+01 8.8206E+00 6.9661E+00 5.5015E+00
         4.3448E+00 3.4313E+00 2.7099E+00 2.1402E+00 1.6902E+00
         1.3348E+00 1.0542E+00 8.3255E-01 6.5751E-01 5.1927E-01
         4.1010E-01 3.2388E-01 2.5578E-01 2.0200E-01 1.5953E-01
         1.2599E-01 9.9503E-02 7.8583E-02 6.2061E-02 4.9013E-02
         3.8708E-02 3.0570E-02 2.4143E-02 1.9067E-02 1.5058E-02
         1.1892E-02 9.3918E-03 7.4172E-03 5.8578E-03 4.6262E-03
         3.6536E-03 2.8854E-03 2.2788E-03 1.7997E-03 1.4213E-03
         1.1225E-03 8.8647E-04 7.0009E-04 5.5290E-04 4.3666E-04
         3.4485E-04 2.7235E-04 2.1509E-04 1.6987E-04 1.3415E-04
         1.0595E-04 8.3672E-05 6.6080E-05 5.2187E-05 4.1215E-05
         3.2549E-05 2.5706E-05 2.0301E-05 1.6033E-05 1.2662E-05
         1.0000E-5)
*
*--------+---------+---------+---------+---------+---------+---------+--
* PARAMETERS FOR FUEL PIN
*--------+---------+---------+---------+---------+---------+---------+--
*
% FR1    =   0.285       /* radius of zirconium (cm)
% FR2    =   0.32        /* inner radius of U-ZrH (cm)
% FR3    =   1.775       /* outer radius of U-ZrH (cm)
% FR4    =   1.82        /* inner radius of cladding (cm)
% FR5    =   1.875       /* outer radius of cladding (cm)
*
% FZ1    = -19.05        /* height of bottom of core (cm)
% FZ2    =  19.05        /* height of top of core (cm)
*
*--------+---------+---------+---------+---------+---------+---------+--
* PARAMETERS FOR FUEL LATTICE
*--------+---------+---------+---------+---------+---------+---------+--
*
% FPP    =    3.75       /* lattice pitch (cm)
*
*--------+---------+---------+---------+---------+---------+---------+--
* TEMPERATURE
*--------+---------+---------+-------- -+---------+---------+---------+--
*
% TP     =   25.0        /* temperature (deg-C)
% TPF    =   25.0        /* fuel temperature (deg-C)
*
*--------+---------+---------+---------+---------+---------+---------+--
* CONSTANTS
*--------+---------+---------+---------+---------+---------+---------+--
*
% FRM    =  100.0        /* water moderator density (%)
*
*--------+---------+---------+---------+---------+---------+---------+--
* CROSS SECTION
*--------+---------+---------+---------+---------+---------+---------+--
$XSEC
* ZIRCONIUM
& IDMAT(1)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  ZR0900J50( 2.2145E-02 )
  ZR0910J50( 4.8293E-03 )
  ZR0920J50( 7.3816E-03 )
  ZR0940J50( 7.4806E-03 )
  ZR0960J50( 1.2052E-03 )
  B00100J50( 1.4455E-08 )
  B00110J50( 5.8182E-08 )
  C00120J50( 3.7180E-05 )
  C00130J50( 4.1353E-07 )
  N00140J50( 1.1171E-05 )
  N00150J50( 4.1488E-08 )
  CR0500J50( 2.3460E-07 )
  CR0520J50( 4.5240E-06 )
  CR0530J50( 5.1293E-07 )
  CR0540J50( 1.2769E-07 )
  FE0540J50( 2.3251E-06 )
  FE0560J50( 3.6146E-05 )
  FE0570J50( 8.2759E-07 )
  FE0580J50( 1.1035E-07 )
  CU0630J50( 5.1287E-07 )
  CU0650J50( 2.2859E-07 )
  HF1740J50( 1.1582E-09 )
  HF1760J50( 3.7220E-08 )
  HF1770J50( 1.3302E-07 )
  HF1780J50( 1.9516E-07 )
  HF1790J50( 9.7440E-08 )
  HF1800J50( 2.5095E-07 )
*
* U-ZrH
& IDMAT(2)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TPF> )
  H0001ZJ50( 5.5586E-02 )
  ZR090ZJ50( 1.7678E-02 )
  ZR091ZJ50( 3.8552E-03 )
  ZR092ZJ50( 5.8928E-03 )
  ZR094ZJ50( 5.9718E-03 )
  ZR096ZJ50( 9.6209E-04 )
  U02350J50( 3.6389E-04 )
  U02380J50( 1.4505E-03 )
  C00120J50( 3.6133E-05 )
  C00130J50( 4.0189E-07 )
  N00140J50( 4.9050E-06 )
  N00150J50( 1.8216E-08 )
  O00160J50( 1.5673E-04 )
  MG0240J50( 5.7755E-06 )
  MG0250J50( 7.3116E-07 )
  MG0260J50( 8.0501E-07 )
  AL0270J50( 5.7067E-06 )
  SI0280J50( 2.4758E-06 )
  SI0290J50( 1.2536E-07 )
  SI0300J50( 8.3215E-08 )
  CL0350J50( 6.6990E-06 )
  CL0370J50( 2.1422E-06 )
  CR0500J50( 1.3069E-07 )
  CR0520J50( 2.5202E-06 )
  CR0530J50( 2.8574E-07 )
  CR0540J50( 7.1134E-08 )
  FE0540J50( 1.1152E-06 )
  FE0560J50( 1.7337E-05 )
  FE0570J50( 3.9695E-07 )
  FE0580J50( 5.2926E-08 )
  NI0580J50( 2.5893E-07 )
  NI0600J50( 9.8989E-08 )
  NI0610J50( 4.2858E-09 )
  NI0620J50( 1.3616E-08 )
  NI0640J50( 3.4514E-09 )
  HF1740J50( 7.9659E-10 )
  HF1760J50( 2.5599E-08 )
  HF1770J50( 9.1490E-08 )
  HF1780J50( 1.3422E-07 )
  HF1790J50( 6.7017E-08 )
  HF1800J50( 1.7259E-07 )
*
* SUS304 CLADDING
& IDMAT(3)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  B00100J50( 1.4944E-06 )
  B00110J50( 6.0150E-06 )
  C00120J50( 2.0959E-04 )
  C00130J50( 2.3311E-06 )
  SI0280J50( 8.4167E-04 )
  SI0290J50( 4.2617E-05 )
  SI0300J50( 2.8290E-05 )
  P00310J50( 3.2378E-05 )
  S00320J50( 1.9388E-05 )
  S00330J50( 1.5303E-07 )
  S00340J50( 8.5901E-07 )
  S00360J50( 4.0808E-09 )
  CR0500J50( 7.3760E-04 )
  CR0520J50( 1.4224E-02 )
  CR0530J50( 1.6127E-03 )
  CR0540J50( 4.0148E-04 )
  MN0550J50( 1.1880E-03 )
  FE0540J50( 3.5498E-03 )
  FE0560J50( 5.5184E-02 )
  FE0570J50( 1.2635E-03 )
  FE0580J50( 1.6847E-04 )
  NI0580J50( 5.0923E-03 )
  NI0600J50( 1.9468E-03 )
  NI0610J50( 8.4288E-05 )
  NI0620J50( 2.6778E-04 )
  NI0640J50( 6.7878E-05 )
*
* MODERATOR
& IDMAT(4)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  H0001HJ50( <6.6655E-02*FRM/100.0> )
  O0016HJ50( <3.3329E-02*FRM/100.0> )
*
$END XSEC
```

```
*
*--------+---------+---------+---------+---------+---------+---------+--
* GEOMETRY
*--------+---------+---------+---------+---------+---------+---------+--
$GEOMETRY
*
RHP (  5000   0.0 0.0 <FZ1>  <FZ2-FZ1>    <FPP> )
CYL (   100   0.0 0.0 <FZ1>  <FZ2-FZ1>    <FR1> ) /* Zr
CYL (   200   0.0 0.0 <FZ1>  <FZ2-FZ1>    <FR2> ) /* void
CYL (   300   0.0 0.0 <FZ1>  <FZ2-FZ1>    <FR3> ) /* U-ZrH
CYL (   400   0.0 0.0 <FZ1>  <FZ2-FZ1>    <FR4> ) /* void
CYL (   500   0.0 0.0 <FZ1>  <FZ2-FZ1>    <FR5> ) /* cladding
*
END
*--------+---------+---------+---------+---------+---------+---------+--
* ZONE
*--------+---------+---------+---------+---------+---------+---------+--
*
  C101     :      : -2000 :  -5000             /* mirror reflection
  C102     : MODR :    4 :   5000  -500         /* moderator
  C103     : CLAD :    3 :    500  -400        /* cladding
  C104     : VOID :    0 :    400  -300        /* void
  C105     : FUEL :    2 :    300  -200        /* u-zrh
  C106     : VOID :    0 :    200  -100        /* void
  C107     : ZIRC :    1 :    100             /* zr
*
*
#TALLY REGION
  DEFINE @FCEL (FUEL ZIRC CLAD MODR VOID)
*
$END GEOMETRY
*
$TALLY
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( @FCEL )
  IENERGY (  1   2   3   4   5   6   7   8   9  10
            11  12  13  14  15  16  17  18  19  20
            21  22  23  24  25  26  27  28  29  30
            31  32  33  34  35  36  37  38  39  40
            41  42  43  44  45  46  47  48  49  50
            51  52  53  54  55  56  57  58  59  60
            61  62  63  64  65  66  67  68  69  70
            71  72  73  74  75  76  77  78  79  80
            81  82  83  84  85  86  87  88  89  90
            91  92  93  94  95  96  97  98  99 100
           101 102 103 104 105 106 107 108 109 110
           111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( FUEL )
  IENERGY (  1   2   3   4   5   6   7   8   9  10
            11  12  13  14  15  16  17  18  19  20
            21  22  23  24  25  26  27  28  29  30
            31  32  33  34  35  36  37  38  39  40
            41  42  43  44  45  46  47  48  49  50
            51  52  53  54  55  56  57  58  59  60
            61  62  63  64  65  66  67  68  69  70
            71  72  73  74  75  76  77  78  79  80
            81  82  83  84  85  86  87  88  89  90
            91  92  93  94  95  96  97  98  99 100
           101 102 103 104 105 106 107 108 109 110
           111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( MODR )
  IENERGY (  1   2   3   4   5   6   7   8   9  10
            11  12  13  14  15  16  17  18  19  20
            21  22  23  24  25  26  27  28  29  30
            31  32  33  34  35  36  37  38  39  40
            41  42  43  44  45  46  47  48  49  50
            51  52  53  54  55  56  57  58  59  60
            61  62  63  64  65  66  67  68  69  70
            71  72  73  74  75  76  77  78  79  80
            81  82  83  84  85  86  87  88  89  90
            91  92  93  94  95  96  97  98  99 100
           101 102 103 104 105 106 107 108 109 110
           111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( THE NUMBER OF NUFISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @FCEL )
  MACRO( NUFISSION )
&
  LABEL( THE NUMBER OF FISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @FCEL )
  MACRO( FISSION )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @FCEL )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NUFISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( FUEL )
  MACRO( NUFISSION )
&
  LABEL( THE NUMBER OF FISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( FUEL )
  MACRO( FISSION )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( FUEL )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( ZIRC )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( CLAD )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( VOID )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( MODR )
  MACRO( CAPTURE )
*
$END TALLY
*
*--------+---------+---------+---------+---------+---------+---------+--
* KINETICS PARAMETERS
*--------+---------+---------+---------+---------+---------+---------+--
$PERTURBATION
&
ID(1)
LABEL( KINETICS PARAMETERS )
BEFF
$END PERTURBATION
*
*--------+---------+---------+---------+---------+---------+---------+--
* SOURCE
*--------+---------+---------+---------+---------+---------+---------+--
$SOURCE
& RATIO( 1.0 )
  @( X Y ) = #DISC( 0.0 <FR3> );
  @Z      = #UNIFORM( <FZ1> <FZ2> );
  @E= #FISSION( U02350J50* 0.0253);
$END SOURCE
*
% NR =%NREG
WGTF( <NR>(1.0) )
/
```

Infinite square lattice system

