Analysis of water ingress accident in the RDE core using MCNPX

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Abstract. The 10 MW Indonesia’s Reaktor Daya Eksperimental (RDE) is a Pebble Bed High Temperature Reactor-type and to be constructed in Serpong Nuclear Zone, Puspiptek, Indonesia. The reactor applies helium gas coolant, graphite moderator, and low uranium enriched fuel (17%). A water-ingress accident may take place in the RDE core and such the accident is caused by a pipe break in the steam generator system of the reactor and hence the accident influences the reactivity of the core. To begin with, an initial core of the RDE should be modelled and the model contains the identification of material zones in the reactor core. To estimate the reactivity change due to the water-ingress accident in the initial RDE core, a void core condition from any coolant should be firstly deliberated. The core reactivity change is then estimated based on effective multiplication factor ($k_{eff}$) as a function of water density which comes into void cells among pebble containing helium coolant in the RDE core and that of the variation of $^{235}\text{U}$ enrichment. The data library of thermal scattering $S(\alpha,\beta)$ as a function of temperature has been applied. The data base of thermal scattering for graphite was also utilized to comprehend the validity calculation using MCNPX. The ENDF/B-VII continuous energy nuclear data library was also smeared for all calculations at temperature of 900 K. For the calculation using MCNPX, two options of KCODE and KSRC were taken into account to estimate $k_{eff}$ of the RDE core. To achieve the accuracy of $k_{eff}$ in the RDE reactor core, the amount of 20,000 neutrons per cycle for 150 non-active cycles and 650 active cycles was taken into account. The results showed that water-ingress accident in the RDE core is a dynamical behaviour which may result in reactivity core change of the RDE core. Finally, from all calculated results taking into account the varieties of water density and $^{235}\text{U}$ fuel enrichment, the RDE reactor core is totally safe in the event of water-ingress accident ensuing during the RDE reactor operation.

1. Introduction

The Act number 17 year 2007 on the Long Term of National Development Plan (RPJPN 2005-2025) and The Attachment of The Government Decree Number 14 Year 2015 on The Master Plan of National Industry Development 2015-2035 (RIPIN 2015-2035) have authorized the application of nuclear energy considering very strict safety in 2015-2019, as well as the use of nuclear-energy-generated industry commencing 2020. In addition, in the Plenary Meeting of the National Energy Chamber (DEN) held on June 22, 2016, the President of the Republic of Indonesia commanded the development of power research reactor and supporting laboratories in which Indonesian nuclear experts are able to express, interact, create and support all nuclear research activities in the country and all significant results can be
preserved to strengthen international collaboration and the world latest nuclear technology always be well informed. In regards with the subject previously mentioned, the Globe trends ([1], [2] and [3]) and internal R&Ds on HTGRs ([4], [5]), the Indonesia National Nuclear Energy Agency (BATAN) decided to develop High Temperature Gas-cooled Reactor (HTGR) in particular the pebble bed reactor (PBR) type called the Reaktor Daya Eksperimental (RDE). The HTGR technology has been selected since the HTGR not only has a very good safety performance, but also can be utilized for other purposes, such as, water desalination, hydrogen production, coal liquefaction, etc. The reactor plans to be the master design of future expansion to support small-medium electric power (10 MWe to 200 MWe) in the Eastern part of Indonesia [5] [6]. In addition, HTGRs can accommodate a flexible fuel cycle including thorium [7], or plutonium [8].

There is a lot of accidents which can be defined in designing a nuclear power plant (NPP) and air-ingress and water-ingress accidents are two of them. The former accident takes place if air in the steam generator cavity enters into the core after pressure equilibrium between the core and the cavity achieves. Oxygen in the air then reacts with graphite on pebble surface, subsequently resulting in oxidation corrosion and challenging fuel integrity [9]. For now and in the future, the safety aspects of HTGR will be more focused on the latter accident which is categorized a significiant phenomenon and entitled one of design basis accidents (DBA) to be fulfilled in an HTGR design as stated in [10], [11], [12], [13] and [14]. The water-ingress accident ensues due to a pipe rupture of steam turbine heat exchanger and hence the amount of water leaks into the reactor core. The incoming water may imply other potential dangers, such as graphite corrosion and the damage of material structure of the reflector as seen in [4], [15] and [16]. This paper designates the effect analysis of the accident to the reactivity of the RDE core using Monte Carlo MCNPX. A reactivity accident principally deals with a sudden and rapid insertion of positive reactivity. This accident scenario includes a control rod ejection in pressurized water reactors (PWRs) and a control rod drop accident (CRDA) for boiling water reactors (BWRs). The uncontrolled movement of a single control rod out of the core results in a positive reactivity insertion which promptly increases a local core power and fuel temperatures also rapidly increase prompting fuel pellet thermal expansion. The reactivity excursinn is initially mitigated by Doppler feedback and delayed neutron effects followed by reactor trip [15].

