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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-11

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the report APR1400-H-N-NR-14012-P, Rev.0, Section 3.4.7.4 (3), the applicant stated that “The thermal stress is classified as secondary stress on the ASME Code Section III, Division 1. Therefore, it is independently evaluated without combining with primary stress of other load condition.” The staff notes that the thermal stress may not be combined with the primary stress; however, the thermal expansion will reduce the gaps between the fuel assembly and the cell as well as between racks. The gap reduction increases the possibility for impact between the fuel assembly and the cell as well as between racks. The applicant in Subsection 3.7.1.3, “Impact Loads” stated that “the baseplate the fuel storage rack for the APR1400 design is installed almost in contact with the adjacent baseplate”. The thermal expansion of the rack potentially imposes load at the base of the pedestal. In accordance with SRP 3.8.4 Appendix D I(4), the applicant is requested to quantify thermally imposed loads at the base of the pedestal and discuss how these thermal load effects have been considered in the analysis and design of the new and spent fuel storage racks.

Response

The thermal expansion of the fuel assembly is conservatively calculated based on the assumption that thermal expansion of the fuel assembly and the SA-240 Type 304L material is identical. The following equation expresses the temperature dependence of the elongation of SA-240 Type 304L material due to thermal expansion.

$$\varepsilon = \alpha\ (T_2 - T_1)$$

where,

ε: Thermal expansion elongation of SA-240 Type 304L (in/in),

α: Thermal expansion coefficient of SA-240 Type 304L = 8.9 x 10^{-6} (in/in-°F),

T_2: Temperature (°F) = 285 °F [Maximum fuel clad cladding temperature of spent fuel assembly at emergency condition per thermal-hydraulic analysis], and

T_1: Temperature (°F) = 106 °F [Bulk temperature on normal condition of Spent Fuel Pool].

Using the above equations, the thermal expansion is calculated to be 0.002 (in/in). The calculated expansion value is very small and is considered to have a negligible effect on the overall analysis. In addition, the APR1400 spent fuel storage racks are free-standing; thus, there is no or minimal restraint against free thermal expansion at the base of the pedestal. Therefore, the gap reduction between fuel assembly and cell as well as between racks by thermal expansion is not considered in the dynamic analysis of the spent fuel storage racks.

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 Environment Report.

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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

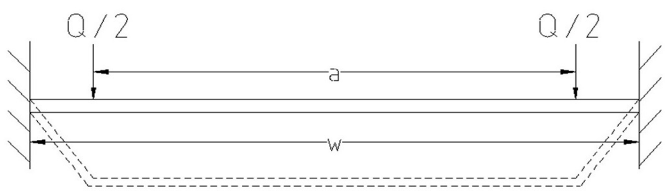
Question No. 09.01.02-13

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. The SRP 3.8.4 Appendix D section I (3), “Seismic and Impact Loads” requires that “Because of gaps between fuel assemblies and the walls of the guide tubes, additional loads will be generated by the impact of fuel assemblies during a postulated seismic excitation. Additional loads resulting from this impact effect may be determined by estimating the kinetic energy of the fuel assembly. The maximum velocity of the fuel assembly may be estimated to be the spectral velocity associated with the natural frequency of the submerged fuel assembly. Loads thus generated should be considered for local as well as overall effects on the walls of the rack, the supporting framework. It should be demonstrated that the consequent loads on the fuel assembly do not lead to damage of the fuel.” In order for the staff to perform its safety evaluation of the racks for impact loads, the applicant in accordance with SRP 3.8.4 Appendix D I.3, is requested to provide the details of how the additional loads due to the impact of fuel assemblies during a postulated seismic excitation are computed and how these loads are considered in the analysis and design of the walls of the rack and supporting framework and demonstrating the structural integrity of the fuel.

Response

The additional loads due to the impact of fuel assemblies during a postulated seismic excitation are computed from the reaction loads on the spring-mass elements of the fuel assembly-to-cell wall by dynamic analysis. The maximum impact load of the fuel support grid is calculated by dividing the maximum impact load (25,000 lbf) per cell by the number of spacer grids (11 ea), which is shown on the Table 3-10 in the report APR1400-H-N-NR-14012-P. All the fuel assemblies in each storage rack module are modeled as one beam of of which the mass equals the sum of the masses of all the fuel assemblies in a rack module. Because the fuel assemblies in a rack module are modeled together, all fuel assemblies move simultaneously in the same direction at the same time. This assumption included in this model brings about a larger impact on the rack module than the actual movement and results in conservative loads on the storage rack. The fuel assembly is modeled with only three nodes so that the calculated impact loads on the nodes will be larger than the actual value, because the fuel assembly actually has spacer grids (11 ea).

The design check of the cell wall for the fuel assembly impact load is performed by comparing the maximum calculated impact load obtained from the computer code ANSYS with the limit load for an individual cell wall.
The limit load for an individual cell wall is determined on a beam strip (the width of a single cell), which is subject to impact loads simulating two corners of a fuel assembly. The collapse load on structure of the panel shape can be explained by the collapse due to bending. The impact of fuel-to-cell wall is assumed to occur over a vertical dimension along the cell wall.



TS

The limit load for an individual cell wall calculated using the above formula is 10,660 lbf. It is much larger than the maximum impact load of fuel support grid (2,273 lbf) given in Table 3-10 in the report APR1400-H-N-NR-14012-P. Therefore, the stresses in the cell membrane are acceptable for the postulated fuel impact.

Cell-to-cell weld evaluation due to an impact load of fuel assembly is addressed in the response for question number 09.01.02-38. And the structural integrity of the fuel considering impact loads is described on section 3.7.2 of the report APR1400-H-N-NR-14012-P.

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 Environment Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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Docket No. 52-046

RAI No.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-14

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the report APR1400-H-N-NR-14012-P, Rev.0, Table 3-9 “Maximum Loads on single Pedestal”, the staff noted that for the spent fuel storage rack, generally the force on the pedestal in the north-south direction is much less (about 50%) than that in the east-west direction. The staff did not find sufficient details and description of the underlying analyses in the report and is not able to confirm large variation in forces in the two horizontal directions. In order for the staff to perform its safety evaluation of the racks, the applicant is requested to provide the basis and justification for such large difference in pedestal forces in the two horizontal directions.

Response

Below figures show the artificial time history data in the east-west and north-south directions for the dynamic analysis of the spent fuel storage racks.

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Time History Data in E-W direction

TS

Time History Data in N-S direction

The maximum seismic input loading in the north-south direction is much less (about 50%) than that of the east-west direction.
Therefore, the difference in pedestal forces in the two horizontal directions is based on the differences in the seismic input loading.

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 Environment Report.

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Docket No. 52-046

RAI No.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-17

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the report APR1400-H-N-NR-14012-P, Rev.0, Subsection 3.1.2.2 “Details for Rack and Fuel Assembly” it is stated that “A vertical movement of fuel assembly is assumed to be the same as the vertical movement of the storage rack”. The applicant’s assumption implies that that there is no fuel rattling in the vertical direction because the vertical displacement of the fuel is the same as the vertical displacement of the rack. However, there is a potential for the fuel assembly to separate from the baseplate during vertical ground motion depending on the vertical frequencies, phasing, and relative maximum vertical input acceleration of the fuel assembly and the storage rack.

In order for the staff to perform its safety evaluation of the fuel and the rack assembly for the vertical seismic input motion, the applicant in accordance with SRP 3.8.4 Appendix D I.3 is requested to provide a technical basis to justify the assumption that the vertical movement of fuel assembly and the storage rack is the same. The applicant is requested to provide the information for the fundamental frequency of the fuel assembly and the storage rack in the vertical direction; and the design response spectrum for the vertical motion at the new and the spent fuel rack locations. The applicant is also requested to show that the fundamental frequency of the fuel assembly and the fuel rack in the vertical direction is above the frequency where the spectral acceleration returns to the ZPA and that the ZPA is less than 1.0g.

Response

The vertical motion of the storage rack and fuel assembly is considered to be rigid body motion because the fundamental frequency of the storage rack and fuel assembly in the vertical direction is greater than 33Hz. And the zero period acceleration (ZPA) for the design response spectra in the vertical direction is less than 1.0g. Therefore, the vertical movement of the fuel assembly is assumed to be the same as the vertical movement of the storage rack, also the impact load of the baseplate by vertical movement of fuel assembly is not considered. The fundamental frequencies of the storage rack and fuel assembly in the vertical direction are as follows:

TS

Design Response Spectra for NFSR (SSE, Vertical Direction)

TS

Design Response Spectra for SFSR (SSE, Vertical Direction)

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 Environment Report.