```
NSRR 19.85%EU infinite square lattice
50 million histories  JENDL-5
*
*--------+---------+---------+---------+---------+---------+---------+--
* OPTIONS
*--------+---------+---------+---------+---------+---------+---------+--
  BETA-EFFECTIVE DOPPLER-SCATTERING(EXACT)
  NEUTRON PERTURBATION DYNAMIC-MEMORY(550000000)
  EIGEN-VALUE FLUX-PRINT PRINT-SUPPRESS(6 7)

% NBT =   500  /* number of effective batches
% NSK =   200  /* number of skipped batches
% NHT = 100000  /* number of particles per batch
*
  NPART(<(NBT+NSK)*NHT>) /* total number of histories
  NHIST(<NHT>)         /* number of particles per batch
  NBANK(<NHT*2>)        /* length of particle bank
  NFBANK(<NHT*2>)       /* length of fission source bank
  NSKIP(<NSK>)         /* number of skipped batches
*
  NMEMO( 100 )         /* number of next-zone memory per zone
*  TCPU( 180 )           /* calculation CPU time limit (min)
  ETOP.N(2.0E7)        /* top of neutron energy (eV)
  EBOT.N(1.0E-5)        /* bottom of neutron energy (eV)
*
  NGROUP.N( 120 )
  ENGYB.N( 2.0000E+07 1.5795E+07 1.2474E+07 9.8515E+06 7.7803E+06
          6.1445E+06 4.8526E+06 3.8324E+06 3.0266E+06 2.3903E+06
          1.8877E+06 1.4909E+06 1.1774E+06 9.2986E+05 7.3436E+05
          5.7996E+05 4.5803E+05 3.6173E+05 2.8568E+05 2.2561E+05
          1.7818E+05 1.4072E+05 1.1113E+05 8.7767E+04 6.9315E+04
          5.4741E+04 4.3232E+04 3.4143E+04 2.6964E+04 2.1295E+04
          1.6818E+04 1.3282E+04 1.0490E+04 8.2841E+03 6.5424E+03
          5.1669E+03 4.0806E+03 3.2226E+03 2.5451E+03 2.0100E+03
          1.5874E+03 1.2537E+03 9.9008E+02 7.8192E+02 6.1752E+02
          4.8769E+02 3.8516E+02 3.0418E+02 2.4023E+02 1.8972E+02
          1.4983E+02 1.1833E+02 9.3451E+01 7.3803E+01 5.8286E+01
          4.6032E+01 3.6354E+01 2.8711E+01 2.2674E+01 1.7907E+01
          1.4142E+01 1.1169E+01 8.8206E+00 6.9661E+00 5.5015E+00
          4.3448E+00 3.4313E+00 2.7099E+00 2.1402E+00 1.6902E+00
          1.3348E+00 1.0542E+00 8.3255E-01 6.5751E-01 5.1927E-01
          4.1010E-01 3.2388E-01 2.5578E-01 2.0200E-01 1.5953E-01
          1.2599E-01 9.9503E-02 7.8583E-02 6.2061E-02 4.9013E-02
          3.8708E-02 3.0570E-02 2.4143E-02 1.9067E-02 1.5058E-02
          1.1892E-02 9.3918E-03 7.4172E-03 5.8578E-03 4.6262E-03
          3.6536E-03 2.8854E-03 2.2788E-03 1.7997E-03 1.4213E-03
          1.1225E-03 8.8647E-04 7.0009E-04 5.5290E-04 4.3666E-04
          3.4485E-04 2.7235E-04 2.1509E-04 1.6987E-04 1.3415E-04
          1.0595E-04 8.3672E-05 6.6080E-05 5.2187E-05 4.1215E-05
          3.2549E-05 2.5706E-05 2.0301E-05 1.6033E-05 1.2662E-05
          1.0000E-5)
*
*--------+---------+---------+---------+---------+---------+---------+--
* PARAMETERS FOR FUEL PIN
*--------+---------+---------+---------+---------+---------+---------+--
*
% FR1   =   0.285       /* radius of zirconium (cm)
% FR2   =   0.32        /* inner radius of U-ZrH (cm)
% FR3   =   1.775       /* outer radius of U-ZrH (cm)
% FR4   =   1.82        /* inner radius of cladding (cm)
% FR5   =   1.875       /* outer radius of cladding (cm)
*
% FZ1   = -19.05        /* height of bottom of core (cm)
% FZ2   =  19.05        /* height of top of core (cm)
*
*--------+---------+---------+---------+---------+---------+---------+--
* PARAMETERS FOR FUEL LATTICE
*--------+---------+---------+---------+---------+---------+---------+--
*
% FPP   =    3.75       /* lattice pitch (cm)
*
```

```
*--------+---------+---------+---------+---------+---------+---------+--
* TEMPERATURE
*--------+---------+---------+-------- -+---------+---------+---------+--
*
% TP    =   25.0        /* temperature (deg-C)
% TPF   =   25.0        /* fuel temperature (deg-C)
*
*--------+---------+---------+---------+---------+---------+---------+--
* CONSTANTS
*--------+---------+---------+---------+---------+---------+---------+--
*
% FRM   =  100.0        /* water moderator density (%)
*
*--------+---------+---------+---------+---------+---------+---------+--
* CROSS SECTION
*--------+---------+---------+---------+---------+---------+---------+--
$XSEC
* ZIRCONIUM
& IDMAT(1)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  ZR0900J50( 2.2145E-02 )
  ZR0910J50( 4.8293E-03 )
  ZR0920J50( 7.3816E-03 )
  ZR0940J50( 7.4806E-03 )
  ZR0960J50( 1.2052E-03 )
  B00100J50( 1.4455E-08 )
  B00110J50( 5.8182E-08 )
  C00120J50( 3.7180E-05 )
  C00130J50( 4.1353E-07 )
  N00140J50( 1.1171E-05 )
  N00150J50( 4.1488E-08 )
  CR0500J50( 2.3460E-07 )
  CR0520J50( 4.5240E-06 )
  CR0530J50( 5.1293E-07 )
  CR0540J50( 1.2769E-07 )
  FE0540J50( 2.3251E-06 )
  FE0560J50( 3.6146E-05 )
  FE0570J50( 8.2759E-07 )
  FE0580J50( 1.1035E-07 )
  CU0630J50( 5.1287E-07 )
  CU0650J50( 2.2859E-07 )
  HF1740J50( 1.1582E-09 )
  HF1760J50( 3.7220E-08 )
  HF1770J50( 1.3302E-07 )
  HF1780J50( 1.9516E-07 )
  HF1790J50( 9.7440E-08 )
  HF1800J50( 2.5095E-07 )
*
* U-ZrH
& IDMAT(2)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TPF> )
  H0001ZJ50( 5.5586E-02 )
  ZR090ZJ50( 1.7678E-02 )
  ZR091ZJ50( 3.8552E-03 )
  ZR092ZJ50( 5.8928E-03 )
  ZR094ZJ50( 5.9718E-03 )
  ZR096ZJ50( 9.6209E-04 )
  U02350J50( 3.6389E-04 )
  U02380J50( 1.4505E-03 )
  C00120J50( 3.6133E-05 )
  C00130J50( 4.0189E-07 )
  N00140J50( 4.9050E-06 )
  N00150J50( 1.8216E-08 )
  O00160J50( 1.5673E-04 )
  MG0240J50( 5.7755E-06 )
  MG0250J50( 7.3116E-07 )
  MG0260J50( 8.0501E-07 )
  AL0270J50( 5.7067E-06 )
  SI0280J50( 2.4758E-06 )
  SI0290J50( 1.2536E-07 )
  SI0300J50( 8.3215E-08 )
  CL0350J50( 6.6990E-06 )
  CL0370J50( 2.1422E-06 )
  CR0500J50( 1.3069E-07 )
  CR0520J50( 2.5202E-06 )
  CR0530J50( 2.8574E-07 )
  CR0540J50( 7.1134E-08 )
  FE0540J50( 1.1152E-06 )
  FE0560J50( 1.7337E-05 )
  FE0570J50( 3.9695E-07 )
  FE0580J50( 5.2926E-08 )
  NI0580J50( 2.5893E-07 )
  NI0600J50( 9.8989E-08 )
  NI0610J50( 4.2858E-09 )
  NI0620J50( 1.3616E-08 )
  NI0640J50( 3.4514E-09 )
  HF1740J50( 7.9659E-10 )
  HF1760J50( 2.5599E-08 )
  HF1770J50( 9.1490E-08 )
  HF1780J50( 1.3422E-07 )
  HF1790J50( 6.7017E-08 )
  HF1800J50( 1.7259E-07 )
*
* SUS304 CLADDING
& IDMAT(3)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  B00100J50( 1.4944E-06 )
  B00110J50( 6.0150E-06 )
  C00120J50( 2.0959E-04 )
  C00130J50( 2.3311E-06 )
  SI0280J50( 8.4167E-04 )
  SI0290J50( 4.2617E-05 )
  SI0300J50( 2.8290E-05 )
  P00310J50( 3.2378E-05 )
  S00320J50( 1.9388E-05 )
  S00330J50( 1.5303E-07 )
  S00340J50( 8.5901E-07 )
  S00360J50( 4.0808E-09 )
  CR0500J50( 7.3760E-04 )
  CR0520J50( 1.4224E-02 )
  CR0530J50( 1.6127E-03 )
  CR0540J50( 4.0148E-04 )
  MN0550J50( 1.1880E-03 )
  FE0540J50( 3.5498E-03 )
  FE0560J50( 5.5184E-02 )
  FE0570J50( 1.2635E-03 )
  FE0580J50( 1.6847E-04 )
  NI0580J50( 5.0923E-03 )
  NI0600J50( 1.9468E-03 )
  NI0610J50( 8.4288E-05 )
  NI0620J50( 2.6778E-04 )
  NI0640J50( 6.7878E-05 )
*
* MODERATOR
& IDMAT(4)
  TPRECS( 0.1 )
```

