Non-Proprietary

REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**179-8190**
SRP Section:	**09.01.01 - Criticality Safety of Fresh and Spent Fuel Storage and Handling**
Application Section:	**DCD Tier 2, Section 9.1.1, Criticality Analysis TeR Sections 2.4 and 2.5**
Date of RAI Issue:	**09/01/2015**

Question No. 09.01.01-21

Question 9.1.1-3: Design of new fuel storage rack system

REQUIREMENTS AND GUIDANCE

In 10 CFR Part 50 Appendix A, General Design Criterion (GDC) 62 requires the prevention of criticality in fuel storage and handling. 10 CFR 50.68(b) sets specific requirements for the demonstration of nuclear criticality prevention in fuel storage. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Section 9.1.1, guides the reviewer to verify that the facility designs are such that a fuel assembly can only be inserted in the designed locations in the fuel racks. NUREG-0800 Section 9.1.1 also refers the reviewer to ANSI/ANS 57.3, “Design Requirements for New Fuel Storage Facilities at Light Water Reactor Plants,” which states that “construction shall be such that it will not be possible to place fuel assemblies closer to one another than the minimum specified separation. This prohibition also applies to adjacent regions external to the racks.” The applicant cites ANSI/ANS 57.3 in DCD Section 9.1.

ISSUE

As described in DCD Section 9.1.1 and the criticality report, the design of the APR1400 new fuel storage pit appears to have spaces between the fuel racks and between the racks and pit walls that are large enough to fit one or more new fuel assemblies. The NRC staff is therefore not able to verify that the design is such that a fuel assembly can only be inserted in the designed locations in the new fuel racks and that construction will be such that it will not be possible to place fuel assemblies closer to one another than the minimum specified separation in the racks and any adjacent regions external to the racks.

INFORMATION NEEDED

The applicant should provide information showing that the design is such that a fuel assembly can only be inserted in the design locations in the new fuel racks or justify the acceptability of the current design where spaces between and around the racks that are large enough to fit one or more fuel assemblies. This should include information describing how the design is bounded by the accompanying criticality analysis report. Any revised or supplemental information addressing this issue should be provided in the applicant's response and reflected in the DCD or its incorporated references as appropriate.

Response – (Rev. 1)

There are spaces between the fuel racks and pit walls that are able to fit a new fuel assembly. An accident analysis, that assumes a fresh fuel assembly is dropped and positioned in the space between fuel racks in the new fuel rack storage pit, has been performed and will be added in the criticality analysis TeR.

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

Sections 2.4.2 and 2.5, Tables 2.4-2 and 2.5-2, Figures 2.4-2 and 2.4-3 in the criticality analysis TeR will be revised as indicated in Attachment.

2.4 Criticality Analysis for New Fuel Storage Rack

2.4.1 Criticality Calculation

The criticality analyses for the NFR consider waters with an optimum moderation condition and the maximum densities, therefore criticality calculations are performed for water densities ranged from 0.01 g/cm^3 to 1.0 g/cm^3 to determine the maximum k_{eff} for an optimum moderation condition. The criticality calculation model including NFSP is shown in Figure 2.4-1.

The calculation results are presented in Table 2.4-1 as the calculated nominal k_{eff} with corresponding water densities. The nominal k_{eff} values in the Table 2.4-1 do not contain any bias or uncertainties.

Section 2.4.2 should be added by page 2 of Attachment.

~~2.4.2~~ 2.4.3 Bias and Uncertainty

The bias and uncertainties by the calculation methods and variations of design parameters are estimated from the following items:

a. Bias and bias uncertainty of a criticality calculation method,

b. Statistical uncertainty of the Monte Carlo calculation, and

c. Uncertainty due to tolerances or variations in the design parameters.

The basis of bias and uncertainty items and their corresponding values considered for the criticality analysis of the NFR are described in below.