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APR1400 Design Certification

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

Docket No. 52-046

RAI No.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-18

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the report APR1400-H-N-NR-14012-P, Rev.0, Subsection 3.4.3 “Structural Damping”, Rayleigh damping is used to specify mass (M) and stiffness (K) proportional damping (C)”. The applicant stated that the constant multiplier to the mass and stiffness matrix are calculated in the range of the lowest and highest frequencies of interest in the dynamic analysis. In accordance with SRP 3.8.4 Appendix D I.5, the applicant is requested to provide (1) the numerical value of the range of the lowest and the highest frequency considered (2) natural frequencies of new and spent fuel storage racks identifying primary horizontal, vertical and rocking frequencies of vibration, and (3) the technical basis why the range of the lowest and highest frequencies specified in the analysis will provide conservative results.

Response

(1) The range of the lowest and highest frequencies considered on dynamic analysis is as follows:
- NFSR : 20 ~ 100 Hz
- SFSR : 1 ~ 100 Hz

(2) Natural frequencies of NFSR and SFSR are as follows:

TS

(3) Rayleigh damping coefficients α and β are calculated such that the required damping is obtained at the lowest and highest frequencies of interest in the dynamic analysis. The range of the lowest and highest frequencies are determined by modal analysis. The Rayleigh damping coefficients are calculated by frequency range of modal analysis result. The calculated Rayleigh damping coefficients by this frequency range are larger than that used in the dynamic analysis.
Therefore, the range of the lowest and highest frequencies specified in the analysis provide conservative results in the dynamic and stress analyses.
Rayleigh damping coefficients α and β are calculated using following formula:

$$\alpha = \frac{4\pi f_i f_j (f_j D_i - f_i D_j)}{(f_j^2 - f_i^2)}$$

$$\beta = \frac{f_j D_j - f_i D_i}{\pi (f_j^2 - f_i^2)}$$

The table below shows the comparison results of Rayleigh damping coefficients, α and β, based on each frequency range.

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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 Environment Report.

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Docket No. 52-046

RAI No.: 287-8272

SRP Section: 09.01.02 – New and Spent Fuel Storage

Application Section: 9.1.2

Date of RAI Issue: 11/02/2015

Question No. 09.01.02-22

The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, "New and Spent Fuel Storage Rack Design", the applicant stated that "The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP". In the report APR1400-H-N-NR-14012-P, Rev.0, Subsection 3.7.3.4 (3) "Secondary Stress by Temperature Effects", it is stated that "a conservative estimate of the weld stresses along the length of an isolated hot cell is obtained by considering a beam strip uniformly heated by 65° F and restrained from growth along one long edge. The Applicant further stated that temperature rise envelops the difference between the maximum local spent fuel pool water temperature (155°F) inside a storage cell and the bulk pool temperature (121°F)) based on the thermal-hydraulic analysis of the spent fuel pool". The Applicant is requested to provide appropriate references and the methodology to calculate the maximum local spent fuel pool water temperature inside a storage cell and the bulk pool temperature.

Response

Bulk pool temperature and the maximum local spent fuel pool water temperature contained in APR1400-H-N-NR-14012-P & NP are based on thermal-hydraulic analysis of abnormal operating conditions, which is one refueling core (100FA) plus one full core (241FA) discharging to the spent fuel pool (SFP) with two cooling trains. The methodology and the references for the calculation of each temperature are as follows;

1. Methodology

1) Bulk pool temperature
In the thermal-hydraulic analysis, the bulk pool temperature for the spent fuel pool is determined based on time, and this temperature can be calculated by using the law of conservation of energy according to the interaction between heat load and heat loss. The mathematical model can be expressed as follows:

$$\frac{d}{dt}(C_W M_W T_W) = Q_{Load} - Q_{Loss}$$

where,
C_W = Specific heat of coolant (J/kg-K)
M_W = Mass of coolant in SFP (kg)
T_W = Bulk SFP temperature (K)

The heat load can be distinguished as decay heat that is generated from the stored spent fuel assemblies in the spent fuel pool. Basically, it is assumed that the spent fuel pool is almost at capacity and has just enough storage space for the newly discharged fuel assemblies. The heat load can be calculated using ORIGEN ARP computer code from Scale6.1, developed at Oak Ridge National Laboratory (ORNL) in 2011.
The heat loss can be distinguished as cooling of the pool mainly through the spent fuel pool cooling system (SFPCS). The pump and heat exchanger in SFPCS, circulate water in the spent fuel pool to remove the heat from the spent fuel assemblies. The other sources of heat loss are evaporation and natural convection of heat transfer process.
For calculating the bulk pool temperature conservatively, the following assumptions are used in the analysis.

- For all discharge scenarios, all the freshly discharged fuel into the SFP from reactor are assumed to be discharged all at one time, after a specified hold time in the shutdown reactor. This is a more conservative assumption than the fact that SFAs are transferred one by one from reactor to SFP.
- All previously discharged fuel and freshly discharged fuel are assumed to have the maximum irradiation exposure, with up to 1,643 effective full power days (3 cycles) in the reactor. This conservatively maximizes the decay heat load associated with all fuel stored in SFP.
- The thermal capacity of the SFP is based on the net water volume above the top of the spent fuel racks (SFRs). Since this conservative assumption disregards total thermal capacity, it results in faster computed heat-up rates.
- The decay heat load of the previously discharged fuel assemblies is assumed constant in all discharge scenarios.

2) Maximum local spent fuel pool water temperature
In the thermal-hydraulic analysis, the maximum local spent fuel pool water temperatures are calculated using the CFD program, Fluent. The inputs required for the calculation are: (1) the spent fuel pool and spent fuel rack dimensional data for three-dimensional CFD model; (2) the spent fuel rack and fuel assembly dimensional data for calculating the hydraulic resistance of the spent fuel assembly stored in the spent fuel rack; (3) the heat load of the discharged spent fuel assembly according to the time after reactor shutdown; (4) the temperature and velocity of coolant from spent fuel pool cooling system.

The configuration of the spent fuel racks and fuel assemblies is modeled as a porous media which is mainly used for flow field analysis and geometric structure. According to the Fluent code user's guide, calculating the hydraulic resistance (i.e., permeability and inertial resistance) is performed assuming a porous media for spent fuel racks and fuel assemblies. For calculating the maximum local spent fuel pool water temperature conservatively, the following assumptions are used in the analysis.

- 50 % SFR cells are assumed to be blocked at the top of the cell. This assumption provides conservative results by increasing the flow resistance of the coolant.
- The hottest among the SFRs are grouped together.
- All SFAs are assumed to be located entirely in pedestal cells. These cells have more restrictive flow resistance characteristics compared to non-pedestal cells.
- The decay heat load contribution of the discharged fuel assemblies is assumed constant in all discharge scenarios. Since it disregards the time-varying exponential decay of the heat generation of spent fuel assembly, this assumption is conservative.

2. References

For characterizing the thermal-hydraulic response of the bulk and local spent fuel pool and demonstrating an adequate margin of safety, the applicant had performed the thermal-hydraulic analysis. And for the NRC staff audit of the spent fuel rack (SFR) and the spent fuel pool (SFP) cooling conducted in July, the applicant had submitted the thermal-hydraulic analysis report for SFR & SFP for review.

As a result of the audit, the applicant received follow-up questions from the NRC staff. After addressing the questions, the applicant will submit the thermal-hydraulic analysis report in the form of a technical report.

3. Modification

According to the results of the thermal-hydraulic analysis, the maximum local spent fuel pool water temperature in abnormal operating conditions is 164°F. However, even considering the temperature differential (44°F) applying the revised maximum local temperature, the temperature differential (65°F) described in APR1400-H-N-NR-14012-P & NP is more conservative.

APR1400-H-N-NR-14012-P, Section 3.7.3.4.(3) second paragraph will be revised to include the revised maximum local SFP water temperature of 164°F.

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

Technical report APR1400-H-N-NR-14012-NP, Section 3.7.3.4 (3) will be revised as shown in the attachment.

the maximum compressive stress in the outermost cell is σ = 2 x 0.6 x 147.5 x FACT2 (from Table 3-12 with FACT2 = 0.314) = 55.6 MPa (8,061 psi) and is within the allowable value of 87.8 MPa (12,731 psi). Therefore, a buckling of the rack cell wall does not occur.

(3) Secondary Stress by Temperature Effects

The temperature gradients across the rack structure caused by differential heating effects between one or more filled cells and one or more adjacent empty cells are considered. The worst thermal stress in a fuel rack is obtained when a storage cell has a fuel assembly generating heat at the maximum postulated rate and the surrounding storage cells contain no fuel. The thermal stress is classified as secondary stress on the ASME Code Section III, Division 1. Therefore, it is independently evaluated without combining with primary stress of other load condition.

A conservative estimate of the weld stresses along the length of an isolated hot cell is obtained by considering a beam strip uniformly heated by ΔT = 36 °C (65 °F), and restrained from growth along one long edge. The temperature rise envelops the difference between the maximum local spent fuel pool water temperature (~~68.3 °C (=155 °F)~~ (73.3 °C (=164 °F) bounding) inside a storage cell and the bulk pool temperature (49.4 °C (= 121 °F)) based on the thermal-hydraulic analysis of the spent fuel pool. The maximum shear stress due to temperature change for isolated hot cell weld is calculated as follows:

$$\tau_{max} = E \times \alpha \times \Delta T$$

where, E = 1.896E+05 N/mm^2(27.5E+06 psi), α = 9.5E-06 in/in-°F, and ΔT = 36 °C(65 °F).