```
  TEMPMT( <273.15+TP> )
  H0001HJ50( <6.6655E-02*FRM/100.0> )
  O0016HJ50( <3.3329E-02*FRM/100.0> )
*
$END XSEC
*
*--------+---------+---------+---------+---------+---------+---------+--
* GEOMETRY
*--------+---------+---------+---------+---------+---------+---------+--
$GEOMETRY
*
RPP (  5000   <-0.5*FPP> <0.5*FPP> <-0.5*FPP> <0.5*FPP>
           <FZ1>  <FZ2> )
CYL (   100   0.0 0.0 <FZ1>  <FZ2-FZ1>   <FR1> ) /* Zr
CYL (   200   0.0 0.0 <FZ1>  <FZ2-FZ1>   <FR2> ) /* void
CYL (   300   0.0 0.0 <FZ1>  <FZ2-FZ1>   <FR3> ) /* U-ZrH
CYL (   400   0.0 0.0 <FZ1>  <FZ2-FZ1>   <FR4> ) /* void
CYL (   500   0.0 0.0 <FZ1>  <FZ2-FZ1>   <FR5> ) /* cladding
*
END
*--------+---------+---------+---------+---------+---------+---------+--
* ZONE
*--------+---------+---------+---------+---------+---------+---------+--
*
  C101     :      : -2000 :  -5000            /* mirror reflection
  C102     : MODR :    4 :   5000  -500        /* moderator
  C103     : CLAD :    3 :    500  -400        /* cladding
  C104     : VOID :    0 :    400  -300        /* void
  C105     : FUEL :    2 :    300  -200        /* u-zrh
  C106     : VOID :    0 :    200  -100        /* void
  C107     : ZIRC :    1 :    100             /* zr
*
*
#TALLY REGION
  DEFINE @FCEL (FUEL ZIRC CLAD MODR VOID)
*
$END GEOMETRY
*
$TALLY
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( @FCEL )
  IENERGY (  1   2   3   4   5   6   7   8   9  10
            11  12  13  14  15  16  17  18  19  20
            21  22  23  24  25  26  27  28  29  30
            31  32  33  34  35  36  37  38  39  40
            41  42  43  44  45  46  47  48  49  50
            51  52  53  54  55  56  57  58  59  60
            61  62  63  64  65  66  67  68  69  70
            71  72  73  74  75  76  77  78  79  80
            81  82  83  84  85  86  87  88  89  90
            91  92  93  94  95  96  97  98  99 100
           101 102 103 104 105 106 107 108 109 110
           111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( FUEL )
  IENERGY (  1   2   3   4   5   6   7   8   9  10
            11  12  13  14  15  16  17  18  19  20
            21  22  23  24  25  26  27  28  29  30
            31  32  33  34  35  36  37  38  39  40
            41  42  43  44  45  46  47  48  49  50
            51  52  53  54  55  56  57  58  59  60
            61  62  63  64  65  66  67  68  69  70
            71  72  73  74  75  76  77  78  79  80
            81  82  83  84  85  86  87  88  89  90
            91  92  93  94  95  96  97  98  99 100
           101 102 103 104 105 106 107 108 109 110
           111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( MODR )
  IENERGY (  1   2   3   4   5   6   7   8   9  10
            11  12  13  14  15  16  17  18  19  20
            21  22  23  24  25  26  27  28  29  30
            31  32  33  34  35  36  37  38  39  40
            41  42  43  44  45  46  47  48  49  50
            51  52  53  54  55  56  57  58  59  60
            61  62  63  64  65  66  67  68  69  70
            71  72  73  74  75  76  77  78  79  80
            81  82  83  84  85  86  87  88  89  90
            91  92  93  94  95  96  97  98  99 100
           101 102 103 104 105 106 107 108 109 110
           111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( THE NUMBER OF NUFISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @FCEL )
  MACRO( NUFISSION )
&
  LABEL( THE NUMBER OF FISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @FCEL )
  MACRO( FISSION )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @FCEL )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NUFISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( FUEL )
  MACRO( NUFISSION )
&
  LABEL( THE NUMBER OF FISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( FUEL )
  MACRO( FISSION )
&
```

```
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( FUEL )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( ZIRC )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( CLAD )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( VOID )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( MODR )
  MACRO( CAPTURE )
*
$END TALLY
*
*--------+---------+---------+---------+---------+---------+---------+--
* KINETICS PARAMETERS
*--------+---------+---------+---------+---------+---------+---------+--
$PERTURBATION
&
ID(1)
LABEL( KINETICS PARAMETERS )
BEFF
$END PERTURBATION
*
*--------+---------+---------+---------+---------+---------+---------+--
* SOURCE
*--------+---------+---------+---------+---------+---------+---------+--
$SOURCE
& RATIO( 1.0 )
  @( X Y ) = #DISC( 0.0 <FR3> );
  @Z      = #UNIFORM( <FZ1> <FZ2> );
  @E= #FISSION( U02350J50* 0.0253);
$END SOURCE
*
% NR =%NREG
WGTF( <NR>(1.0) )
/
```

Finite hexagonal lattice system, 55 fuel rods

```
NSRR 19.85%EU finite hexagonal lattice 11by11 55rods
50 million histories  JENDL-5
*
*--------+---------+---------+---------+---------+---------+---------+--
* OPTIONS
*--------+---------+---------+---------+---------+---------+---------+--
  AUTO-RESTART BETA-EFFECTIVE DOPPLER-SCATTERING(EXACT)
  NEUTRON PERTURBATION DYNAMIC-MEMORY(550000000)
  EIGEN-VALUE  FREE-LATTICE-FRAME  LATTICE  FLUX-PRINT
  PRINT-SUPPRESS(6 7)