(1) Bias and bias uncertainty of a criticality calculation method

Bias and bias uncertainty are evaluated to validate the criticality analysis methodology through the benchmark calculations based on the criticality experiments (Reference 7).

a. Bias: [ ]^{TS}

b. Bias uncertainty: [ ]^{TS}

(2) Statistical uncertainty of the Monte Carlo calculation

Statistical uncertainty (2σ) of the criticality calculation for full density water model (reference model) is [ ]^{TS} as shown in Table 2.4-2.

(3) Uncertainty due to tolerances or variations in the design parameters

To evaluate uncertainties due to the tolerances in the mechanical and material specifications of the fuel and rack structures, sensitivity analyses are performed for the fuel rack cell in various conditions including the dimensional and material tolerances of the structure. Items in the sensitivity analysis for the criticality uncertainty evaluation are as follows:

a. UO_2 pellet stack density: [ ]^{TS},

b. UO_2 pellet diameter: [ ]^{TS},

c. Fuel rod pitch: [ ]^{TS},

d. Fuel clad outer diameter: [ ]^{TS},

e. Fuel assembly position in fuel rack cell: [ ]^{TS},

f. NFR cell pitch: [ ]^{TS}, and

2.4.2 Criticality Calculation for a Dropped Fuel Assembly Accident

For one of postulated accident conditions, a fresh fuel assembly is assumed to be dropped and positioned in the space between the fuel racks in dry air environment. The dropped fuel assembly accident evaluation considers the fully loaded NFR model with a dropped fresh 5.0 wt% fuel assembly between the fuel racks. Two sub-cases are considered. Subcase 1 is for a dropped fuel assembly face adjacent to the one of rack cells as its closest proximity and subcase 2 is for a dropped fuel assembly being centered in the space between the fuel racks. The criticality calculation models for a dropped fuel assembly cases are shown in Figures 2.4-2 and 2.4-3.

The calculation results are presented in Table 2.4-2 with the k_{eff} for normal dry condition of NFR system. The k_{eff} values in the Table 2.4-2 do not contain any bias or uncertainties.

Table 2.4-2 Calculated Uncertainties due to Tolerances or Variations in the Design Parameters

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This table should be replaced with table on page 4 of Attachment.

Table 2.4-2 Calculation Results of k_{eff} for a Dropped Fuel Assembly Accident

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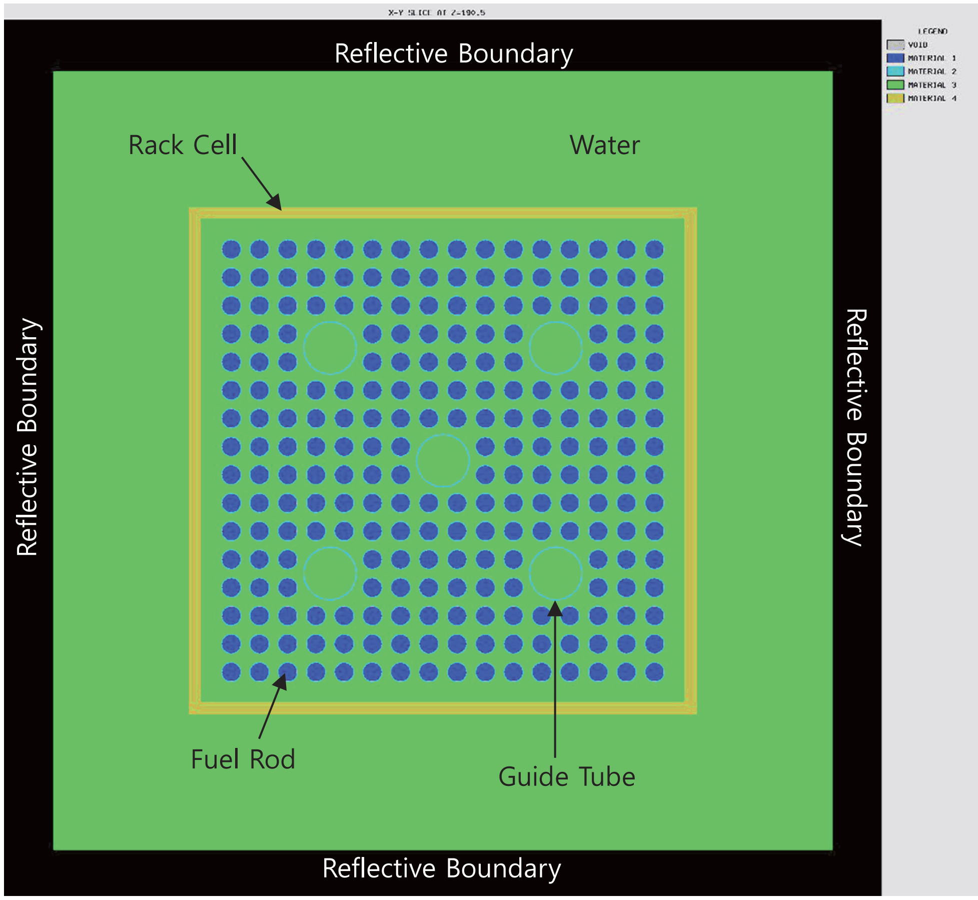