In this paper, the calculation of water ingress accident following reactivity core changes in the RDE core was utilized MCNPX as previously mentioned. Since the RDE will apply pebble bed fuels having the $^{235}$U enrichment of 17%, and also due to for more comprehensive consideration of safety design, the varieties of $^{235}$U enrichment from 5% to 20% as function of water density have also been accomplished. The results of analysis perform the estimate of the amount of water resulting in the water ingress reactivity accident in the RDE reactor core. The results showed that water-ingress accident in the RDE core is a dynamical behaviour which may result in rectivity change of the RDE reactor core. From all calculated results taking into account the varieties of water density and $^{235}$U fuel enrichment, the RDE reactor core is totally safe in the event of a water-ingress accident during its operation.

2. Description of RDE
The RDE is to be constructed in Kawasan Nuklir Serpong, Puspiptek, Tangerang Selatan and the reactor is expected to be commissioned in 2022/2023. The reference of RDE is based on the High Temperature Reactor of 10 MW in China (HTR-10) which firstly achieved critical in 2000. The RDE is designed not only to generate electricity, but also to produce hydrogen production, water desalination, coal liquefation etc. The RDE is developed to enhance design, construction, operation and maintenance and hence enabling to face HTGR commercialization in Indonesia in the future and the RDE design specification can be seen in Table 1.
Table 1. Design specification of RDE [5, 6].

| Design Specification of RDE                                      |          |
|-----------------------------------------------------------------|----------|
| Reactor thermal power                                           | 10 MW thermal |
| Outlet coolant temperature                                     | 700°C    |
| Inlet coolant temperature                                      | 250°C    |
| Fuel material (enrichment)                                     | UO₂ (17%) |
| Primary coolant pressure                                       | 3.0 MPa  |
| Plant lifetime                                                  | 40 years |
| Volume of active core                                           | 5 m³     |
| Reactor core diameter                                           | 180 cm   |
| Reactor core height                                             | 197 cm   |
| Total steam flow                                                | 3.7 kg s⁻¹ |
| Ratio of fuel/moderator pebbles                                 | 0.52/0.48 |
| # Control assemblies at reflector side                          | 10       |
| # Absorber balls at reflector side                              | 7        |

The RDE applies graphite moderator and helium gas coolant to maintain inlet/outlet temperatures at 250 °C/700 °C. The ratio between fuel pebbles in the active core and moderator pebble is 52/48. While the diameter of RDE 180 cm, the average height of the core is 197 cm. The active core which contains mixed fuel and moderator pebbles is surrounded graphite reflector. The reflector is also blocked by boronated carbon bricks. Inside of the reflector, near to the active core, there are 10 channels with 130 mm diameter for control element insertion, 7 channels for small ball absorbers and 3 channels with 130 mm diameter for irradiation [4]. In outlet of reflector, there are 20 channels with 80 mm diameter for helium inlet of the reactor. While Table 1 shows the design specification of RDE, Figure 1 deploys cross-section of RDE reactor system.

Core loading using multi-pass method is initially to place moderator pebble or graphite-based dummy balls into the cone at the bottom of the reactor core. The mixture of fuel pebble and moderator pebble is loaded gradually until the first criticality achieved. The percentage of fuel pebble and moderator pebble is respectively 52% and 48%. After the first criticality achieved, the mixtures of those pebbles which have the same percentage is further loaded until the full core and hence achieving the reactor at full power. The full core has an estimated volume of 5 m³ containing around 27,000 pebble fuels elements spread out randomly with a packing fraction of 0.61 [4].
RDE fuel forms of pebble as fuels applied in the HTR-10 China [17] and in Advanced Very High Temperature Reactor (AVR) Germany. Each pebble containing 5 grams is formed from 8,335 TRISO-layer article particles in graphite matrix dispersion and each TRISO particle contains UO$_2$ kernel with low enrichment and layer coating. The TRISO coating consists of 4 layers, namely, a porous carbon buffer layer (C) having low density which is close to fuel kernel, high density inner pyrolytic carbon (IPyC) layer as well as a silicon carbide (SiC) layer and outer pyrolytic carbon (OPyC) layer. The specification of those 4 layers is summarized in Table 2.