% NBT =   500  /* number of effective batches
% NSK =   200  /* number of skipped batches
% NHT = 100000  /* number of particles per batch
*
  NPART(<(NBT+NSK)*NHT>) /* total number of histories
  NHIST(<NHT>)          /* number of particles per batch
  NBANK(<NHT*2>)        /* length of particle bank
  NFBANK(<NHT*2>)       /* length of fission source bank
  NSKIP(<NSK>)          /* number of skipped batches
*
  NMEMO( 100 )          /* number of next-zone memory per zone
  TCPU( 1320 )           /* calculation CPU time limit (min)
  ETOP.N(2.0E7)         /* top of neutron energy (eV)
  EBOT.N(1.0E-5)        /* bottom of neutron energy (eV)
*
  NGROUP.N( 120 )
  ENGYB.N( 2.0000E+07 1.5795E+07 1.2474E+07 9.8515E+06 7.7803E+06
         6.1445E+06 4.8526E+06 3.8324E+06 3.0266E+06 2.3903E+06
         1.8877E+06 1.4909E+06 1.1774E+06 9.2986E+05 7.3436E+05
         5.7996E+05 4.5803E+05 3.6173E+05 2.8568E+05 2.2561E+05
         1.7818E+05 1.4072E+05 1.1113E+05 8.7767E+04 6.9315E+04
         5.4741E+04 4.3232E+04 3.4143E+04 2.6964E+04 2.1295E+04
         1.6818E+04 1.3282E+04 1.0490E+04 8.2841E+03 6.5424E+03
         5.1669E+03 4.0806E+03 3.2226E+03 2.5451E+03 2.0100E+03
         1.5874E+03 1.2537E+03 9.9008E+02 7.8192E+02 6.1752E+02
         4.8769E+02 3.8516E+02 3.0418E+02 2.4023E+02 1.8972E+02
         1.4983E+02 1.1833E+02 9.3451E+01 7.3803E+01 5.8286E+01
         4.6032E+01 3.6354E+01 2.8711E+01 2.2674E+01 1.7907E+01
         1.4142E+01 1.1169E+01 8.8206E+00 6.9661E+00 5.5015E+00
         4.3448E+00 3.4313E+00 2.7099E+00 2.1402E+00 1.6902E+00
         1.3348E+00 1.0542E+00 8.3255E-01 6.5751E-01 5.1927E-01
         4.1010E-01 3.2388E-01 2.5578E-01 2.0200E-01 1.5953E-01
         1.2599E-01 9.9503E-02 7.8583E-02 6.2061E-02 4.9013E-02
         3.8708E-02 3.0570E-02 2.4143E-02 1.9067E-02 1.5058E-02
         1.1892E-02 9.3918E-03 7.4172E-03 5.8578E-03 4.6262E-03
         3.6536E-03 2.8854E-03 2.2788E-03 1.7997E-03 1.4213E-03
         1.1225E-03 8.8647E-04 7.0009E-04 5.5290E-04 4.3666E-04
         3.4485E-04 2.7235E-04 2.1509E-04 1.6987E-04 1.3415E-04
         1.0595E-04 8.3672E-05 6.6080E-05 5.2187E-05 4.1215E-05
         3.2549E-05 2.5706E-05 2.0301E-05 1.6033E-05 1.2662E-05
         1.0000E-5)
*
*--------+---------+---------+---------+---------+---------+---------+--
* PARAMETERS FOR FUEL PIN
*--------+---------+---------+---------+---------+---------+---------+--
*
% FR1    =   0.285       /* radius of zirconium (cm)
% FR2    =   0.32        /* inner radius of U-ZrH (cm)
% FR3    =   1.775       /* outer radius of U-ZrH (cm)
% FR4    =   1.82        /* inner radius of cladding (cm)
% FR5    =   1.875       /* outer radius of cladding (cm)
% FR6    =   1.815       /* radius of Mo disc (cm)
% FR7    =   1.715       /* radius of axial graphite reflector (cm)
% FR8    =   0.8775      /* rad_1 ot top end cap (cm)
% FR9    =   1.937       /* rad_2 of top end cap (cm)
% FR10   =   0.795       /* rad_1 of bottom end cap (cm)
% FR11   =   1.855       /* rad_2 of bottom end cap (cm)
% FR12   =   0.32        /* rad_3 of bottom end cap (cm)
*
% FZ1    = -19.05        /* height of bottom of core (cm)
% FZ2    =  19.05        /* height of top of core (cm)
% FZ3    = <FZ1> - 0.08   /* height of bottom of Mo disc (cm)
% FZ4    = <FZ3> - 8.69   /* height of bottom of bottom graphite (cm)
% FZ5    = <FZ4> - 0.91   /* height of bottom of cladding (cm)
% FZ6    = <FZ5> - 1.01   /* h1 of bottom end cap (cm)
% FZ7    = <FZ6> - 3.345  /* h2 of bottom end cap and top of b_grid (cm)
% FZ8    = <FZ7> - 1.535  /* h3 of bottom end cap (cm)
% FZ9    = <FZ8> - 1.7    /* height of bottom of fuel rod (cm)
*
% FZ10   = <FZ2>  + 8.69  /* height of top of top graphite (cm)
% FZ11   = <FZ10> + 0.63  /* height of bottom of top plug (cm)
% FZ12   = <FZ11> + 0.9   /* height of top of cladding (cm)
% FZ13   = <FZ12> + 1.01  /* h1 of top end cap (cm)
% FZ14   = <FZ13> + 2.15  /* h2 of top end cap (cm)
% FZ15   = <FZ14> + 4.34  /* height of top of fuel rod (cm)
*
*--------+---------+---------+---------+---------+---------+---------+--
* PARAMETERS FOR FUEL LATTICE
*--------+---------+---------+---------+---------+---------+---------+--
*
% FPN    =   11          /* number of cells in lattice (FPN by FPN)
% FPP    =    3.75        /* lattice pitch (cm)
*
% PPP    = <FPP>/SQRT(3)
*
*--------+---------+---------+---------+---------+---------+---------+--
* TEMPERATURE
*--------+---------+---------+-------- -+---------+---------+---------+--
*
% TP     =   25.0        /* temperature (deg-C)
% TPF    =   25.0        /* fuel temperature (deg-C)
*
*--------+---------+---------+---------+---------+---------+---------+--
* CONSTANTS
*--------+---------+---------+---------+---------+---------+---------+--
*
% FRM    =  100.0        /* water moderator density (%)
*
% FRR    =  100.0        /* water reflector density (%)
*
*--------+---------+---------+---------+---------+---------+---------+--
* CROSS SECTION
*--------+---------+---------+---------+---------+---------+---------+--
$XSEC
* ZIRCONIUM
& IDMAT(1)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  ZR0900J50( 2.2145E-02 )
  ZR0910J50( 4.8293E-03 )
  ZR0920J50( 7.3816E-03 )
  ZR0940J50( 7.4806E-03 )
  ZR0960J50( 1.2052E-03 )
  B00100J50( 1.4455E-08 )
  B00110J50( 5.8182E-08 )
  C00120J50( 3.7180E-05 )
  C00130J50( 4.1353E-07 )
  N00140J50( 1.1171E-05 )
  N00150J50( 4.1488E-08 )
  CR0500J50( 2.3460E-07 )
  CR0520J50( 4.5240E-06 )
  CR0530J50( 5.1293E-07 )
  CR0540J50( 1.2769E-07 )
  FE0540J50( 2.3251E-06 )
  FE0560J50( 3.6146E-05 )
  FE0570J50( 8.2759E-07 )
  FE0580J50( 1.1035E-07 )
  CU0630J50( 5.1287E-07 )
  CU0650J50( 2.2859E-07 )
  HF1740J50( 1.1582E-09 )
  HF1760J50( 3.7220E-08 )
  HF1770J50( 1.3302E-07 )
  HF1780J50( 1.9516E-07 )
  HF1790J50( 9.7440E-08 )
  HF1800J50( 2.5095E-07 )
*
* U-ZrH
& IDMAT(2)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TPF> )
  H0001ZJ50( 5.5586E-02 )
  ZR090ZJ50( 1.7678E-02 )
  ZR091ZJ50( 3.8552E-03 )
  ZR092ZJ50( 5.8928E-03 )
  ZR094ZJ50( 5.9718E-03 )
  ZR096ZJ50( 9.6209E-04 )
  U02350J50( 3.6389E-04 )
  U02380J50( 1.4505E-03 )
  C00120J50( 3.6133E-05 )
  C00130J50( 4.0189E-07 )
  N00140J50( 4.9050E-06 )
  N00150J50( 1.8216E-08 )
  O00160J50( 1.5673E-04 )
  MG0240J50( 5.7755E-06 )
  MG0250J50( 7.3116E-07 )
  MG0260J50( 8.0501E-07 )
  AL0270J50( 5.7067E-06 )
  SI0280J50( 2.4758E-06 )
  SI0290J50( 1.2536E-07 )
  SI0300J50( 8.3215E-08 )
  CL0350J50( 6.6990E-06 )
  CL0370J50( 2.1422E-06 )
  CR0500J50( 1.3069E-07 )
  CR0520J50( 2.5202E-06 )
  CR0530J50( 2.8574E-07 )
  CR0540J50( 7.1134E-08 )
  FE0540J50( 1.1152E-06 )
  FE0560J50( 1.7337E-05 )
  FE0570J50( 3.9695E-07 )
  FE0580J50( 5.2926E-08 )
  NI0580J50( 2.5893E-07 )
  NI0600J50( 9.8989E-08 )
  NI0610J50( 4.2858E-09 )
  NI0620J50( 1.3616E-08 )
  NI0640J50( 3.4514E-09 )
  HF1740J50( 7.9659E-10 )
  HF1760J50( 2.5599E-08 )
  HF1770J50( 9.1490E-08 )
  HF1780J50( 1.3422E-07 )
  HF1790J50( 6.7017E-08 )
  HF1800J50( 1.7259E-07 )
*
* SUS304 CLADDING
```

```
& IDMAT(3)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  B00100J50( 1.4944E-06 )
  B00110J50( 6.0150E-06 )
  C00120J50( 2.0959E-04 )
  C00130J50( 2.3311E-06 )
  SI0280J50( 8.4167E-04 )
  SI0290J50( 4.2617E-05 )
  SI0300J50( 2.8290E-05 )
  P00310J50( 3.2378E-05 )
  S00320J50( 1.9388E-05 )
  S00330J50( 1.5303E-07 )
  S00340J50( 8.5901E-07 )
  S00360J50( 4.0808E-09 )
  CR0500J50( 7.3760E-04 )
  CR0520J50( 1.4224E-02 )
  CR0530J50( 1.6127E-03 )
  CR0540J50( 4.0148E-04 )
  MN0550J50( 1.1880E-03 )
  FE0540J50( 3.5498E-03 )
  FE0560J50( 5.5184E-02 )
  FE0570J50( 1.2635E-03 )
  FE0580J50( 1.6847E-04 )
  NI0580J50( 5.0923E-03 )
  NI0600J50( 1.9468E-03 )
  NI0610J50( 8.4288E-05 )
  NI0620J50( 2.6778E-04 )
  NI0640J50( 6.7878E-05 )
*
* SUS304 PLUG
& IDMAT(4)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  C00120J50( 1.0617E-04 )
  C00130J50( 1.1809E-06 )
  SI0280J50( 8.6253E-04 )
  SI0290J50( 4.3674E-05 )
  SI0300J50( 2.8991E-05 )
  P00310J50( 2.4669E-05 )
  S00320J50( 2.8304E-05 )
  S00330J50( 2.2340E-07 )
  S00340J50( 1.2540E-06 )
  S00360J50( 5.9574E-09 )
  CR0500J50( 7.4225E-04 )
  CR0520J50( 1.4314E-02 )
  CR0530J50( 1.6229E-03 )
  CR0540J50( 4.0401E-04 )
  MN0550J50( 1.1126E-03 )
  FE0540J50( 3.5599E-03 )
  FE0560J50( 5.5341E-02 )
  FE0570J50( 1.2671E-03 )
  FE0580J50( 1.6894E-04 )
  NI0580J50( 4.9719E-03 )
  NI0600J50( 1.9008E-03 )
  NI0610J50( 8.2295E-05 )
  NI0620J50( 2.6145E-04 )
  NI0640J50( 6.6273E-05 )
*
* MO DISC
& IDMAT(5)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  MO0920J50( 9.5767E-03 )
  MO0940J50( 5.9693E-03 )
  MO0950J50( 1.0274E-02 )
  MO0960J50( 1.0764E-02 )
  MO0970J50( 6.1629E-03 )
  MO0980J50( 1.5572E-02 )
  MO1000J50( 6.2145E-03 )
  H00010J50( 1.2284E-05 )
  O00160J50( 9.6734E-06 )
  N00140J50( 2.2017E-06 )
  N00150J50( 8.1766E-09 )
  NA0230J50( 2.1542E-06 )
  AL0270J50( 3.5532E-06 )
  SI0280J50( 5.3522E-06 )
  SI0290J50( 2.7100E-07 )
  SI0300J50( 1.7990E-07 )
  P00310J50( 5.9961E-07 )
  CA0400J50( 3.1479E-08 )
  CA0420J50( 6.4050E-09 )
  CA0430J50( 9.8908E-08 )
  CA0440J50( 1.9379E-10 )
  CA0460J50( 9.0425E-09 )
  CA0480J50( 8.6656E-09 )
  CR0500J50( 5.1732E-08 )
  CR0520J50( 9.9761E-07 )
  CR0530J50( 1.1311E-07 )
  CR0540J50( 2.8158E-08 )
  MN0550J50( 1.1269E-06 )
  FE0540J50( 2.6162E-07 )
  FE0560J50( 4.0672E-06 )
  FE0570J50( 9.3121E-08 )
  FE0580J50( 1.2416E-08 )
  NI0580J50( 7.2015E-07 )
  NI0600J50( 2.7532E-07 )
  NI0610J50( 1.1920E-08 )
  NI0620J50( 3.7869E-08 )
  NI0640J50( 9.5992E-09 )
  CU0630J50( 8.0864E-07 )
  CU0650J50( 3.6042E-07 )
  W01800J50( 3.6367E-09 )
  W01820J50( 7.9703E-07 )
  W01830J50( 4.3276E-07 )
  W01840J50( 9.3038E-07 )
  W01860J50( 8.6674E-07 )
*
* GRAPHITE
& IDMAT(6)
  TPRECS( 1.0 )
  TEMPMT( <273.15+TP> )
  C0012CJ50P00( 8.5785E-02 )
  C0013CJ50P00( 9.5413E-04 )
*
* MODERATOR
& IDMAT(7)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  H0001HJ50( <6.6655E-02*FRM/100.0> )
  O0016HJ50( <3.3329E-02*FRM/100.0> )
*
* REFLECTOR
& IDMAT(8)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  H0001HJ50( <6.6655E-02*FRR/100.0> )
  O0016HJ50( <3.3329E-02*FRR/100.0> )
*
```