The maximum shear stress due to the temperature gradient for an isolated hot cell is calculated as 117.1 MPa (16,981 psi). Since this thermal stress is classified as secondary stress, the allowable shear stress criteria for Level D condition (0.42 S_u = 191.4 MPa (27,762 psi)) is used as the limits of allowable. Therefore, the maximum shear stress due to the temperature gradient is acceptable.

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Application Section:	**9.1.2**
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Question No. 09.01.02-23

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the report APR1400-H-N-NR-14012-P, Rev.0, Section 4.1 “Description of Mechanical Accident”, the applicant considered a drop of fuel assembly in an interior cell away from the support pedestal for one of the ‘Straight Deep Drops’ scenario. The applicant is requested to provide specific location(s) of the drop on the rack base plate that were considered to maximize the deformation of the rack base plate and whether it also considered a deep drop into a cell along the perimeter and half way between the supports. It is not clear from the description whether the rack baseplate evaluation due to fuel impact assumed that other fuel assemblies are in place when a fuel assembly drops through an empty cell. A full load of fuel assemblies may introduce progressive deformation of the baseplate after a fuel assembly impacts the rack baseplate. The maximum downward deformation of the baseplate may be significant enough to initiate a progressive deformation. Therefore, the applicant is also requested to provide (1) the technical basis and justification for not considering all other fuel assemblies in place when a fuel assembly drops through an empty cell and (2) the design basis for the rack baseplate including the basis for determining the most critical locations of the fuel assembly drop.

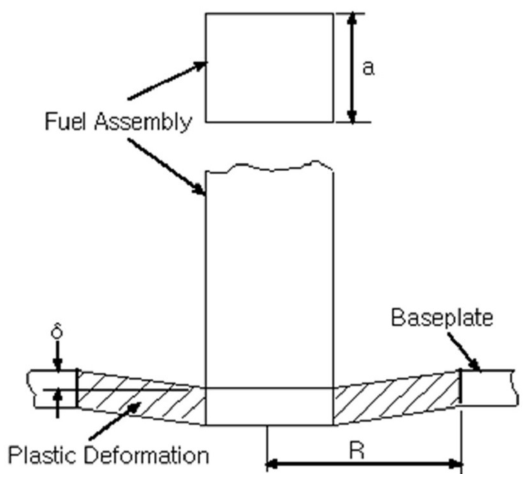
The applicant is requested to identify any proposed changes to and provide a mark-up of Subsections in the DCD Tier 2 and the report APR1400-H-N-NR-14012-P, Rev.0, as appropriate.

Response

(1) The calculated deflection of the baseplate due to the deep drop conservatively ignores the reinforcing effect of the cell-to-baseplate welds. The strength provided by the cell-to-baseplate weld reinforcement would offset the added static load of the fuel assemblies. Therefore, all other fuel assemblies in place is not considered when a fuel assembly drops through an empty cell.

(2) When a fuel assembly drops to the baseplate of a rack, the baseplate must not experience gross failure (i.e., puncture), and the deformed baseplate must not impact the pool liner. In the deep drop analysis (away from the pedestal), a specific location on the rack baseplate was not considered because the maximum deformation of the rack baseplate is calculated without a support under the rack baseplate.

The figure below shows the final deformed shape of the baseplate considered in deep drop analysis.



Deformed Shape of the Rack Baseplate

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

APR1400-H-N-NR-14012-NP, Section 4.3.3 will be revised as shown in the attachment.

4.3.3 Methodology for Straight Deep Drop Accident (Away from the Pedestal)

When a dropping object impacts to the baseplate of a rack, the deformation of the baseplate and the potential for impact on the pool liner is evaluated.

[Insert]
In the deep drop analysis (away from the pedestal), a specific location on the rack baseplate was not considered because the maximum deformation of the rack baseplate is calculated without a support under the rack baseplate.

The energy dissipated by plastic deformation of the baseplate is calculated as

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SRP Section: **09.01.02 – New and Spent Fuel Storage**

Application Section: **9.1.2**

Date of RAI Issue: **11/02/2015**

Question No. 09.01.02-25

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, "New and Spent Fuel Storage Rack Design", the applicant stated that "The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP". In the report APR1400-H-N-NR-14012-P, Rev.0, Section 4.5 "Results of Analyses", the applicant provided the results of fuel assembly drop analyses but did not provide the structural assessment of the dropped fuel assemblies due to impact with the rack and the rack baseplate. The staff notes that the applicant in Subsection 3.7.2 of the report provided structural evaluation of the fuel for the lateral impact loads on the fuel assembly due to fuel-to-cell wall impact. The applicant is requested to provide the results of its structural evaluation of the fuel assembly from the mechanical drop accident scenarios described in Section 4.1 of the report.

The applicant is requested to identify any proposed changes to and provide a mark-up of Subsections in the DCD Tier 2 and the report APR1400-H-N-NR-14012-P, Rev.0, as appropriate.

Response

The structural integrity evaluation of new and spent fuel storage rack under the mechanical drop accident scenarios is described in the Section 4.5 of the report APR1400-H-N-NR-14012-P, Mechanical Accident Analysis, includes descriptions of the straight shallow drop and two straight deep drop scenarios. In the "straight shallow" and "straight deep" drop events, the fuel assembly is treated as a rigid mass with conservative frontal area and total weight (total weight is the sum of fuel assembly and handling tool).

The radiological fuel damage caused by a fuel handling accident is evaluated in accordance with NRC RG 1.183, Appendix B. The radiological consequence for fuel assembly in postulated fuel handling accident is addressed in DCD Tier 2, Section 15.7.4.

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 Environment Report.

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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-28

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the technical report APR1400-H-N-NR-14012-P, Rev 0, Subsection 3.7.3.3, “Stresses on Welds”, the applicant evaluated stresses in cell-to-baseplate and baseplate-to-pedestal welds but did not calculate the base metal shear stress. The safety factor (ratio of allowable to actual shear stress) for the base metal may be lower than that for the weld. This reduction is noted in safety factors in Table 3-13 “Stress Evaluation for Fuel Racks. The staff notes that the safety factor for the cell-to cell weld stress is 5.42 that is reduced to 3.68 for the base metal shear. The applicant is requested to provide the base metal shear stress and corresponding safety factor for the cell-to-baseplate and baseplate-to-pedestal weld connections so the staff can make safety conclusions related to the rack welded connections.

Response

The evaluation results of the base metal shear stress for the cell-to-baseplate and baseplate-to-pedestal weld are as follows:

Region	Type	Calculated Stress, MPa (psi)	Allowable Stress, MPa (psi)(*)	Safety Factor (-)
Rack Cell-to-Baseplate	Base Metal Shear	84 (12,183)	118.0 (17,120)	1.41
Baseplate-to-Pedestal		87.7 (12,721)	118.0 (17,120)	1.35

(*) The allowable stress is calculated using 304 material yield strength.

Table 3-13 will be revised to include the base metal shear values.

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

APR1400-H-N-NR-14012-NP, Table 3-13 will be revised as shown in the attachment.

Non-Proprietary

Table 3-13 Stress Evaluation for Fuel Racks

Region	Type	Calculated Stress, MPa (psi)	Allowable Stress, MPa (psi)	Safety Factor (-)
Rack Cell-to-Baseplate	Weld	203.7 (29,545)	246.1 (35,694)	1.21
Baseplate-to-Pedestal	Weld	124.1 (17,992)	246.1 (35,694)	1.98
Cell-to-Cell	Weld	45.4 (6,581)	246.1 (35,694)	5.42
	Base Metal Shear	32.1 (4,653)	118.0 (17,120)	3.68
Pedestal Thread	Shear	40.4 (6,507)	106.2 (15,408)	2.63

Notes:
(1) Stresses on weld of the baseplate-to-support pedestal of the rack are conservatively evaluated by applying the maximum support loads acting on the NFSRs as shown on Table 3-9 to the weld of the support pedestal of the SFSRs.

Region	Type	Calculated Stress, MPa (psi)	Allowable Stress, MPa (psi)	Safety Factor (-)
Rack Cell-to-Baseplate	Weld	203.7 (29,545)	246.1 (35,694)	1.21
	Base Metal Shear	84 (12,183)	118.0 Note 2 (17,120)	1.41
Baseplate-to-Pedestal	Weld	124.1 (17,992)	246.1 (35,694)	1.98
	Base Metal Shear	87.7 (12,721)	118.0 Note 2 (17,120)	1.35
Cell-to-Cell	Weld	45.4 (6,581)	246.1 (35,694)	5.42
	Base Metal Shear	32.1 (4,653)	118.0 Note 2 (17,120)	3.68
Pedestal Thread	Shear	40.4 (6,507)	106.2 (15,408)	2.63

Notes:
(1) Stresses on weld of the baseplate-to-support pedestal of the rack are conservatively evaluated by applying the maximum support loads acting on the NFSRs as shown on Table 3-9 to the weld of the support pedestal of the SFSRs.
(2) The allowable stress is calculated using 304 material yield strength.