**Table 2.** Material specification of TRISO particle.

| Layer | Composition | Density (g cm$^{-3}$) | Radius (cm) |
|-------|-------------|------------------------|-------------|
| Kernel | UO$_2$      | 10.41                  | 0.0250      |
| Buffer | C           | 1.14                   | 0.0340      |
| IpyC   | C           | 1.89                   | 0.0380      |
| SiC    | SiC         | 3.20                   | 0.0415      |
| OpyC   | C           | 1.87                   | 0.0455      |

Specific coating is devoted to resist and contain gaseous and metallic fission product and hence to maintain the integrity of TRISO particle. Fuel pebble with 6 cm diameter consists of fueled zone with 5 cm diameter in which the composition of graphite matrix contains TRISO and graphite shell with 0.5 cm thick. The graphite shell as a moderator surrounding fuel is reserved to protect fueled zone during pebble movement. Figure 2 depicts the schematic of TRISO particles which are distributed in fuel pebbles.
3. Methodology

MCNPX, a well known, widely used Monte Carlo transport code, was used to model the RDE reactor ([19] and [20]) and the modeling technique used in estimating the accident analysis of water ingress in the RDE core is considered the most representative detail one. The RDE core representing all reactor components is modeled in detail explicitly. The MCNPX calculation was begun by modeling TRISO particles in fuel pebble. The TRISO particle in a graphite matrix is represented in a simple cubic lattice (SC). A unit cell of a lattice, containing three regions of fuel kernel of UO$_2$, TRISO coating layer, and graphite matrix, is illustrated in Figure 3.

![Figure 3. Schematic of unit cell for a simple cubic lattice model.](image)

The calculated dimensions of unit cells are deployed in Table 3 showing the dimension of every region in a unit cell taken into account the number of particles per pebble. In addition, the table also demonstrates geometry specification as well as a specified void fraction. The size of pitch of a unit of a simple cubic is estimated from the following relationship:

$$ p = R \sqrt[3]{\frac{4\pi}{3N}} $$

(1)
where $R_f$ is the radius of fueled zone and $N$ is the amount of TRISO particles in every fuel pebble (8,335).

**Table 3.** Unit cell dimension for a simple cubic model.

| No. | Diameter of region | Size (cm) |
|-----|--------------------|-----------|
| 1   | Diameter of kernel | 0.0500    |
| 2   | Diameter of buffer | 0.0680    |
| 3   | Diameter of IPyC   | 0.0760    |
| 4   | Diameter of SiC    | 0.0830    |
| 5   | Diameter of OpyC   | 0.0910    |
| 6   | Pitch              | 0.198789  |

The RDE core consists of around 27,000 pebbles spread out randomly in the RDE core and the pebble packing of 0.61 or the void fractions of 0.39. Since the random packing cannot be modelled using MCNPX, the cell structure should then be employed. A unit cell consists of fuel pebble in the centred of the cell and one-eighth (1/8) of the moderator pebble in every point of a cell corner so that two pebbles in a unit cell can be attained. While the content of two pebbles of body centred cubic (BCC) lattice makes simple to change the radius of moderator pebble ($R_{M}$), the radius of fuel pebble keeps constant to consider the effect of double heterogeneity.

**Table 4.** Geometry specification of pebble fuel and moderator.

| Geometry specification                  | Size (cm)  |
|----------------------------------------|------------|
| Ratio of fuel and moderator pebbles    | 52:48      |
| Radius of fuel pebble                  | 3.0        |
| Radius of fueled zone                  | 2.5        |
| Thickness of graphite shell            | 0.5        |
| Packing fraction of pebble             | 0.61       |
| Radius of moderator pebble             | 2.92102    |
| Size of cell unit                      | 7.193      |

To accomplish the amount of fuel pebble ($F$) and moderator pebble ($M$) using ratio specification of 52/48, the radius of moderator pebble changes from 3.0 cm to 2.92102 cm using the following equation:

$$R_{M} = R_f \left( \frac{M}{F} \right)^{\frac{1}{3}}$$  \hspace{1cm} (2)

Since the moderator pebble and the pebble packing fraction ($f$) should be kept constant at 0.61, the size of unit cell to be confirmed on 7.09193 cm using the following equation:

$$a = R_f \sqrt[3]{\frac{4\pi}{3f} \left( 1 + \frac{M}{F} \right)}$$  \hspace{1cm} (3)
The geometry specification of fuel pebble and moderator pebble in MCNPX modeling is shown in Table 4. A unit cell of a lattice, containing three regions of fuel pebble, moderator pebble and helium coolant, is illustrated in Figure 4. The MCNPX model of RDE reactor is illustrated in Figure 5.