```
$END XSEC
*
*--------+---------+---------+---------+---------+---------+---------+--
* GEOMETRY
*--------+---------+---------+---------+---------+---------+---------+--
$GEOMETRY
*
% DH1 = 14.0*<PPP>
*
* hexagonal lattice (U-ZrH)
*
IDLAT(100)
 LTYP(2) NVLAT(<FPN> <FPN> 1)
 SZLAT(<FPP> 0.0 <FZ2-FZ1>)
 RCELL(6 6)
 SZHEX( 0.0 0.0 <DH1> <FZ2-FZ1> 0.0)
 KLATT(
           2 2 2 2 2 2 0 0 0 0 0
          2 2 1 1 1 2 2 0 0 0 0
         2 1 1 1 1 1 1 2 0 0 0
        2 1 1 1 1 1 1 1 2 0 0
       2 1 1 1 1 1 1 1 1 2 0
      2 2 1 1 1 1 1 1 1 2 2
     0 2 1 1 1 1 1 1 1 1 2
    0 0 2 1 1 1 1 1 1 1 2
   0 0 0 2 1 1 1 1 1 1 2
  0 0 0 0 2 2 1 1 1 2 2
 0 0 0 0 0 2 2 2 2 2 2
  )
 KSLAT (<11*11>(0))
*
* hexagonal lattice (over U-ZrH)
*
IDLAT(200)
 LTYP(2) NVLAT(<FPN> <FPN> 1)
 SZLAT(<FPP> 0.0 <FZ15-FZ2>)
 RCELL(6 6)
 SZHEX( 0.0 0.0 <DH1> <FZ15-FZ2> 0.0)
 KLATT(
           4 4 4 4 4 4 0 0 0 0 0
          4 4 3 3 3 4 4 0 0 0 0
         4 3 3 3 3 3 3 4 0 0 0
        4 3 3 3 3 3 3 3 4 0 0
       4 3 3 3 3 3 3 3 3 4 0
      4 4 3 3 3 3 3 3 3 4 4
     0 4 3 3 3 3 3 3 3 3 4
    0 0 4 3 3 3 3 3 3 3 4
   0 0 0 4 3 3 3 3 3 3 4
  0 0 0 0 4 4 3 3 3 4 4
 0 0 0 0 0 4 4 4 4 4 4
  )
 KSLAT (<11*11>(0))
*
* hexagonal lattice (under U-ZrH)
*
IDLAT(300)
 LTYP(2) NVLAT(<FPN> <FPN> 1)
 SZLAT(<FPP> 0.0 <FZ1-FZ9>)
 RCELL(6 6)
 SZHEX( 0.0 0.0 <DH1> <FZ1-FZ9> 0.0)
 KLATT(
           6 6 6 6 6 6 0 0 0 0 0
          6 6 5 5 5 6 6 0 0 0 0
         6 5 5 5 5 5 5 6 0 0 0
        6 5 5 5 5 5 5 5 6 0 0
       6 5 5 5 5 5 5 5 5 6 0
      6 6 5 5 5 5 5 5 5 6 6
     0 6 5 5 5 5 5 5 5 5 6
    0 0 6 5 5 5 5 5 5 5 6
   0 0 0 6 5 5 5 5 5 5 6
  0 0 0 0 6 6 5 5 5 6 6
 0 0 0 0 0 6 6 6 6 6 6
  )
 KSLAT (<11*11>(0))
*
END
*--------+---------+---------+---------+---------+---------+---------+--
* BODY
*--------+---------+---------+---------+---------+---------+---------+--
*
* outer boundary
RHP ( 10000  0.0  0.0  <FZ9-30.0>  <FZ15-FZ9+60.0>  <DH1+60.0> )
* lattice boundary
RHP (  1000  0.0  0.0  <FZ1>      <FZ2-FZ1>      <DH1>     )
RHP (  2000  0.0  0.0  <FZ2>      <FZ15-FZ2>     <DH1>     )
RHP (  3000  0.0  0.0  <FZ9>      <FZ1-FZ9>      <DH1>     )
* lattice 100
RHP (   100  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FPP>     )
CYL (    10  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR1>     ) /* Zr
CYL (    11  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR2>     ) /* v
CYL (    12  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR3>     ) /* UZrH
CYL (    13  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR4>     ) /* v
CYL (    14  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR5>     ) /* clad
* lattice 200
RHP (   200  0.0  0.0  <FZ2>      <FZ15-FZ2>     <FPP>     )
CYL (    20  0.0  0.0  <FZ2>      <FZ10-FZ2>     <FR7>     )  /* C
CYL (    21  0.0  0.0  <FZ2>      <FZ11-FZ2>     <FR4>     )  /* v
CYL (    22  0.0  0.0  <FZ11>     <FZ12-FZ11>    <FR4>      )  /* cap
CYL (    23  0.0  0.0  <FZ2>      <FZ12-FZ2>     <FR5>     )  /* clad
CYL (    24  0.0  0.0  <FZ12>     <FZ13-FZ12>    <FR8>      )  /* c1
CYL (    25  0.0  0.0  <FZ13>     <FZ14-FZ13>    <FR9>      )  /* c2
CYL (    26  0.0  0.0  <FZ14>     <FZ15-FZ14>    <FR8>      )  /* c3
* lattice 300
RHP (   300  0.0  0.0  <FZ9>      <FZ1-FZ9>      <FPP>     )
CYL (    30  0.0  0.0  <FZ9>      <FZ8-FZ9>      <FR12>    )  /* c4
TRC (    31  0.0  0.0  <FZ8>   0.0  0.0  <FZ7-FZ8>
                                     <FR12>  <FR11>    )  /* c3
CYL (    32  0.0  0.0  <FZ7>      <FZ6-FZ7>      <FR11>    )  /* c2
CYL (    33  0.0  0.0  <FZ6>      <FZ5-FZ6>      <FR10>    )  /* c1
CYL (    34  0.0  0.0  <FZ5>      <FZ1-FZ5>      <FR5>     )  /* clad
CYL (    35  0.0  0.0  <FZ5>      <FZ4-FZ5>      <FR4>     )  /* cap
CYL (    36  0.0  0.0  <FZ4>      <FZ1-FZ4>      <FR4>     )  /* v
CYL (    37  0.0  0.0  <FZ4>      <FZ3-FZ4>      <FR7>     )  /* C
CYL (    38  0.0  0.0  <FZ3>      <FZ1-FZ3>      <FR6>     )  /* Mo
*
END
*--------+---------+---------+---------+---------+---------+---------+--
* ZONE
*--------+---------+---------+---------+---------+---------+---------+--
*
  VOUT    :      : -1000 : -10000                 /* outer void
  REFL    : REFL :     8 :  10000 -1000 -2000 -3000 /* water reflector
  LAT1    : LAT1 :  -100 :   1000                 /* U-ZrH
  LAT2    : LAT2 :  -200 :   2000                 /* over U-ZrH
  LAT3    : LAT3 :  -300 :   3000                 /* under U-ZrH
*
#CELL ID(1)  TYPE(HEXA)
  C101     :      :  -999 :   -100
  C102     : MODR :     7 :    100  -14            /* moderator
```