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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-29

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the technical report APR1400-H-N-NR-14012-P, Rev 0, Subsection 3.7.3.3, “Stresses on Welds”, the applicant evaluated stresses in cell-to-cell welds. An underlying assumption in the modeling of the rack as a single beam using the overall bending stiffness of the entire rack is that the cell-to-cell welds are intact and can carry the internal forces necessary to validate this assumption. This is not addressed in the report. The applicant is requested to provide a quantitative evaluation demonstrating that this loading in conjunction with the other loadings discussed in the report does not create an overstress condition in the cell-to-cell welds.

Response

The cell-to-cell weld stress is calculated based on the maximum fuel-to-cell impact load and the cell wall shear stress. Overstress in the cell-to-cell weld can be caused by using this load in conjunction with other loads, which include cell wall tensile and bending loads. The tensile and bending stress on the cell wall is calculated by multiplying the tensile or bending allowable stress under Level D conditions and the cell wall stress coefficient, FACT2= 0.314, per Table 3-12 of the report APR1400-H-N-NR-14012-P. The cell-to-cell weld evaluation results including the cell wall tensile and bending stress are as shown below:

Region	Type	Calculated Stress, MPa (psi)	Allowable Stress, MPa (psi)	Safety Factor (-)
Cell-to-Cell	Weld	71.8 (10,408)	246.1 (35,694)	3.43
	Base Metal Shear	50.7 (7,358)	118.0 (17,120)	3.49

Therefore, the cell-to-cell weld does not create an overstress condition.

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

APR1400-H-N-NR-14012-NP, Section 3.1.2.2 will be revised as shown in the attachment.

Figure 3-3 shows the sketch of nodes and elements of a dynamic analysis model for the SFSR. The racks and fuel assemblies are modeled as 3-D elastic beam (BEAM4) and lumped mass (MASS21) of ANSYS finite element analysis program (Reference 6). The BEAM4 element indicates the dynamic characteristics of storage racks using the effective structural property. Effective structural properties for the dynamic model are determined from the natural frequencies and mode shapes of the detailed model. Details of effective structural properties for the APR1400 racks are shown in Reference 7.

[Insert]
An underlying assumption in the modeling of the rack as a single beam using the overall bending stiffness of the entire rack is that the cell-to-cell welds are intact and can carry the internal forces.

Lumped mass of rack and fuel assemblies is assigned to the three nodes for rack cells and fuel assemblies. All the fuel assemblies in each storage rack module are modeled as one beam of which the mass equals the sum of the masses of all the fuel assemblies in a rack module. Because the fuel assemblies in a rack module are modeled together, all fuel assemblies move simultaneously in one direction. The assumption included in this model brings about larger impact on the rack module than the actual case and results in the conservative loads to the storage rack. The fuel assembly is modeled with only three nodes so that the calculated impact loads on the nodes will be larger than the actual value, because the fuel assembly actually has spacer grids of eleven parts. The mass of the upper, the central and the lower nodes is 1/4, 1/2 and 1/4 of the total mass, respectively.

Figure 3-4 shows a two-dimensional elevation schematic depicting the three masses of fuel and rack cells, and their associated fuel assembly/rack cell spring elements, the support pedestal spring elements, and adjacent rack impact spring elements. Nonlinear gap element and linear friction spring element are used to represent the vertical and horizontal motions of support pedestals, respectively. These elements are used in the representation of slant or sliding phenomenon of the storage rack. A directional stiffness value of pedestals is assigned to linear friction spring element. The pool bottom is assumed as a rigid body, and is contacted with pedestals. In order to represent an impact of rack-to-rack and rack-to-pool wall, compression impact spring elements between the lumped masses are used. Impact spring element of horizontal direction between racks is assigned to upper and lower of storage rack. The initial distance between impacts objects is determined by arrangement of storage rack, size of fuel assembly and cell. Stiffness and masses of racks are different according to size and characteristics.

The hydrodynamic masses on rack-to-fuel, rack-to-rack, and rack-to-pool wall are modeled as mass MATRIX27 element of ANSYS finite element analysis program (Reference 6). This element connects two nodes for the rack-to-fuel, rack-to-rack, and rack-to-pool wall.

3.1.2.3 Hydrodynamic Mass

In addition to the structural mass of racks and fuel assemblies, hydrodynamic masses of rack-to-rack and rack-to-fuel assembly for the SFSRs are included in the total mass to consider the fluid coupling effect. Details for the hydrodynamic mass are described in the followings:

(1) Between Cell and Fuel Assembly

Fuel assembly consists of several fuel rods and guide tubes, and is supported by spacer grid. A hydrodynamic mass is calculated assuming the structure as of long cylinders whose centers match with the center of the structure. A hydrodynamic mass acting at the centers of the two rigid bodies and liquid filled therein is represented using following formula of Reference 4.

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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-33

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the technical report APR1400-H-N-NR-14012-P, Rev 0, Section 4, “MECHANICAL ACCIDENTS ANALYSIS”, Subsection 4.3, “Analysis Method”, states that “This calculation covers the new fuel storage racks in NFP and the spent fuel storage racks of Region I and Region II in SFP. Region I racks are structurally stronger than Region II racks. To conservatively estimate the damage of the racks due to the postulated drop accidents, the calculation is performed for Region II racks. Since the new fuel storage rack is held down by firmly attached to the embedment plates of NFP using a stud bolt and is supported by additional intermediate plate, and has no “poison zone”, the drop accident evaluation is performed only for the case of drop (away from pedestal) on baseplate of the fuel rack”. The applicant is requested to provide the technical basis for concluding that the spent fuel storage racks of Region I are structurally stronger than the Region II racks and also provide a technical justification that the dynamic response and the design safety factors for the Region II racks will bound the Region I racks and the design stress limits for region I racks will not be exceeded under the required load combinations in the Table 3-1. The applicant is requested to identify any proposed changes to and provide a mark-up of Subsections in the DCD Tier 2 and the report APR1400-H-N-NR-14012-P, Rev.0, as appropriate.

Response

In the report APR1400-H-N-NR-14012-P, Section 4.3, the sentence “Region I racks are structurally stronger than Region II racks” will be deleted. And the sentence “To conservatively

estimate the damage of the racks due to the postulated drop accidents, the calculation is performed for Region II racks" will be revised as "To conservatively estimate the damage of the racks due to the postulated drop accidents, a calculation is performed for Region II racks using the damaged fuel canister inside dimension of Region I rack" regarding the mechanical accident evaluation.
Stress evaluation for Region I racks is shown in the Table 3-12 in the report APR1400-H-N-NR-14012-P.

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

APR1400-H-N-NR-14012-NP, Section 4.3 will be revised as shown in the attachment.

(3) Straight Deep Drop (Scenario 3; Over a pedestal)

For the postulated deep drop event (over a pedestal), the compressive stress on the concrete floor underneath the embedment plates shall not be exceeded the maximum allowable stress of 16.4 MPa (2,375 psi) as specified on the paragraph 5.3.4.4 of design specification (Reference 12).

(4) Stuck Fuel Assembly (Scenario 4)

Similar to the shallow drop accident, the damage of the cell wall shall be limited to the portion of the cell above the top of the "poison zone". The distance measured from the top of the rack to the upper boundary of the "poison zone" is 0.61 m (2 ft).

4.3 Analysis Method

The rack structure must either absorb the energy elastically or sustain some degree of plastic deformation. If the rack behaves plastically, the energy dissipated by plastic deformation is assumed equal to the kinetic energy of the impact. Based on this assumption, the extent of the damage to the upper portion of the cell structure or, in the case of a deep drop, to the rack base structure can be determined. This calculation covers the new fuel storage racks in NFP and the spent fuel storage racks of Region I and Region II in SFP. ~~Region I racks are structurally stronger than Region II racks. To conservatively estimate the damage of the racks due to the postulated drop accidents, the calculation is performed for Region II racks.~~ Since the new fuel storage rack is held down by firmly attached to the embedment plates of NFP using a stud bolt and is supported by additional intermediate plate, and has no "poison zone", the drop accident evaluation is performed only for the case of drop (away from pedestal) on baseplate of the fuel rack.

To conservatively estimate the damage of the racks due to the postulated drop accidents, a calculation is performed for Region II racks using the damaged fuel canister inside dimension of Region I rack.