Figure 2.4-2 Unit Cell Model for Uncertainty Analysis

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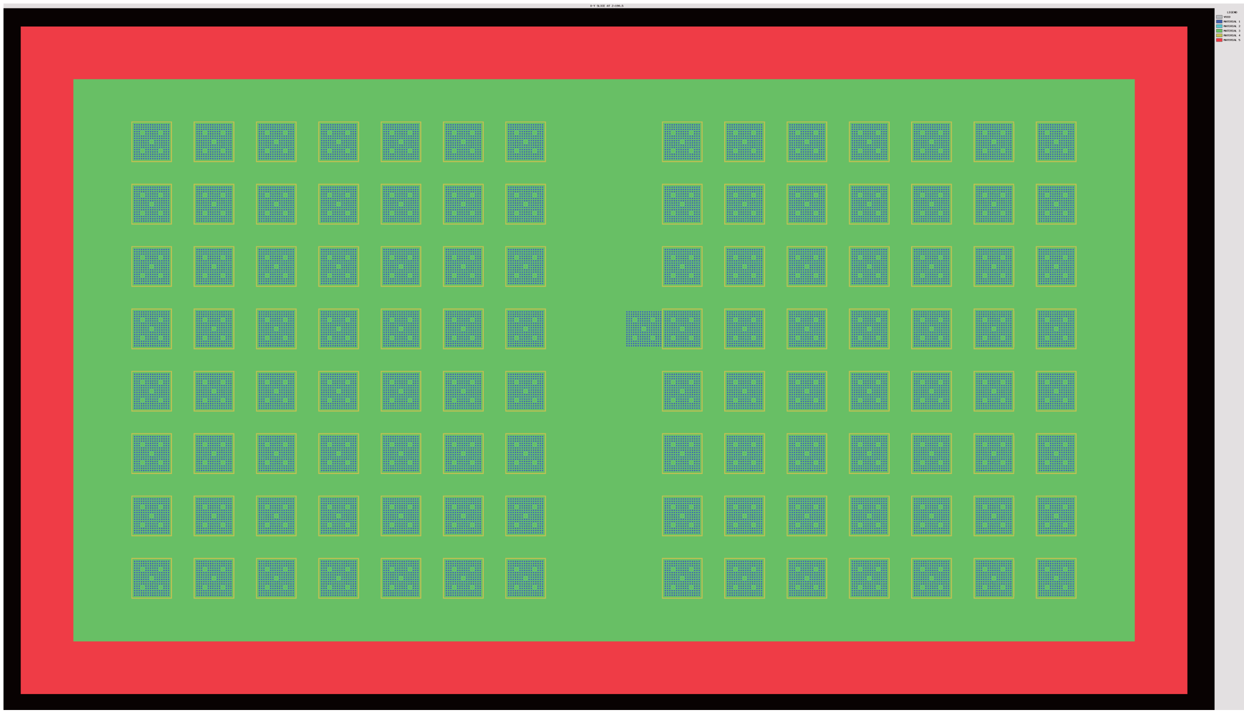