Figure 4. Schematic of unit cell for a body centered cubic lattice model.

Modelings of TRISO particle, fuel pebble and RDE core have been implemented based on the transport code of Monte Carlo MCNPX as the first significant step for the preparation of water ingress accident analysis in the RDE core. In safety analysis of RDE, thermohydraulic and neutronic effects need to be determined [21], especially for the investigation on the influence of water ingress accident of the RDE reactor core reactivity and other reactors in [19] and [20] which have the same fuel specification, as mentioned earlier using MCNPX [15].
4. Results and Discussions
To estimate a core reactivity change due to water-ingress accidents in the RDE, a void core condition from any coolant should be firstly calculated. The core reactivity change is then calculated based on the effective multiplication factor ($k_{\text{eff}}$) as a function of the water density which comes into void cells among pebbles containing helium coolant in the RDE reactor core. To approximate the water density in the reactor core, the profile density formulated by Khan was applied [19]. The data library “lwtr” of thermal scattering $S(\alpha,\beta)$ as a function of temperature, has been applied as well. This was developed to consider the interaction between water and thermal neutrons with an energy around and below 4 eV. The data base of thermal scattering for graphite was also adopted to comprehend the validity of the calculation using MCNPX. While the ENDF/B-VII continuous energy nuclear data library was employed for all calculations at the temperature of 900 K (627 C) [21], the vacuum boundary condition was utilized at the outer boundary of RDE reactor system. Furthermore, for the calculation using the MCNPX code, two options of KCODE and KSRC were taken into account to estimate $k_{\text{eff}}$ of the RDE core. The former, KCODE, is defined as the active cycle quantities to monitor the neutron population development in stabilizing a chain reaction in the RDE reactor core. To obtain the accuracy of $k_{\text{eff}}$ in the RDE core, 20,000 neutrons per cycle for 150 non-active cycles and 650 active cycles were simulated. The latter, KSRC, is distinct as neutron-source location at the beginning of cycle in fissile materials to commence the reactor calculation from one fission generation event to the next generation event. If the system is close to the critical condition, the position of the absolute beginning neutron source does not significantly influence the final result. The source position from one cycle to the following cycle was applied to generate the following neutron source, so that it is firmly to deal with the whole position of fissile material in the reactor system. For this calculation, the original neutron source was allocated at many points to reduce the convergent time of the distributed source.

Table 5. Atom densities of TRISO particle (atom/barn-cm).

| Enrichment | 238U | 235U | 16O |
|------------|------|------|-----|
| 5 %        | 1.17435e-3 | 2.20309e-2 | 4.64105e-2 |
| 8 %        | 1.87888e-3 | 2.13342e-2 | 4.64261e-2 |
| 11 %       | 2.58334e-3 | 2.06376e-2 | 4.64418e-2 |
| 14 %       | 3.28774e-2 | 1.99410e-2 | 4.64575e-2 |
| 17 %       | 3.99207e-2 | 1.92445e-2 | 4.64732e-2 |
| 20 %       | 4.69634e-2 | 0.85481e-2 | 4.64889e-2 |
| C          | 2.2832e-2 | 2.19009e-2 | 1.12472e-3 |
| Porous carbon buffer layer | 5.51513e-2 | - | - |
| Inner pyrolytic carbon (IPyC) layer | 9.52614e-2 | - | - |
| Silicon carbide (SiC) layer | 4.77590e-2 | 2.20097e-2 | 1.12472e-3 |
| Outer pyrolytic carbon (IPyC) layer | 9.52614e-2 | - | - |
Table 6. Atom densities of graphite matrix/shell and moderator pebble (atom/barn-cm)

| Graphite matrix/shell | Moderator pebble |
|-----------------------|------------------|
| C                     | 9.22571e-2       |
| $^{10}$B              | 2.29490e-9       |
| $^{11}$B              | 9.23725e-2       |
| C                     | 9.81232e-2       |
| $^{10}$B              | 2.33514e-10      |
| $^{11}$B              | 9.45851e-10      |