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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-36

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the technical report APR1400-H-N-NR-14012-P, Rev 0, Subsection 3.7.1.1, “Displacements of Rack”, it is stated that “Actually, impact on rack-to-rack occurs at baseplate of the SFSRs because the installed racks are in contact with each other. The maximum impact loads generated at the NFSRs and the SFSRs are summarized in Table 3-10.” In Subsection 3.7.1.3 (2), “Impact Loads”, it is stated that “The prominent baseplate of the fuel storage rack for the APR1400 design is installed almost in contact with the adjacent baseplate.”

In accordance with SRP 3.8.4 Appendix D I (3, 5), the applicant is requested to provide the following information so that the staff can perform its safety evaluation of the seismic analysis of new and spent fuel storage racks (NFSR and SFSR).

a. For NFSR and SFSR, provide the baseplate dimensions and layout and plan view clearly showing gap or no gap between the adjacent baseplates; the gaps between the baseplates and the spent fuel pool walls; and the rack-to-rack gaps at midheight and at the top of the racks. Identify the elevation of the gaps shown in Figure 2-4.

b. Discuss how the effect of adjacent baseplates that are in contact is modeled in the nonlinear dynamic models.

c. The pool multi-rack dynamic analysis model in Figure 3-2 shows gaps between the adjacent base plates of all 29 racks. Describe how the contact between the baseplates is modeled in the whole pool multi-rack model. If the racks are installed such that their baseplates are in contact, provide the technical basis why the whole pool multi-rack model, with gaps, shown in Figure 3-2, predicts conservative dynamic responses for the racks and SFP walls.

d. Discuss how the thermal load effects are considered for the installed racks that are in contact (no gap) with each other at the baseplate. Also discuss the effect on the design forces at the pedestal due to the thermal expansion of the installed racks.

e. The applicant is requested to provide COL information items that include the development of post seismic event inspection procedures to measure gaps between the new and spent fuel storage racks.

The applicant is requested to identify any proposed changes to and provide a mark-up of Subsections in the DCD Tier 2 and the report APR1400-H-N-NR-14012-P, Rev.0, as appropriate.

Response

a. The baseplate dimensions and layout and plan view for NFSR and SFSR as below figures.

TS

New Fuel Storage Rack Layout

TS

Spent Fuel Storage Rack Layout

TS

Spent Fuel Storage Rack Layout

b. The adjacent baseplates are connected by a spring element and the stiffness value of the baseplate is assigned to the impact spring for impact phenomena. Figure 3-4 of the report APR1400-H-N-NR-14012-P shows schematic of spring element used for SFSR.

c. The baseplate of the fuel storage rack is installed barely in contact with the adjacent baseplate.
Therefore, the contact between the baseplates in the whole pool multi-rack model is modeled by ANSYS CONTAC52 element. Figure 3-2 shows the simplified rack beam model except ANSYS CONTAC52 element.

d. The effect of the thermal load and the thermal expansion for the installed racks is addressed in the report APR1400-H-N-NR-14012-P, Section 3.2.2 and the response for question number 09.01.02-11. The APR1400 SFSRs are free-standing; thus, there is no or minimal restraint against free thermal expansion at the base of the pedestal.
Therefore, the effect of thermal load on the rack baseplate was not considered.

e. A COL item for including the development of post seismic event inspection procedures will be added in DCD Tier 2 Subsection 9.1.2.3.1 and 9.1.2.3.2.

Impact on DCD

DCD Tier 2 Section 9.1.2.3.1, 9.1.2.3.2, 9.1.6 and Table 1.8-2 will be revised as indicated in the attached markup.

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 Environment Report.

The new fuel assemblies are stored dry. The rack structure is designed to maintain a safe geometric array for normal and postulated accident conditions. The rack structure maintains the required degree of subcriticality for normal and postulated accident conditions such as flooding with pure water and worst-case moderator density. The COL applicant is to provide post seismic event inspection procedures to measure gaps between the new fuel storage racks (COL 9.1(7)).

9.1.2.3.2 Spent Fuel Storage Racks

The spent fuel storage racks are designed to seismic Category I requirements (described in Section 3.2) and are capable of withstanding normal and postulated dead loads, live loads, loads resulting from thermal effects, and loads caused by an SSE.

The spent fuel racks are designed with adequate energy absorption capabilities to withstand the impact of a dropped fuel assembly from the maximum lift height of the fuel handling machine, as described in Subsection 9.1.2.3.3. Handling equipment capable of carrying loads heavier than fuel components (e.g., spent fuel cask handling crane) is prevented by design from carrying heavy loads over the spent fuel storage area. The spent fuel storage racks can withstand an uplift force greater than or equal to the uplift capability of the fuel handling machine (2,268 kg [5,000 lb]).

Materials used in rack fabrication are compatible with the storage pool environment, and surfaces that come into contact with the fuel assemblies are made of annealed austenitic stainless steel. Structural materials are corrosion resistant and do not contaminate the fuel assemblies or pool environment. The neutron absorbing material used in the rack design is suitable for the storage environment.

Design of the spent fuel storage facility is in accordance with NRC RG 1.13 (Reference 11).

The thermal-hydraulic analysis demonstrating that the flow through the spent fuel rack is adequate for decay heat removal from the spent fuel assemblies during anticipated operating conditions is provided in the thermal-hydraulic analysis report.

The spent fuel storage racks and storage facility are designed to seismic Category I requirements. The spent fuel storage rack is designed to meet the following criteria under plant conditions such as seismic or fuel handling accidents:

a. Prevent physical damage to the stored fuel

b. Maintain the stored fuel in a subcritical configuration

c. Maintain the capability to remove and insert fuel assemblies

d. Maintain the stored fuel in a coolable geometry

The spent fuel storage racks and storage facility are designed to maintain the minimum allowable fuel spacing during the fuel storage. The structural material of the spent fuel storage rack is designed to withstand corrosion from contact with the cooling water.

The COL applicant is to provide post seismic event inspection procedures to measure gaps between the spent fuel storage racks (COL 9.1(7)).

9.1.2.3.3 Fuel Assembly Drop Analysis

New and spent fuel storage racks are evaluated for withstanding a postulated drop of a fuel assembly and its associated handling tool to maintain a subcritical array assuming the maximum weight handled on each rack and the maximum drop height, as described in Table 9.1.2-1.

9.1.2.4 Inspection and Testing Requirements

Refer to Subsection 14.2.12.1.33 for the initial plant startup test program related to the proper operation of the fuel handling equipment, including the spent fuel storage rack positions.

A coupon surveillance program monitors the neutron absorbing material (METAMIC™) over the lifetime of the racks to verify their integrity. The coupons are taken from the same production lot as used for fabrication of the rack and characterized for comparison with subsequent measurements. At least one archive specimen is retained for later comparison with the irradiated coupons.

A minimum of 14 coupons are immersed into the storage racks in the SFP. Additional coupons may be used to address potential license extensions and post-shutdown fuel storage. Each coupon is large enough to obtain a tensile test specimen (approximately 10.16 × 20.32 cm [4 × 8 in]). The coupons are adjacent to freshly discharged irradiated fuel in an empty fuel compartment in regions I and II.

COL 9.1(4) The COL applicant is to provide plant procedures for preventing and mitigating inadvertent reactor cavity drain down events, maintenance procedures for the maintenance and inspection of refueling pool seal, and emergency response procedures for the proper measures during pool drain down events.

COL 9.1(5) The COL applicant is to provide plant operating procedure guidelines for preoperational load testing and checks of interlocks, blocks, hoisting cables, control circuitry, and lubrication of fuel handling equipment.

9.1.7 References

1. 10 CFR Part 50, Appendix A, General Design Criterion 62, "Prevention of Criticality in Fuel Storage and Handing," U.S. Nuclear Regulatory Commission.

2. 10 CFR 50.68, "Criticality Accident Requirements," U.S. Nuclear Regulatory Commission, November 1998.

3. DSS-ISG-2010-01, "Staff Guidance Regarding the Nuclear Criticality Safety Analysis for Spent Fuel Pools," U.S. Nuclear Regulatory Commission, October 2011.

4. NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," U.S. Nuclear Regulatory Commission, January 2001.

5. ORNL/TM-2005/39, "Scale: A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design," Version 6.1, ORNL, June 2011.

6. M. B. Chadwick et al., "ENDF/B-VII.0 Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology," Special Issue on Evaluated Nuclear Data File ENDF/B-VII.0 Nuclear Data Sheets, 107(12), 2931-3059, December 2006.

7. NEA/NSC/DOC(95), "International Handbook of Evaluated Criticality Safety Benchmark Experiments," OECD NEA Nuclear Science Committee, September 2008.

8. NUREG/CR-6361, "Criticality Benchmark Guide for LWR Fuel in Transportation and Storage Packages," U.S. Nuclear Regulatory Commission, September 2008.

COL 9.1(7) The COL applicant is to provide post seismic event inspection procedures to measure gaps between the new and spent fuel storage racks.