```
 C103     : CLAD :    3 :    14  -13           /* cladding
 C104     : VOID :    0 :    13  -12           /* void
 C105     : FUEL :    2 :    12  -11           /* u-zrh
 C106     : VOID :    0 :    11  -10           /* void
 C107     : ZIRC :    1 :    10                /* zr
#END CELL
*
#CELL ID(2)  TYPE(HEXA)
 C201     :      : -999 :  -100
 C202     : REFL :    8 :   100                /* water reflector
#END CELL
*
#CELL ID(3)  TYPE(HEXA)
 C301     :      : -999 :  -200
 C302     : REFL :    8 :   200  -23 -24 -25 -26  /* reflector
 C305     : SUSX :    3 :    23  -21 -22          /* cladding
 C306     : VOID :    0 :    21  -20           /* void
 C307     : GRAP :    6 :    20                /* graphite
 C308     : SUSX :    4 :    22                /* top plug
 C309     : SUSX :    4 :    24                /* top c1
 C310     : SUSX :    4 :    25                /* top c2
 C311     : SUSX :    4 :    26                /* top c3
#END CELL
*
#CELL ID(4)  TYPE(HEXA)
 C401     :      : -999 :  -200
 C402     : REFL :    8 :   200                /* water reflector
#END CELL
*
#CELL ID(5)  TYPE(HEXA)
 C501     :      : -999 :  -300
 C502     : REFL :    8 :   300  -30 -31 -32 -33 -34 /* reflector
 C504     : SUSX :    3 :    34  -35 -36          /* cladding
 C505     : VOID :    0 :    36  -37 -38          /* void
 C506     : GRAP :    6 :    37                /* graphite
 C507     : MOLY :    5 :    38                /* mo
 C508     : SUSX :    4 :    35                /* bottom plug
 C509     : SUSX :    4 :    33                /* bottom c1
 C510     : SUSX :    4 :    32                /* bottom c2
 C511     : SUSX :    4 :    31                /* bottom c3
 C512     : SUSX :    4 :    30                /* bottom c4
#END CELL
*
#CELL ID(6)  TYPE(HEXA)
 C601     :      : -999 :  -300
 C602     : REFL :    8 :   300                /* water reflector
#END CELL
*
*
#TALLY REGION
 DEFINE @FCEL (FUEL ZIRC CLAD MODR)
 DEFINE @EXTX (SUSX GRAP MOLY REFL)
*
$END GEOMETRY
*
$TALLY
&
 LABEL( NEUTRON FLUX 120 ENERGY GROUP )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION  ENERGY)
 REGION( @FCEL )
 IENERGY (  1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
 LABEL( NEUTRON FLUX 120 ENERGY GROUP )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION  ENERGY)
 REGION( FUEL )
 IENERGY (  1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
 LABEL( NEUTRON FLUX 120 ENERGY GROUP )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION  ENERGY)
 REGION( MODR )
 IENERGY (  1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
 LABEL( NEUTRON FLUX 120 ENERGY GROUP )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION  ENERGY)
 REGION( REFL )
 IENERGY (  1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
 LABEL( NEUTRON FLUX 120 ENERGY GROUP )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION  ENERGY)
 REGION( GRAP )
 IENERGY (  1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
 LABEL( THE NUMBER OF NUFISSION PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( @FCEL )
 MACRO( NUFISSION )
&
 LABEL( THE NUMBER OF FISSION PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( @FCEL )
 MACRO( FISSION )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( @FCEL )
 MACRO( CAPTURE )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( @EXTX )
 MACRO( CAPTURE )
&
 LABEL( THE NUMBER OF NUFISSION PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( FUEL )
 MACRO( NUFISSION )
&
 LABEL( THE NUMBER OF FISSION PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( FUEL )
 MACRO( FISSION )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( FUEL )
 MACRO( CAPTURE )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( ZIRC )
 MACRO( CAPTURE )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( CLAD )
 MACRO( CAPTURE )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( SUSX )
 MACRO( CAPTURE )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( GRAP )
 MACRO( CAPTURE )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( MOLY )
 MACRO( CAPTURE )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( MODR )
 MACRO( CAPTURE )
&
 LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
 EVENT( TRACK )
 NEUTRON
 DIMENSION ( REGION )
 REGION( REFL )
 MACRO( CAPTURE )
*
$END TALLY
*
*--------+---------+---------+---------+---------+---------+---------+--
* KINETICS PARAMETERS
*--------+---------+---------+---------+---------+---------+---------+--
$PERTURBATION
&
ID(1)
LABEL( KINETICS PARAMETERS )
BEFF
$END PERTURBATION
*
*--------+---------+---------+---------+---------+---------+---------+--
```

```
* SOURCE
*--------+---------+---------+---------+---------+---------+---------+--
$SOURCE
& RATIO( 1.0 )
  @( X Y ) = #DISC( 0.0 <0.5*DH1> );
  @Z      = #UNIFORM( <FZ1> <FZ2> );
  @E= #FISSION( U02350J50* 0.0253);
$END SOURCE
*
% NR =%NREG
WGTF( <NR>(1.0) )
/
```

Finite square lattice system, 57 fuel rods

```
NSRR 19.85%EU finite square lattice 9by9 57rods
50 million histories  JENDL-5
*
*--------+---------+---------+---------+---------+---------+---------+--
* OPTIONS
*--------+---------+---------+---------+---------+---------+---------+--
  AUTO-RESTART BETA-EFFECTIVE DOPPLER-SCATTERING(EXACT)
  NEUTRON PERTURBATION DYNAMIC-MEMORY(550000000)
  EIGEN-VALUE  FREE-LATTICE-FRAME  LATTICE  FLUX-PRINT
  PRINT-SUPPRESS(6 7)

% NBT =   500  /* number of effective batches
% NSK =   200  /* number of skipped batches
% NHT = 100000  /* number of particles per batch
*
  NPART(<(NBT+NSK)*NHT>) /* total number of histories
  NHIST(<NHT>)          /* number of particles per batch
  NBANK(<NHT*2>)        /* length of particle bank
  NFBANK(<NHT*2>)       /* length of fission source bank
  NSKIP(<NSK>)          /* number of skipped batches
*
  NMEMO( 100 )          /* number of next-zone memory per zone
  TCPU( 1320 )            /* calculation CPU time limit (min)
  ETOP.N(2.0E7)         /* top of neutron energy (eV)
  EBOT.N(1.0E-5)        /* bottom of neutron energy (eV)
*
  NGROUP.N( 120 )
  ENGYB.N( 2.0000E+07 1.5795E+07 1.2474E+07 9.8515E+06 7.7803E+06
          6.1445E+06 4.8526E+06 3.8324E+06 3.0266E+06 2.3903E+06
          1.8877E+06 1.4909E+06 1.1774E+06 9.2986E+05 7.3436E+05
          5.7996E+05 4.5803E+05 3.6173E+05 2.8568E+05 2.2561E+05
          1.7818E+05 1.4072E+05 1.1113E+05 8.7767E+04 6.9315E+04
          5.4741E+04 4.3232E+04 3.4143E+04 2.6964E+04 2.1295E+04
          1.6818E+04 1.3282E+04 1.0490E+04 8.2841E+03 6.5424E+03
          5.1669E+03 4.0806E+03 3.2226E+03 2.5451E+03 2.0100E+03
          1.5874E+03 1.2537E+03 9.9008E+02 7.8192E+02 6.1752E+02
          4.8769E+02 3.8516E+02 3.0418E+02 2.4023E+02 1.8972E+02
          1.4983E+02 1.1833E+02 9.3451E+01 7.3803E+01 5.8286E+01
          4.6032E+01 3.6354E+01 2.8711E+01 2.2674E+01 1.7907E+01
          1.4142E+01 1.1169E+01 8.8206E+00 6.9661E+00 5.5015E+00
          4.3448E+00 3.4313E+00 2.7099E+00 2.1402E+00 1.6902E+00
          1.3348E+00 1.0542E+00 8.3255E-01 6.5751E-01 5.1927E-01
          4.1010E-01 3.2388E-01 2.5578E-01 2.0200E-01 1.5953E-01
          1.2599E-01 9.9503E-02 7.8583E-02 6.2061E-02 4.9013E-02
          3.8708E-02 3.0570E-02 2.4143E-02 1.9067E-02 1.5058E-02
          1.1892E-02 9.3918E-03 7.4172E-03 5.8578E-03 4.6262E-03
          3.6536E-03 2.8854E-03 2.2788E-03 1.7997E-03 1.4213E-03
          1.1225E-03 8.8647E-04 7.0009E-04 5.5290E-04 4.3666E-04
          3.4485E-04 2.7235E-04 2.1509E-04 1.6987E-04 1.3415E-04
          1.0595E-04 8.3672E-05 6.6080E-05 5.2187E-05 4.1215E-05
          3.2549E-05 2.5706E-05 2.0301E-05 1.6033E-05 1.2662E-05
          1.0000E-5)
*
*--------+---------+---------+---------+---------+---------+---------+--
* PARAMETERS FOR FUEL PIN
*--------+---------+---------+---------+---------+---------+---------+--
*
% FR1    =   0.285       /* radius of zirconium (cm)
% FR2    =   0.32        /* inner radius of U-ZrH (cm)
% FR3    =   1.775       /* outer radius of U-ZrH (cm)
% FR4    =   1.82        /* inner radius of cladding (cm)
% FR5    =   1.875       /* outer radius of cladding (cm)
% FR6    =   1.815       /* radius of Mo disc (cm)
% FR7    =   1.715       /* radius of axial graphite reflector (cm)
% FR8    =   0.8775      /* rad_1 ot top end cap (cm)
% FR9    =   1.937       /* rad_2 of top end cap (cm)
% FR10   =   0.795       /* rad_1 of bottom end cap (cm)
% FR11   =   1.855       /* rad_2 of bottom end cap (cm)
% FR12   =   0.32        /* rad_3 of bottom end cap (cm)
*
% FZ1    = -19.05        /* height of bottom of core (cm)
% FZ2    =  19.05        /* height of top of core (cm)
% FZ3    = <FZ1> - 0.08   /* height of bottom of Mo disc (cm)
% FZ4    = <FZ3> - 8.69   /* height of bottom of bottom graphite (cm)
% FZ5    = <FZ4> - 0.91   /* height of bottom of cladding (cm)
% FZ6    = <FZ5> - 1.01   /* h1 of bottom end cap (cm)
% FZ7    = <FZ6> - 3.345  /* h2 of bottom end cap and top of b_grid (cm)
% FZ8    = <FZ7> - 1.535  /* h3 of bottom end cap (cm)
% FZ9    = <FZ8> - 1.7    /* height of bottom of fuel rod (cm)
*
% FZ10   = <FZ2>  + 8.69  /* height of top of top graphite (cm)
% FZ11   = <FZ10> + 0.63  /* height of bottom of top plug (cm)
% FZ12   = <FZ11> + 0.9   /* height of top of cladding (cm)
% FZ13   = <FZ12> + 1.01  /* h1 of top end cap (cm)
% FZ14   = <FZ13> + 2.15  /* h2 of top end cap (cm)
% FZ15   = <FZ14> + 4.34  /* height of top of fuel rod (cm)
*
*--------+---------+---------+---------+---------+---------+---------+--
* PARAMETERS FOR FUEL LATTICE
*--------+---------+---------+---------+---------+---------+---------+--
*
% FPN    =    9          /* number of cells in lattice (FPN by FPN)
% FPP    =    3.75        /* lattice pitch (cm)
*
*--------+---------+---------+---------+---------+---------+---------+--
* TEMPERATURE
*--------+---------+---------+-------- -+---------+---------+---------+--
*
% TP     =   25.0        /* temperature (deg-C)
% TPF    =   25.0        /* fuel temperature (deg-C)
*
*--------+---------+---------+---------+---------+---------+---------+--
* CONSTANTS
*--------+---------+---------+---------+---------+---------+---------+--
*
% FRM    =  100.0        /* water moderator density (%)
*
% FRR    =  100.0        /* water reflector density (%)
*
*--------+---------+---------+---------+---------+---------+---------+--
* CROSS SECTION
*--------+---------+---------+---------+---------+---------+---------+--
$XSEC
```