The atom densities of TRISO particle as a function of $^{235}$U enrichment is shown in Table 5. Due to the same materials used for graphite matrix/shell and pebble moderator but different in volume, they are identical and the two-atom densities are given in Table 6. The impurity of natural boron in the fuel and graphite is considered to be 1.3 ppm. Finally, the results of reactor effective multiplication factors ($k_{eff}$) as a result of water ingress accident taking place in the RDE reactor core as well as that of various enrichment of $^{235}$U are illustrated in Figure 7. In addition, although the RDE uses the $^{235}$U enrichment of 17%, to achieve more comprehensive consideration of the safety design, the varieties of $^{235}$U enrichment from 5% to 20% as function of water density have also been implemented.

![Figure 7. $k_{eff}$ in the water-ingress accident vs. water ingress density and $^{235}$U enrichment.](image)

To clearly interpretate the analysis results, the summary of $k_{eff}$ as function of water density and enrichment of $^{235}$U clearly seen in Figure 7 is also arrayed in Table 7. It is noted that with the varieties of water densities during the accident from 0 to 1 g/cm$^3$ and those of $^{235}$U enrichments, there are 228 values of $k_{eff}$s. Every calculated $k_{eff}$ has one standard deviation and from all calculated deviation of standards, the biggest value of those is 0.00091 (0.091 %). In addition, from Figure 6 previously mentioned and Table 7 shown below, in the case of water-ingress accident in the RDE core, it is very transparent that the $k_{eff}$ changes are relatively constant for the varieties of water densities starting from 0 gr/cm$^3$ (0 kg/m$^3$) to 0.04 gr/cm$^3$ (40 kg/m$^3$). Also, the same matter took place to those of $^{235}$U fuel

![Table 7. Summary of $k_{eff}$ as function of water density and $^{235}$U enrichment.](image)
enrichments and the ratio of $k_{\text{eff}}$ at 0.04 gr/cm$^3$ to 0.0 gr/cm$^3$ ranges from -2% to +12%. In general, effective multiplication factor ($k_{\text{eff}}$) increases, mostly from 0 until water density of 0.04 gr/cm$^3$ (40 kg/m$^3$), and these are similar trends as those estimated in [15]. The $k_{\text{eff}}$ indeed increases as the additional enrichment of $^{235}$U. However, $k_{\text{eff}}$ then decreases because of the water density addition and $^{235}$U enrichment. This means that the reactor system is in typical under moderated condition. The increase of $k_{\text{eff}}$ is followed due to both spectral neutron thermalization and the water density addition phase and hence the reactor system is over moderated. In the water-ingress accident, water, instead of moderator, is then changed to high absorption neutron poison and this makes $k_{\text{eff}}$ in the reactor core decrease sharply enough.

**Table 7.** $K_{\text{eff}}$ as function of the varieties of water density and $^{235}$U enrichment.

| Water density (gr cm$^{-3}$) | Percentage of $^{235}$U enrichment |
|------------------------------|-----------------------------------|
|                              | 5%      | 11%     | 14%     | 17%     | 18%     |
| 0.000                        | 0.6343  | 0.9246  | 1.0087  | 1.0695  | 1.1190  |
| 0.004                        | 0.6347  | 0.9253  | 1.0089  | 1.0696  | 1.1210  |
| 0.040                        | 0.6243  | 0.9353  | 1.0258  | 1.0948  | 1.1516  |
| 0.100                        | 0.5790  | 0.8985  | 0.9979  | 1.7048  | 1.1368  |
| 0.500                        | 0.3384  | 0.6050  | 0.7048  | 0.7889  | 0.8598  |
| 1.000                        | 0.2063  | 0.3921  | 0.4682  | 0.5343  | 0.5940  |

$k_{\text{eff}}$ ratio of $0.040$ to $0.00$ gr cm$^3$ is 98% 101% 112% 102% 103%

To estimate the reactivity change ($\Delta \rho$) in the RDE core during water-ingress accident, it is firstly to estimate $k_{\text{eff}}$ as a function of water density coming into void cells among pebble containing helium and the reactivity core change of the RDE ($\Delta \rho$) can then be appraised utilizing the following formula:

$$\Delta \rho = \frac{k_{\text{eff}}^n - k_{\text{void}}}{k_{\text{eff}}^n \times k_{\text{void}}} \times 100\%$$

where:

- $\Delta \rho$ = reactivity change,
- $k_{\text{eff}}$ = effective multiplication factor in water ingress accident at density $n$,
- $k_{\text{void}}$ = $k_{\text{eff}}$ at void from coolant.
Figure 8. Reactivity-core change as function of water ingress density and $^{235}\text{U}$ enrichment.