Table 1.8-2 (12 of 29)

Item No.	Description
COL 9.1(4)	The COL applicant is to provide plant procedures for preventing and mitigating inadvertent reactor cavity drain down events, maintenance procedures for the maintenance and inspection of refueling pool seal, and emergency response procedures for the proper measures during pool drain down events.
COL 9.1(5)	The COL applicant is to provide plant operating procedure guidelines for preoperational load testing and checkouts of interlocks, blocks, hoisting cables, control circuity and lubrication of fuel handling equipment.
COL 9.2(1)	The COL applicant is to develop procedures for system filling, venting, and operational procedures to minimize the potential for water hammer; to analyze the system for water hammer impacts; to design the piping system to withstand potential water hammer forces; and to analyze inadvertent water hammer events in accordance with NUREG-0927 in the ESWS.
COL 9.2(2)	The COL applicant is to develop layout of the site-specific portion of the system to minimize the potential for water hammer in the ESWS.
COL 9.2(3)	The COL applicant is to (1) to determine required pump design head, using pressure drop from the certified design portion of the plant and adding site-specific head requirements, (2) determine pump shutoff head to establish system design pressure, which is not to exceed APR1400 system design pressure, and (3) evaluate potential for vortex formation at the pump suction based on the most limiting applicable conditions in the ESWS.
COL 9.2(4)	The COL applicant is to determine the design details of the backwashing line, vent line, and their discharge locations in the ESWS.
COL 9.2(5)	The COL applicant is to provide the evaluation of the ESW pump at the high and low water levels of the UHS. In the event of approaching low UHS water level, the COL applicant is to develop a recovery procedure.
COL 9.2(6)	The COL applicant is to provide measures to prevent long-term corrosion and organic fouling that may degrade system performance in the ESWS.
COL 9.2(7)	The COL applicant is to evaluate the need and design and install freeze protection in the ESWS if required.
COL 9.2(8)	The COL applicant is to conduct periodic inspection, monitoring, maintenance, performance, and functional testing of the ESWS and UHS piping and components, including the heat transfer capability of the CCW heat exchangers based on GL 89-13 and GL 89-13 Supplement 1.

COL 9.1(7) The COL applicant is to provide post seismic event inspection procedures to measure gaps between the new and spent fuel storage racks.

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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-40

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, "New and Spent Fuel Storage Rack Design", the applicant stated that "The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP". In the technical report APR1400-H-N-NR-14012-P, Rev 0, the applicant in Subsection 3.2.2.3 "Faulted (Abnormal) Conditions (Level D)", specified the allowable compressive stress as two-thirds of the critical buckling stress for the stress limit criteria for combined axial compression + bending loads,. However, in subsection 3.7.3.4(2), "Local Stress Evaluation", the applicant calculated the critical buckling stress of 12,731 psi but did not reduce it to two-thirds to obtain allowable compressive stress for the rack cell wall. In accordance with SRP 3.8.4 Appendix D I (3), the applicant is requested to provide the technical justification for using the calculated critical buckling stress as the limit under Service Level D condition, instead of the two-thirds of the critical buckling stress as stated in the Level D stress limit criteria. Also, in the calculation of critical buckling stress, BETA (value of coefficient) = 4.0 is used. The applicant is requested to explain what boundary conditions are assumed on the long edges of the simplified cell wall buckling model, and provide the technical basis for this designation. The applicant is requested to identify any proposed changes to and provide a mark-up of Subsections in the DCD Tier 2 and the report APR1400-H-N-NR-14012-P, Rev.0, as appropriate.

Response

The evaluation for cell wall buckling will be revised to reflect the two-thirds of the critical buckling stress as stated in the Level D stress limit criteria.
Section 3.7.3.4(2) of the report APR1400-H-N-NR-14012-P, will be revised as shown below.

“(2) Cell Wall Buckling

The allowable local buckling stresses of the cell walls for the fuel storage rack are obtained by using classical plate buckling analysis on the lower portion of the cell walls. A critical bucking stress of cell walls can be calculated by following equation (Reference 19).

$$\sigma_{cr} = K \frac{E}{(1-\nu^2)} \left(\frac{t}{b}\right)^2$$

Where, E (Young’s modulus) = 1.896E+05 N/mm^2(27.5E+06 psi), υ (Poisson’s ratio) = 0.3, t (Cell Thickness) = 2.5 mm(0.098 in), b (Cell width) = 220 mm (8.66 in). The K factor varies depending on the plate length/width ratio and the boundary support conditions at the side of the plate. At the base of the rack, the cell wall acts alone in compression for a length of about 5.1 inch up to the point where the cover plate for the neutron absorber sheathing is attached. Above this level, the cover plate for the neutron absorber sheathing provides additional strength against buckling, which is not considered here. Therefore, the length/width ratio for the 220 mm (8.66 in) wide cell wall will be taken as 0.59. From Table 35 of Roark’s Formulas for stress & strain, 6th edition (Reference 19), the value of K is taken as 5.80, which is the corresponding value for a/b (length/width ratio) = 0.6, for two edges simply supported and two opposite edges clamped.

For the given data above, two-thirds of the critical buckling stress (σ_{cr}) as the limit under Service Level D condition is calculated as 103.2 MPa (14,964 psi) for all racks. It should be noted that this calculation is based on the applied stress being uniform along the entire length of the cell wall. In the actual fuel rack, the compressive stress comes from consideration of the overall bending of the rack structures during a seismic event and as such is negligible at the rack top. In the simulation, the maximum compressive stress due to overall bending is generated near the baseplate. This local buckling stress limit is not violated anywhere in the body of the rack modules, since the maximum compressive stress in the outermost cell is σ = 2 x 0.6 x 147.5 x FACT2 (from Table 3-12 with FACT2 = 0.314) = 55.6 MPa (8,061 psi) and is within the allowable value of 103.2 MPa (14,964 psi). Therefore, a buckling of the rack cell wall does not occur.”

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

APR1400-H-N-NR-14012-NP, Section 3.7.3.4(2) will be revised as shown in the attachment.

The weld stress on the baseplate-to-pedestal is conservatively evaluated using the maximum pedestal load of the NFSR and the dimension of support pedestal welds of spent fuel storage rack. The weld between baseplate and support pedestal is checked using finite element analysis to determine that the maximum stress is 124.1 MPa (17,992 psi) under a Level D condition. This calculated stress value is well below the Level D allowable of 246.1 MPa (35,694 psi). Therefore, all weld stresses between baseplate and support pedestal are acceptable.

(3) Cell-to-Cell Weld

Stress of cell-to-cell weld is calculated by combination the shear stress due to horizontal load acting on rack and the shear stress due to impact load of rack cell-to-fuel assembly. Cell-to-cell connections are by a series of connecting welds along the cell height. Stresses in storage cell to cell welds develop due to fuel assembly impacts with the cell wall. These weld stresses are conservatively considered by assuming that fuel assemblies in adjacent cells are moving out of phase with one another so that impact loads in two adjacent cells are in opposite directions and are applied simultaneously. This load application tends to separate the two cells from each other at the weld. Stress of cell-to-cell weld is combined by the square root of the sum of the squares (SRSS) method for the shear stress due to horizontal load acting on rack and the shear stress due to impact load of rack cell-to-fuel assembly. The calculated stresses of the cell-to-cell weld and the base metal shear are well below the allowable, and the results are summarized in Table 3-13.

3.7.3.4 Local Stress Evaluation

(1) Cell Wall Impact

The maximum impact loads of fuel-to-cell wall on the NFSRs and the SFSRs are 3.5 kN (798 lbf) and 10.1 kN (2,273 lbf), respectively, which are as shown in Table 3-10. The evaluation for cell wall for impact is performed to guarantee that local impact does not affect criticality of stored fuel. Integrity of local cell wall is evaluated conservatively using the peak impact load. Limit impact load to induce overall permanent deformation is calculated by plastic analysis. The cell walls of the new and the spent fuel storage racks endure the side load of the maximum 273.2 kN (61,410 lbf) and 47.4 kN (10,660 lbf), respectively (Reference 7). Therefore, the cell wall of racks satisfies the requirement with the maximum impact loads less than the allowable loads.

(2) Cell Wall Buckling

The allowable local buckling stresses of cell walls for fuel storage rack are obtained by using classical plate buckling analysis on the lower portion of the cell walls. A critical bucking stress of cell walls can be calculated by following equation.

$$\sigma_{cr} = \frac{\beta \pi^2 E t^2}{12 b^2 (1-\nu^2)}$$

Where, E (Young's modulus) = 1.896E+05 N/mm^2 (27.5E+06 psi), υ (Poisson's ratio) = 0.3, t (Cell Thickness) = 2.5 mm(0.098 in), b (Cell width) = 220 mm(8.66 in), and β (Value of coefficient) = 4.0 which is indicated for a long plate (Reference 16).