Figure 2.4-2 Criticality Calculation Model for a Dropped Fuel Assembly Accident (Contact)

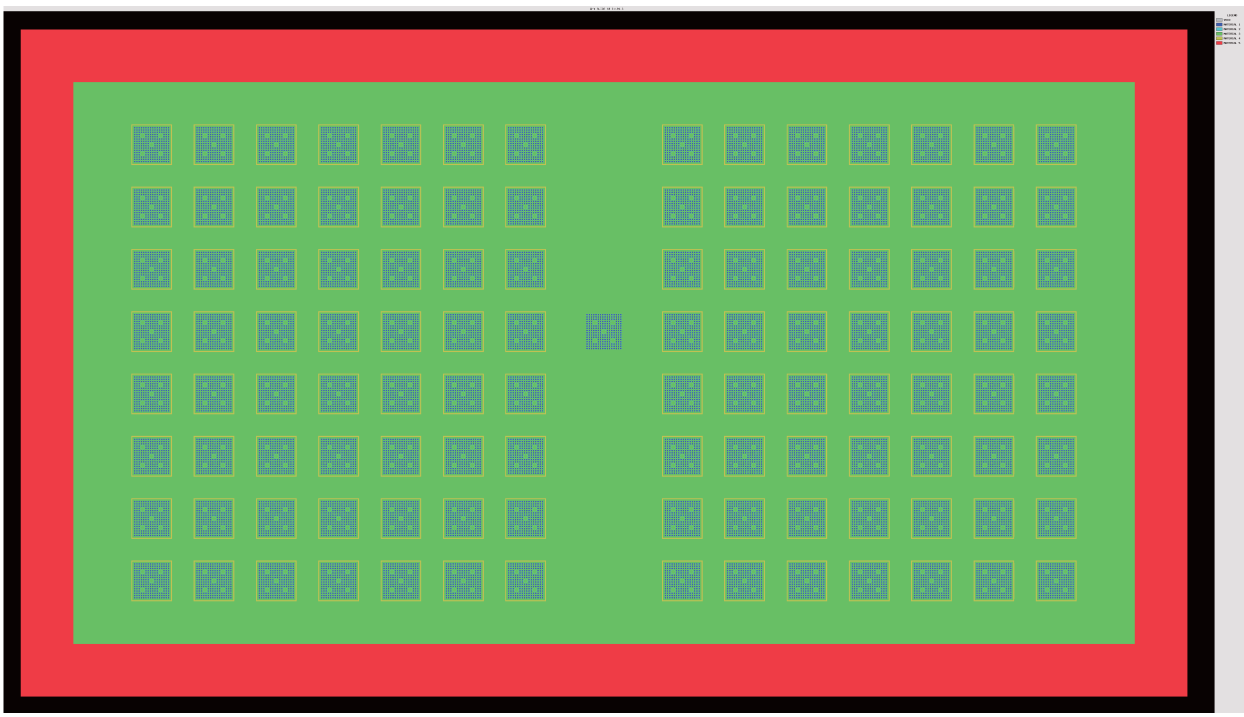

Figure 2.4-3 Criticality Calculation Model for a Dropped Fuel Assembly Accident (Centered)

This figure should be added.

2.5 Results

Table 2.5-2 shows the evaluated k_{eff} for postulated accident cases of a dropped fuel assembly in the space between fuel racks.