From Figure 8, it is clear that during the accident and when water density is 0.04 g/cm$^3$ (40 kg/m$^3$) as shown in Table 8, $\Delta\rho$ of the RDE core goes to negative for 5% $^{235}\text{U}$ enrichment but mostly positive for others. However, when water density is 0.05 g/cm$^3$ (50 kg/m$^3$), the $\Delta\rho$ tends to be mostly negative. This is due to the reactor core more moderated than the previous one. Finally, when water densities are equal and more 0.06 g/cm$^3$ (60 kg/m$^3$) and for all varieties of the enrichment, it is very apparent that all reactivity-core changes of the RDE core are all negative due to the RDE core over-moderated. In this condition, again, water, instead of moderator, is then changed to high absorption neutron poison and this results in $\Delta\rho$ in the reactor core decreased sharply. It is also very apparent from Figure 7 that the decrease sharpness of core reactivity changes is dependent on the $^{235}\text{U}$ enrichment of the RDE fuel. In addition, as depicted in Table 8, if it is assumed, the reactivity change of the RDE core using 5% $^{235}\text{U}$ enrichment is zero, so that the increase of core reactivity change using 11% $^{235}\text{U}$ enrichment is 51.1%. For the uses of 17% and 20% $^{235}\text{U}$ enrichment, the increases of core reactivity changes in the RDE core are 65.9% and 70.1%, respectively. Moreover, when water density is 1.0 g/cm$^3$ (1,000 kg/m$^3$) and the enrichment is 20% during the water-ingress accident in the RDE core, the RDE reactor core remains safe, since the core reactivity change is totally negative (-14.534%). Finally, from all calculated results, it is concluded that the RDE reactor is totally safe in the event of water ingress during the RDE reactor operation.
Table 8. Reactivity change as function of water-ingress density and $^{235}$U enrichment.

| Water density (g cm$^{-3}$) | $^{235}$U enrichment |
|-----------------------------|-----------------------|
|                             | 5%        | 14%        | 17%        | 20%        |
| 0.0000                      | 0         | 0          | 0          | 0          |
| 0.0004                      | 0.127     | 0.011      | -0.124     | 0.082      |
| 0.0100                      | -0.032    | -0.064     | 0.038      | 0.055      |
| 0.0200                      | -0.035    | -0.063     | 0.038      | 0.054      |
| 0.0300                      | -1.152    | 0.318      | 1.020      | 1.289      |
| 0.0400                      | -1.529    | 0.045      | 0.041      | 0.253      |
| 0.0500                      | -1.976    | -0.410     | 0.064      | 0.038      |
| 0.0600                      | -1.764    | -0.593     | -0.271     | -0.123     |
| 0.1000                      | -2.179    | -0.986     | -0.557     | -0.305     |
| 0.3000                      | -30.953   | -13.467    | -8.428     | -7.041     |
| 0.5000                      | -32.436   | -14.861    | -9.604     | -8.233     |
| 0.7000                      | -34.464   | -15.803    | -10.313    | -8.961     |
| 1.0000                      | -48.620   | -23.766    | -16.571    | -14.534    |

Increase of $\Delta \rho$

| 0%      | 51.1% | 65.9% | 70.1% |

5. Conclusion

Analysis of core reactivity during a water-ingress accident in the RDE reactor has been accomplished using Monte Carlo code MCNPX and the continuous energy library ENDF/B-VII at the temperature of 900°K (627° C). To obtain the accuracy of $k_{eff}$ in the RDE reactor core, the amount of 20,000 neutrons per cycle for 150 non-active cycles and 650 active cycles were taken into account. For the calculation of water-ingress accident in the RDE core using MCNPX, two options of KCODE and KSRC were taken into account to estimate $k_{eff}$ in the core. The results showed that water-ingress accident in the RDE core is a dynamical behaviour which may result in reactivity change of the RDE reactor core. From all calculated results taking into account the varieties of water density and $^{235}$U fuel enrichment, the RDE reactor core is totally safe in the event of a water-ingress accident during the RDE reactor operation.

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