For the given data above, the critical buckling stress (σ_{cr}) is conservatively calculated as 87.8 MPa (12,731 psi) for all racks. It should be noted that this calculation is based on the applied stress being uniform along the entire length of the cell wall. In the actual fuel rack, the compressive stress comes from consideration of overall bending of the rack structures during a seismic event and as such is negligible at the rack top. In the simulation, the maximum compressive stress due to overall bending is generated near baseplate. This local buckling stress limit is not violated anywhere in the body of the rack modules, since

~~the maximum compressive stress in the outermost cell is σ = 2 x 0.6 x 147.5 x FACT2 (from Table 3-12 with FACT2 = 0.314) = 55.6 MPa (8,061 psi) and is within the allowable value of 87.8 MPa (12,731 psi). Therefore, a buckling of the rack cell wall does not occur.~~

The allowable local buckling stresses of the cell walls for the fuel storage rack are obtained by using classical plate buckling analysis on the lower portion of the cell walls. A critical bucking stress of cell walls can be calculated by following equation (Reference 19).

$$\sigma_{cr} = K\frac{E}{(1-\nu^2)}\left(\frac{t}{b}\right)^2$$

Where, E (Young's modulus) = 1.896E+05 N/mm2(27.5E+06 psi), υ (Poisson's ratio) = 0.3, t (Cell Thickness) = 2.5 mm(0.098 in), b (Cell width) = 220 mm (8.66 in). The K factor varies depending on the plate length/width ratio and the boundary support conditions at the side of the plate. At the base of the rack, the cell wall acts alone in compression for a length of about 5.1 inch up to the point where the cover plate for the neutron absorber sheathing is attached. Above this level, the cover plate for the neutron absorber sheathing provides additional strength against buckling, which is not considered here. Therefore, the length/width ratio for the 220 mm (8.66 in) wide cell wall will be taken as 0.59. From Table 35 of Roark's Formulas for stress & strain, 6th edition (Reference 19), the value of K is taken as 5.80, which is the corresponding value for a/b (length/width ratio) = 0.6, for two edges simply supported and two opposite edges clamped.

For the given data above, two-thirds of the critical buckling stress (σcr) as the limit under Service Level D condition is calculated as 103.2 MPa (14,964 psi) for all racks. It should be noted that this calculation is based on the applied stress being uniform along the entire length of the cell wall. In the actual fuel rack, the compressive stress comes from consideration of the overall bending of the rack structures during a seismic event and as such is negligible at the rack top. In the simulation, the maximum compressive stress due to overall bending is generated near the baseplate. This local buckling stress limit is not violated anywhere in the body of the rack modules, since the maximum compressive stress in the outermost cell is σ = 2 x 0.6 x 147.5 x FACT2 (from Table 3-12 with FACT2 = 0.314) = 55.6 MPa (8,061 psi) and is within the allowable value of 103.2 MPa (14,964 psi). Therefore, a buckling of the rack cell wall does not occur.''

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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-41

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, "New and Spent Fuel Storage Rack Design", the applicant stated that "The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP". In accordance with SRP 3.8.4 Appendix D I (3, 4, 5, 6), the applicant is requested to provide the following additional information in the technical report.

(a) In the technical report APR1400-H-N-NR-14012-P, Rev 0, Subsection 3.7.2, "Fuel structural Evaluation", the applicant did not discuss the location of the impact on the fuel where the maximum impact force occurs. The applicant is requested to provide the impact load for both the top and at the mid height of the fuel assembly. The staff notes in Subsection 3.1.2.2, "Details for Rack and Fuel Assembly", that "The mass of the upper, the central and the lower nodes is 1/4, 1/2 and 1/4 of the total mass, respectively". Since only 25 percent of the mass is assumed at the ends of the fuel assembly, there is a potential for a higher g-load on the fuel assembly at the top compared to that at the mid height if the impact load at the top of the fuel assembly is more than half the impact load calculated at the mid height. The applicant is requested to provide a technical justification for not determining the g-load on the fuel assembly at the top and at the mid-height and then using the maximum of the g-load in subsequent fuel assembly structural integrity evaluations.

(b) The staff in reviewing Table 3-10, "Impact Loads on Rack", notes that the impact load on the fuel assembly in the East-West and North-South directions is 25000 lbf and 18,594 lbf respectively. In subsection 3.7.2,"Fuel structural Evaluation", the applicant considered only the 25000 lbf load in evaluation the fuel assembly. The applicant is requested to provide the technical basis for not combining the impact load on the fuel assembly in the north-south and east-west directions simultaneously to obtain the total lateral impact load for use in evaluating the structural integrity of the fuel assembly.

(c) The applicant is also requested to provide the general criteria used for combining the seismic responses in the design and analysis of the fuel assembly, rack structure, welded connections, and the rack supports of NFSR and SFSR due to the SSE excitation along the three orthogonal directions (2 horizontal and vertical) imposed simultaneously.

The applicant is requested to identify any proposed changes to and provide a mark-up of Subsections in the DCD Tier 2 and the report APR1400-H-N-NR-14012-P, Rev.0, as appropriate.

Response

(a) The impact loads for both the top and at the mid height of the fuel assembly are as shown in the table below:

TS

(b) The structural integrity of the fuel assembly will be evaluated by combining the impact load on the fuel assembly in the north-south and east-west directions simultaneously to obtain the total lateral impact load. The report APR1400-H-N-NR-14012-P including the structural integrity evaluation of the fuel assembly will be provided by April 30, 2016.

(c) Seismic loadings for the three orthogonal directions (2 horizontal and vertical) are applied simultaneously to the rack models. The seismic responses are combined using the square root of the sum of the squares (SRSS) method in the design and analysis of the fuel assembly, rack structure, welded connections, and the rack supports of NFSR and SFSR due to the SSE excitation.

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 Environment Report.

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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-42

The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, "New and Spent Fuel Storage Rack Design", the applicant stated that "The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP". In the technical report APR1400-H-N-NR-14012-P, Rev 0, Table 3-11, "Stress Evaluation for Fuel Assembly", the applicant provides allowable limit for fuel grid spacer and fuel rod cladding. The staff did not find the basis for the bending stress calculation in the fuel rod cladding reported in the Table 3-11. In order for the staff to perform its safety evaluation of the fuel assembly, the applicant in accordance with SRP 3.8.4 Appendix D I (6) is requested to provide the technical basis for calculating the bending stress and the acceptance criteria used for the evaluation the fuel cladding. The applicant is also requested to provide the stress/strain evaluation of fuel cladding and an evaluation of the fuel channel. The applicant is requested to identify any proposed changes to and provide a mark-up of Subsections in the DCD Tier 2 and the report APR1400-H-N-NR-14012-P, Rev.0, as appropriate.

Response

The details for the bending stress calculation in the fuel rod cladding are described in Section 3.7.2.2 of the report APR1400-H-N-NR-14012-P. Section 3.7.2.2 of the report APR1400-H-N-NR-14012-P will be revised to include the strain evaluation of fuel cladding.

But the fuel channel evaluation is not included because a fuel channel is not part of the Plus7 fuel assembly design.

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

APR1400-H-N-NR-14012-NP, Section 3.7.2.2 will be revised as shown in the attachment.

w = Weight of one fuel assembly (= 657 kgf (1,448 lbf)).

The structural integrity of fuel assembly is evaluated for the maximum lateral acceleration load (17.3 g).

3.7.2.1 Buckling Evaluation of Fuel Spacer Grid

The lateral impact loads on a single fuel grid spacer is compared against its buckling capacity, which is derived from the data in SANDIA Report SAND90-2406 (Reference 15). This report provides an analysis which predicts the onset of buckling of the pressurized water reactor (PWR) spacer grid at 66.8 N (15 lbf) of load per fuel rod. The initial loading from the fuel rods on a lateral impact compresses the leaf springs onto the spacer grid frame. And then the spacer compresses the springs to the bottom, resulting in a deflection of the spacer grid frame. The spacer grid frames provide resistance to the point where the frame begins to buckle. After buckling, the frame offers a minimal resistance to further load. The objective of this analysis is to demonstrate that the spacer grids do not buckle and consequently rod-to-rod contact does not occur.

The fuel assembly spacer grid model for the PWR 15 x 15 fuel assemblies is based on the nonlinear spring element of the fuel assembly spacer grid obtained from the analysis of a single spacer grid cell. The basis of this cell model is verified through extensive modeling of entire spacer grid frames, as described in the SANDIA report (Reference 15). Appendix III.5.3 of the SANDIA report (Reference 15) shows the deflected shape from the PWR 15 x 15 single-bay slice model analysis and the force deflection spring elements developed for the Babcock and Wilcox (B&W) assembly models used to simulate the spacer grid for the two-dimensional side drop assembly analyses. Each spring element of PWR 15 x 15 fuel assemblies will accrue the force from the all rods adjacent to the spring of interest, and so the buckling force of 934 N (210 lbf) for an individual cell is equivalent to a force of 66.8 N (15.0 lbf) in each rod that buckles at the last cell in the row. The buckling capacity of the spacer grid is inversely proportional to the square of the cell size, i.e., the length of the unsupported column, and the cell size is directly related to the fuel rod pitch.