```
* ZIRCONIUM
& IDMAT(1)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  ZR0900J50( 2.2145E-02 )
  ZR0910J50( 4.8293E-03 )
  ZR0920J50( 7.3816E-03 )
  ZR0940J50( 7.4806E-03 )
  ZR0960J50( 1.2052E-03 )
  B00100J50( 1.4455E-08 )
  B00110J50( 5.8182E-08 )
  C00120J50( 3.7180E-05 )
  C00130J50( 4.1353E-07 )
  N00140J50( 1.1171E-05 )
  N00150J50( 4.1488E-08 )
  CR0500J50( 2.3460E-07 )
  CR0520J50( 4.5240E-06 )
  CR0530J50( 5.1293E-07 )
  CR0540J50( 1.2769E-07 )
  FE0540J50( 2.3251E-06 )
  FE0560J50( 3.6146E-05 )
  FE0570J50( 8.2759E-07 )
  FE0580J50( 1.1035E-07 )
  CU0630J50( 5.1287E-07 )
  CU0650J50( 2.2859E-07 )
  HF1740J50( 1.1582E-09 )
  HF1760J50( 3.7220E-08 )
  HF1770J50( 1.3302E-07 )
  HF1780J50( 1.9516E-07 )
  HF1790J50( 9.7440E-08 )
  HF1800J50( 2.5095E-07 )
*
* U-ZrH
& IDMAT(2)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TPF> )
  H0001ZJ50( 5.5586E-02 )
  ZR090ZJ50( 1.7678E-02 )
  ZR091ZJ50( 3.8552E-03 )
  ZR092ZJ50( 5.8928E-03 )
  ZR094ZJ50( 5.9718E-03 )
  ZR096ZJ50( 9.6209E-04 )
  U02350J50( 3.6389E-04 )
  U02380J50( 1.4505E-03 )
  C00120J50( 3.6133E-05 )
  C00130J50( 4.0189E-07 )
  N00140J50( 4.9050E-06 )
  N00150J50( 1.8216E-08 )
  O00160J50( 1.5673E-04 )
  MG0240J50( 5.7755E-06 )
  MG0250J50( 7.3116E-07 )
  MG0260J50( 8.0501E-07 )
  AL0270J50( 5.7067E-06 )
  SI0280J50( 2.4758E-06 )
  SI0290J50( 1.2536E-07 )
  SI0300J50( 8.3215E-08 )
  CL0350J50( 6.6990E-06 )
  CL0370J50( 2.1422E-06 )
  CR0500J50( 1.3069E-07 )
  CR0520J50( 2.5202E-06 )
  CR0530J50( 2.8574E-07 )
  CR0540J50( 7.1134E-08 )
  FE0540J50( 1.1152E-06 )
  FE0560J50( 1.7337E-05 )
  FE0570J50( 3.9695E-07 )
  FE0580J50( 5.2926E-08 )
  NI0580J50( 2.5893E-07 )
  NI0600J50( 9.8989E-08 )
  NI0610J50( 4.2858E-09 )
  NI0620J50( 1.3616E-08 )
  NI0640J50( 3.4514E-09 )
  HF1740J50( 7.9659E-10 )
  HF1760J50( 2.5599E-08 )
  HF1770J50( 9.1490E-08 )
  HF1780J50( 1.3422E-07 )
  HF1790J50( 6.7017E-08 )
  HF1800J50( 1.7259E-07 )
*
* SUS304 CLADDING
& IDMAT(3)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  B00100J50( 1.4944E-06 )
  B00110J50( 6.0150E-06 )
  C00120J50( 2.0959E-04 )
  C00130J50( 2.3311E-06 )
  SI0280J50( 8.4167E-04 )
  SI0290J50( 4.2617E-05 )
  SI0300J50( 2.8290E-05 )
  P00310J50( 3.2378E-05 )
  S00320J50( 1.9388E-05 )
  S00330J50( 1.5303E-07 )
  S00340J50( 8.5901E-07 )
  S00360J50( 4.0808E-09 )
  CR0500J50( 7.3760E-04 )
  CR0520J50( 1.4224E-02 )
  CR0530J50( 1.6127E-03 )
  CR0540J50( 4.0148E-04 )
  MN0550J50( 1.1880E-03 )
  FE0540J50( 3.5498E-03 )
  FE0560J50( 5.5184E-02 )
  FE0570J50( 1.2635E-03 )
  FE0580J50( 1.6847E-04 )
  NI0580J50( 5.0923E-03 )
  NI0600J50( 1.9468E-03 )
  NI0610J50( 8.4288E-05 )
  NI0620J50( 2.6778E-04 )
  NI0640J50( 6.7878E-05 )
*
* SUS304 PLUG
& IDMAT(4)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  C00120J50( 1.0617E-04 )
  C00130J50( 1.1809E-06 )
  SI0280J50( 8.6253E-04 )
  SI0290J50( 4.3674E-05 )
  SI0300J50( 2.8991E-05 )
  P00310J50( 2.4669E-05 )
  S00320J50( 2.8304E-05 )
  S00330J50( 2.2340E-07 )
  S00340J50( 1.2540E-06 )
  S00360J50( 5.9574E-09 )
  CR0500J50( 7.4225E-04 )
  CR0520J50( 1.4314E-02 )
  CR0530J50( 1.6229E-03 )
  CR0540J50( 4.0401E-04 )
  MN0550J50( 1.1126E-03 )
  FE0540J50( 3.5599E-03 )
```