The criticality analysis for the NFR with 5.0 wt% enrichment of the PLUS7 fuel is performed by using SCALE 6.1.2 code. Table 2.5-1 and Figure 2.5-1 show the evaluated effective neutron multiplication factors according to various water densities. The evaluated results for the criticality analysis include the evaluated total bias and uncertainty (Δk_{NFR}). An optimum moderation condition occurs at water density of 0.14 g/cm^3.

The evaluated effective neutron multiplication factors for the NFR have the additional margin due to the conservative assumptions for the criticality analysis as follows:

- The design maximum enrichment of 5.0 wt% is applied to all the UO_2 fuel rods in the NFR,
- Miscellaneous structures such as grid, spring, end caps, etc., are not included in the calculation model,
- Burnable absorber rods in fuel assembly or axial blankets in fuel rod are not considered in the calculation model, and
- Zoning to alleviate the power peak in the fuel assembly is not considered and all fuel rods are assumed to have the same maximum enrichment.

As a conclusion, the evaluated effective neutron multiplication factors for the NFR satisfy the acceptance criteria as follows:

Description	k_{eff}	Acceptance criteria
k_{eff} for flooded by pure water	0.91257	≤ 0.95
k_{eff} for optimum moderation	0.93298	≤ 0.98

This table should be replaced with table on page 9 of Attachment.

Description	k_{eff}	Acceptance criteria
k_{eff} for flooded by pure water	0.91393	≤ 0.95
k_{eff} for optimum moderation	0.93439	≤ 0.98

Table 2.5-2 Evaluation Results of k_{eff} for a Dropped Fuel Assembly Accident

TS

This table should be added.

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Date of RAI Issue:	**09/01/2015**

Question No. 09.01.01-22

Question 9.1.1-5: Reactivity of new fuel storage pit concrete

REQUIREMENTS AND GUIDANCE

In 10 CFR Part 50 Appendix A, General Design Criterion (GDC) 62 requires the prevention of criticality in fuel storage and handling. 10 CFR 50.68(b) sets specific requirements for the demonstration of nuclear criticality prevention in fuel storage. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Section 9.1.1, guides the reviewer, in part, to verify that the materials of structures near racks that may provide neutron reflection, such as floors and walls, are provided and conservatively incorporated into the criticality analysis.

ISSUE

The applicant’s criticality analyses for the new fuel storage pit explicitly model the reactivity effects (i.e., neutron moderation and reflection) of the concrete walls and floor. The staff is aware that the concrete reactivity effects in such cases can vary significantly with the various compositions of common concretes. In describing the analyses, the applicant neither states nor demonstrates that the modeled concrete composition is no less reactive than the specified design composition of the new fuel storage pit walls. Moreover, the staff is aware that other concrete compositions identified in the SCALE code and elsewhere can be significantly more reactive than the composition modeled by the applicant.

INFORMATION NEEDED

The applicant should provide a justification or analysis to address this issue and describe the analysis and results in the DCD or its incorporated references. If an analysis is provided,

included should be an analysis of the sensitivity of new fuel storage criticality results to various modeled compositions of storage pit concrete. If the justification or analysis concludes that more reactive concrete compositions could be used in the storage pit, it may be appropriate to (a) replace the modeled concrete composition with one that is more clearly conservative, and/or (b) establish a related design specification for the range of allowed concrete compositions, and/or (c) add or modify ITAAC to verify that the as-built composition of the storage pit concrete is no more reactive than the modeled composition.

Response – (Rev.1)

Table 1 shows the sensitivity analysis results of k_{eff} for various compositions of the storage pit concrete in optimum moderation condition. As shown in Table 1, there are no significant changes of k_{eff} from the reference case and the maximum differences are on the order of one tenth of the total uncertainty. Therefore, it can be concluded that the types or compositions of surrounding concrete have negligible effects on the neutron multiplication factor of the new fuel storage rack system.

Table 1 Calculation Results of k_{eff} for Various Compositions of Storage Pit Concrete

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Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.