Since the cells in the PWR 16 x 16 spacer grids for the APR1400 design are smaller than the PWR 15 x 15 spacer grids, the smaller cells are more resistant to buckling. The ratio of rod pitch for each fuel assembly is calculated as follows:

$$\text{Ratio} = \frac{P15\times15}{P16\times16} = \frac{1.443}{1.285} = 1.123$$

Therefore, the critical buckling load of the fuel spacer grid for the APR1400 design is 934 x $(1.123)^2$ = 1,178 N (265 lbf). ~~Furthermore, the mass of the fuel assembly channel does not contribute to the buckling loads on the spacer grid, so only the fuel rod mass is considered in this analysis.~~ The fuel rod mass is applied as 0.61 kg/m (0.034 lbm/in) from Table 3-3. The load imposed on a cell in the spacer grid is 1/2 the mass of the fuel rod on each side of the spacer cell or 2 x (359.4 / (2 x1,000)) (0.61) (17.3 g) = 37.2 N (8.4 lbf), and the combined load from 15 fuel rods adjacent to the critical cell is 15 x 37.2 = 558 N (125 lbf).

3.7.2.2 Stress Evaluation of Fuel Cladding

The maximum lateral acceleration acting on the fuel mass is used to calculate a load uniformly distributed over a single fuel rod modeled as a beam simply supported by the spacer grids, and the maximum fuel rod length between the spacer grids is 359.4 mm (14.148 in) as shown in Table 3-3.

The uniformly distributed load on the fuel rod is calculated as follows:

$$q = a \times W_{fuel} = 17.3 \times 0.61 = 103.4 \text{ N/m (0.59 lbm/in)}$$

where,

a = Maximum lateral acceleration in g's (=17.3 g), and

W_{fuel} = Fuel assembly rod mass per unit length (= 0.61 kg/m).

The maximum bending moment for uniform load is calculated as

$M = (q \times L_{spacer}^2) / 8 = (103.4)(359.4/1{,}000)^2 / 8 = 1.67$ N-m (14.77 lbf-in)

where,

L_{spacer} = Maximum fuel rod length between spacer grids (=359.4 mm (14.148 in)).

The resulting maximum bending stress in the fuel cladding is calculated as 49.4 MPa (7,166 psi) from equation below.

$$\sigma_b = \frac{M \cdot R_o}{I} = 49.4 \text{ MPa (7,166 psi)}$$

where,

R_o = Outer radius of fuel rod (= 4.75 mm (0.187 in)), and
I = Moment of inertia of fuel rod cladding (= 160.4 mm^4 (3.853 x 10^{-4} in^4))

As results for fuel assembly evaluation, both the maximum impact load on an individual fuel grid spacer cell and the bending stress induced in the fuel rod cladding due to the maximum lateral acceleration are summarized in Table 3-11. The structural integrity of the stored fuel assemblies under the SSE event is assured, because the safety factors are greater than 1.0.

[Insert]

This bending stress is compared to the yield stress of 540.3 MPa (78,365 psi) per Table 3-3 for fuel rod cladding, the resulting safety factor is 10.9 as summarized in Table 3-11. The strain associated with this maximum stress is $\varepsilon = \sigma_b / E = 0.0005$ in/in, which is below the yield strain of 0.0081 in/in for irradiated ZIRLO cladding.

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.:	**287-8272**
SRP Section:	**09.01.02 – New and Spent Fuel Storage**
Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-43

1. The 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4, 5, 63, and 10CFR 52.80 (a) provide the regulatory requirements for the design of the new and spent fuel storage facilities. Standard Review Plan (SRP) Sections 9.1.2 and 3.8.4, Appendix D describes specific SRP acceptance criteria for the review of the fuel racks that are acceptable to meet the relevant requirements of the Commission's regulations identified above. In DCD Tier 2, Section 9.1.2.2.3, “New and Spent Fuel Storage Rack Design”, the applicant stated that “The dynamic and stress analyses are performed as described in report APR1400-H-N-NR-14012-P & NP”. In the technical report APR1400-H-N-NR-14012-P, Rev 0, Subsection 3.7.3, “Rack structural evaluation”, the staff did not find the punching shear evaluation of the baseplate against the rack pedestal impact loads. The credible failure mode for the rack baseplate is a punching shear failure due to the concentrated load transmitted by a support pedestal under SSE conditions and impact load on the rack baseplate due to an accidental drop of a fuel assembly. In order for the staff to perform its safety evaluation of the rack supports, the applicant in accordance with SRP 3.8.4 Appendix D I (3) is requested to demonstrate that the capacity of the baseplate against the punching is larger than the calculated rack pedestal impact load. The applicant is requested to identify any proposed changes to and provide a mark-up of Subsections in the DCD Tier 2 and the report APR1400-H-N-NR-14012-P, Rev.0, as appropriate.

Response

APR1400-H-N-NR-14012-P, Section 3.7.3.4(4) will be revised to include a punching shear analysis of the baseplate above a support leg as follows:

(4) Punching Shear Analysis of Rack Baseplate

A punching shear analysis has been performed for the rack baseplate under seismic loading conditions. The analysis demonstrates that the maximum vertical load on a single support pedestal is less than the force necessary for the 285 mm (11.2 in) square pedestal block to punch through the 0.984 inch thickness of the baseplate. The punching shear capacity of the baseplate (F_v) can be calculated by following equation.

$$F_v = \frac{S_y}{\sqrt{3}} 4 \cdot L \cdot t$$

Where, $\frac{S_y}{\sqrt{3}}$ (shear stress limit according to the distortion energy theory of yielding), S_y (yield strength of baseplate) = 147.5 MPa (21,400 psi), L (side length of the pedestal block) = 285 mm (11.2 in), t (thickness of the baseplate) = 25 mm (0.984 in).

The above equation yields F_v = 2,427 kN (545,657 lbf), which exceeds the maximum pedestal load (= 658.3 kN (148,000 lbf) per Table 3-9). Therefore, a punching shear failure of the rack baseplate will not occur.
And the maximum impact load on the rack baseplate due to an accidental drop of a fuel assembly from a height of 0.61 m (2 ft) above the top of rack is less than the maximum vertical load on a support pedestal due to SSE loading. Therefore, the above punching shear analysis is bounding for the fuel assembly drop impact loads.

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

APR1400-H-N-NR-14012-NP, Section 3.7.3.4(4) will be revised as shown in attachment.

the maximum compressive stress in the outermost cell is σ = 2 x 0.6 x 147.5 x FACT2 (from Table 3-12 with FACT2 = 0.314) = 55.6 MPa (8,061 psi) and is within the allowable value of 87.8 MPa (12,731 psi). Therefore, a buckling of the rack cell wall does not occur.

(3) Secondary Stress by Temperature Effects

The temperature gradients across the rack structure caused by differential heating effects between one or more filled cells and one or more adjacent empty cells are considered. The worst thermal stress in a fuel rack is obtained when a storage cell has a fuel assembly generating heat at the maximum postulated rate and the surrounding storage cells contain no fuel. The thermal stress is classified as secondary stress on the ASME Code Section III, Division 1. Therefore, it is independently evaluated without combining with primary stress of other load condition.

A conservative estimate of the weld stresses along the length of an isolated hot cell is obtained by considering a beam strip uniformly heated by ΔT = 36 °C (65 °F), and restrained from growth along one long edge. The temperature rise envelops the difference between the maximum local spent fuel pool water temperature (68.3 °C (=155 °F) bounding) inside a storage cell and the bulk pool temperature (49.4 °C (= 121 °F)) based on the thermal-hydraulic analysis of the spent fuel pool. The maximum shear stress due to temperature change for isolated hot cell weld is calculated as follows:

[Insert]

(4) Punching Shear Analysis of Rack Baseplate

A punching shear analysis has been performed for the rack baseplate under seismic loading conditions. The analysis demonstrates that the maximum vertical load on a single support pedestal is less than the force necessary for the 285 mm (11.2 in) square pedestal block to punch through the 0.984 inch thickness of the baseplate. The punching shear capacity of the baseplate (Fv) can be calculated by following equation.

$$F_v = \frac{S_y}{\sqrt{3}} 4 \cdot L \cdot t$$

Where, $\frac{S_y}{\sqrt{3}}$ (shear stress limit according to the distortion energy theory of yielding), Sy (yield strength of baseplate) = 147.5 MPa (21,400 psi), L (side length of the pedestal block) = 285 mm (11.2 in), t (thickness of the baseplate) = 25 mm (0.984 in).

The above equation yields Fv = 2,427 kN (545,657 lbf), which exceeds the maximum pedestal load (= 658.3 kN (148,000 lbf) per Table 3-9). Therefore, a punching shear failure of the rack baseplate will not occur.
And the maximum impact load on the rack baseplate due to an accidental drop of a fuel assembly from a height of 0.61 m (2 ft) above the top of rack is less than the maximum vertical load on a support pedestal due to SSE loading. Therefore, the above punching shear analysis is bounding for the fuel assembly drop impact loads.