```
  FE0560J50( 5.5341E-02 )
  FE0570J50( 1.2671E-03 )
  FE0580J50( 1.6894E-04 )
  NI0580J50( 4.9719E-03 )
  NI0600J50( 1.9008E-03 )
  NI0610J50( 8.2295E-05 )
  NI0620J50( 2.6145E-04 )
  NI0640J50( 6.6273E-05 )
*
* MO DISC
& IDMAT(5)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  MO0920J50( 9.5767E-03 )
  MO0940J50( 5.9693E-03 )
  MO0950J50( 1.0274E-02 )
  MO0960J50( 1.0764E-02 )
  MO0970J50( 6.1629E-03 )
  MO0980J50( 1.5572E-02 )
  MO1000J50( 6.2145E-03 )
  H00010J50( 1.2284E-05 )
  O00160J50( 9.6734E-06 )
  N00140J50( 2.2017E-06 )
  N00150J50( 8.1766E-09 )
  NA0230J50( 2.1542E-06 )
  AL0270J50( 3.5532E-06 )
  SI0280J50( 5.3522E-06 )
  SI0290J50( 2.7100E-07 )
  SI0300J50( 1.7990E-07 )
  P00310J50( 5.9961E-07 )
  CA0400J50( 3.1479E-08 )
  CA0420J50( 6.4050E-09 )
  CA0430J50( 9.8908E-08 )
  CA0440J50( 1.9379E-10 )
  CA0460J50( 9.0425E-09 )
  CA0480J50( 8.6656E-09 )
  CR0500J50( 5.1732E-08 )
  CR0520J50( 9.9761E-07 )
  CR0530J50( 1.1311E-07 )
  CR0540J50( 2.8158E-08 )
  MN0550J50( 1.1269E-06 )
  FE0540J50( 2.6162E-07 )
  FE0560J50( 4.0672E-06 )
  FE0570J50( 9.3121E-08 )
  FE0580J50( 1.2416E-08 )
  NI0580J50( 7.2015E-07 )
  NI0600J50( 2.7532E-07 )
  NI0610J50( 1.1920E-08 )
  NI0620J50( 3.7869E-08 )
  NI0640J50( 9.5992E-09 )
  CU0630J50( 8.0864E-07 )
  CU0650J50( 3.6042E-07 )
  W01800J50( 3.6367E-09 )
  W01820J50( 7.9703E-07 )
  W01830J50( 4.3276E-07 )
  W01840J50( 9.3038E-07 )
  W01860J50( 8.6674E-07 )
*
* GRAPHITE
& IDMAT(6)
  TPRECS( 1.0 )
  TEMPMT( <273.15+TP> )
  C0012CJ50P00( 8.5785E-02 )
  C0013CJ50P00( 9.5413E-04 )
*
* MODERATOR
& IDMAT(7)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  H0001HJ50( <6.6655E-02*FRM/100.0> )
  O0016HJ50( <3.3329E-02*FRM/100.0> )
*
* REFLECTOR
& IDMAT(8)
  TPRECS( 0.1 )
  TEMPMT( <273.15+TP> )
  H0001HJ50( <6.6655E-02*FRR/100.0> )
  O0016HJ50( <3.3329E-02*FRR/100.0> )
*
$END XSEC
*
*--------+---------+---------+---------+---------+---------+---------+--
* GEOMETRY
*--------+---------+---------+---------+---------+---------+---------+--
$GEOMETRY
*
% DH1 = <FPN*FPP>
*
* square lattice (U-ZrH)
*
IDLAT(100)
 LTYP(1) NVLAT(<FPN> <FPN> 1)
 SZLAT(<FPP> <FPP> <FZ2-FZ1>)
 KLATT(
   2 2 2 1 1 1 2 2 2
   2 2 1 1 1 1 1 2 2
   2 1 1 1 1 1 1 1 2
   1 1 1 1 1 1 1 1 1
   1 1 1 1 1 1 1 1 1
   1 1 1 1 1 1 1 1 1
   2 1 1 1 1 1 1 1 2
   2 2 1 1 1 1 1 2 2
   2 2 2 1 1 1 2 2 2
  )
 KSLAT (<9*9>(0))
*
* square lattice (over U-ZrH)
*
IDLAT(200)
 LTYP(1) NVLAT(<FPN> <FPN> 1)
 SZLAT(<FPP> <FPP> <FZ15-FZ2>)
 KLATT(
   4 4 4 3 3 3 4 4 4
   4 4 3 3 3 3 3 4 4
   4 3 3 3 3 3 3 3 4
   3 3 3 3 3 3 3 3 3
   3 3 3 3 3 3 3 3 3
   3 3 3 3 3 3 3 3 3
   4 3 3 3 3 3 3 3 4
   4 4 3 3 3 3 3 4 4
   4 4 4 3 3 3 4 4 4
  )
 KSLAT (<9*9>(0))
*
* square lattice (under U-ZrH)
*
IDLAT(300)
 LTYP(1) NVLAT(<FPN> <FPN> 1)
 SZLAT(<FPP> <FPP> <FZ1-FZ9>)
 KLATT(
   6 6 6 5 5 5 6 6 6
   6 6 5 5 5 5 5 6 6
   6 5 5 5 5 5 5 5 6
   5 5 5 5 5 5 5 5 5
   5 5 5 5 5 5 5 5 5
   5 5 5 5 5 5 5 5 5
   6 5 5 5 5 5 5 5 6
   6 6 5 5 5 5 5 6 6
   6 6 6 5 5 5 6 6 6
  )
 KSLAT (<9*9>(0))
*
END
*--------+---------+---------+---------+---------+---------+---------+--
* BODY
*--------+---------+---------+---------+---------+---------+---------+--
*
* outer boundary
RPP ( 10000 <-DH1/2-30.0> <DH1/2+30.0> <-DH1/2-30.0> <DH1/2+30.0>
           <FZ9-30.0> <FZ15+30.0> )
* lattice boundary
RPP (  1000 -<DH1/2> <DH1/2> -<DH1/2> <DH1/2> <FZ1>  <FZ2>    )
RPP (  2000 -<DH1/2> <DH1/2> -<DH1/2> <DH1/2> <FZ2>  <FZ15>   )
RPP (  3000 -<DH1/2> <DH1/2> -<DH1/2> <DH1/2> <FZ9>  <FZ1>    )
* lattice 100
RPP (   100 -<FPP/2> <FPP/2> -<FPP/2> <FPP/2> <FZ1>  <FZ2>   )
CYL (    10  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR1>     ) /* Zr
CYL (    11  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR2>     ) /* v
CYL (    12  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR3>     ) /* UZrH
CYL (    13  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR4>     ) /* v
CYL (    14  0.0  0.0  <FZ1>      <FZ2-FZ1>      <FR5>     ) /* clad
* lattice 200
RPP (   200 -<FPP/2> <FPP/2> -<FPP/2> <FPP/2> <FZ2>  <FZ15>   )
CYL (    20  0.0  0.0  <FZ2>      <FZ10-FZ2>     <FR7>     )  /* C
CYL (    21  0.0  0.0  <FZ2>      <FZ11-FZ2>     <FR4>     )  /* v
CYL (    22  0.0  0.0  <FZ11>     <FZ12-FZ11>    <FR4>     )  /* cap
CYL (    23  0.0  0.0  <FZ2>      <FZ12-FZ2>     <FR5>     )  /* clad
CYL (    24  0.0  0.0  <FZ12>     <FZ13-FZ12>    <FR8>     )  /* c1
CYL (    25  0.0  0.0  <FZ13>     <FZ14-FZ13>    <FR9>     )  /* c2
CYL (    26  0.0  0.0  <FZ14>     <FZ15-FZ14>    <FR8>     )  /* c3
* lattice 300
RPP (   300 -<FPP/2> <FPP/2> -<FPP/2> <FPP/2> <FZ9>  <FZ1>    )
CYL (    30  0.0  0.0  <FZ9>      <FZ8-FZ9>      <FR12>    )  /* c4
TRC (    31  0.0  0.0  <FZ8>  0.0  0.0  <FZ7-FZ8>
                                   <FR12>  <FR11>    )  /* c3
CYL (    32  0.0  0.0  <FZ7>      <FZ6-FZ7>      <FR11>    )  /* c2
CYL (    33  0.0  0.0  <FZ6>      <FZ5-FZ6>      <FR10>    )  /* c1
CYL (    34  0.0  0.0  <FZ5>      <FZ1-FZ5>      <FR5>     )  /* clad
CYL (    35  0.0  0.0  <FZ5>      <FZ4-FZ5>      <FR4>     )  /* cap
CYL (    36  0.0  0.0  <FZ4>      <FZ1-FZ4>      <FR4>     )  /* v
CYL (    37  0.0  0.0  <FZ4>      <FZ3-FZ4>      <FR7>     )  /* C
CYL (    38  0.0  0.0  <FZ3>      <FZ1-FZ3>      <FR6>     )  /* Mo
*
END
*--------+---------+---------+---------+---------+---------+---------+--
* ZONE
*--------+---------+---------+---------+---------+---------+---------+--
*
  VOUT    :      : -1000 : -10000                /* outer void
  REFL    : REFL :    8 :  10000 -1000 -2000 -3000 /* water reflector
  LAT1    : LAT1 :  -100 :   1000                /* U-ZrH
  LAT2    : LAT2 :  -200 :   2000                /* over U-ZrH
  LAT3    : LAT3 :  -300 :   3000                /* under U-ZrH
*
#CELL ID(1)  TYPE(BOX)
  C101     :      :  -999 :   -100
  C102     : MODR :     7 :    100  -14            /* moderator
  C103     : CLAD :     3 :     14  -13            /* cladding
  C104     : VOID :     0 :     13  -12            /* void
  C105     : FUEL :     2 :     12  -11            /* u-zrh
  C106     : VOID :     0 :     11  -10            /* void
  C107     : ZIRC :     1 :     10                 /* zr
#END CELL
*
#CELL ID(2)  TYPE(BOX)
  C201     :      :  -999 :   -100
  C202     : REFL :     8 :    100                 /* water reflector
#END CELL
*
#CELL ID(3)  TYPE(BOX)
  C301     :      :  -999 :   -200
  C302     : REFL :     8 :    200  -23 -24 -25 -26  /* reflector
  C305     : SUSX :     3 :     23  -21 -22        /* cladding
  C306     : VOID :     0 :     21  -20            /* void
  C307     : GRAP :     6 :     20                 /* graphite
  C308     : SUSX :     4 :     22                 /* top plug
  C309     : SUSX :     4 :     24                 /* top c1
  C310     : SUSX :     4 :     25                 /* top c2
  C311     : SUSX :     4 :     26                 /* top c3
#END CELL
*
#CELL ID(4)  TYPE(BOX)
  C401     :      :  -999 :   -200
  C402     : REFL :     8 :    200                 /* water reflector
#END CELL
*
#CELL ID(5)  TYPE(BOX)
  C501     :      :  -999 :   -300
  C502     : REFL :     8 :    300  -30 -31 -32 -33 -34 /* reflector
  C504     : SUSX :     3 :     34  -35 -36        /* cladding
  C505     : VOID :     0 :     36  -37 -38        /* void
  C506     : GRAP :     6 :     37                 /* graphite
  C507     : MOLY :     5 :     38                 /* mo
  C508     : SUSX :     4 :     35                 /* bottom plug
  C509     : SUSX :     4 :     33                 /* bottom c1
  C510     : SUSX :     4 :     32                 /* bottom c2
  C511     : SUSX :     4 :     31                 /* bottom c3
  C512     : SUSX :     4 :     30                 /* bottom c4
#END CELL
*
#CELL ID(6)  TYPE(BOX)
  C601     :      :  -999 :   -300
  C602     : REFL :     8 :    300                 /* water reflector
#END CELL
*
*
#TALLY REGION
  DEFINE @FCEL (FUEL ZIRC CLAD MODR)
  DEFINE @EXTX (SUSX GRAP MOLY REFL)
*
$END GEOMETRY
*
$TALLY
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
```

```
  REGION( @FCEL )
  IENERGY ( 1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( FUEL )
  IENERGY ( 1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( MODR )
  IENERGY ( 1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( REFL )
  IENERGY ( 1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( NEUTRON FLUX 120 ENERGY GROUP )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION  ENERGY)
  REGION( GRAP )
  IENERGY ( 1   2   3   4   5   6   7   8   9  10
           11  12  13  14  15  16  17  18  19  20
           21  22  23  24  25  26  27  28  29  30
           31  32  33  34  35  36  37  38  39  40
           41  42  43  44  45  46  47  48  49  50
           51  52  53  54  55  56  57  58  59  60
           61  62  63  64  65  66  67  68  69  70
           71  72  73  74  75  76  77  78  79  80
           81  82  83  84  85  86  87  88  89  90
           91  92  93  94  95  96  97  98  99 100
          101 102 103 104 105 106 107 108 109 110
          111 112 113 114 115 116 117 118 119 120 )
&
  LABEL( THE NUMBER OF NUFISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @FCEL )
  MACRO( NUFISSION )
&
  LABEL( THE NUMBER OF FISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @FCEL )
  MACRO( FISSION )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @FCEL )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( @EXTX )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NUFISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( FUEL )
  MACRO( NUFISSION )
&
  LABEL( THE NUMBER OF FISSION PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( FUEL )
  MACRO( FISSION )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( FUEL )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( ZIRC )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( CLAD )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( SUSX )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( GRAP )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( MOLY )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( MODR )
  MACRO( CAPTURE )
&
  LABEL( THE NUMBER OF NON-FISSION CAPTURE PER SOURCE )
  EVENT( TRACK )
  NEUTRON
  DIMENSION ( REGION )
  REGION( REFL )
  MACRO( CAPTURE )
*
$END TALLY
*
*--------+---------+---------+---------+---------+---------+---------+--
* KINETICS PARAMETERS
*--------+---------+---------+---------+---------+---------+---------+--
$PERTURBATION
&
ID(1)
LABEL( KINETICS PARAMETERS )
BEFF
$END PERTURBATION
*
*--------+---------+---------+---------+---------+---------+---------+--
* SOURCE
*--------+---------+---------+---------+---------+---------+---------+--
$SOURCE
& RATIO( 1.0 )
  @( X Y ) = #DISC( 0.0 <0.5*DH1> );
  @Z      = #UNIFORM( <FZ1> <FZ2> );
  @E= #FISSION( U02350J50* 0.0253);
$END SOURCE
*
% NR =%NREG
WGTF( <NR>(1.0) )
/
```