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. 09.01.02-26

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". The staff noted that APR1400-H-N-NR-14012-P, Rev.0 did not consider seismic-induced sloshing effects in the nonlinear seismic analyses of the rack structure. The SRP 3.8.4 Appendix D, Section I.5 requires that the effect of sloshing water be quantified. In accordance with SRP 3.8.4 Appendix D, Section I.5, the applicant is requested to quantify the effect of sloshing water or provide the technical basis and justification for not considering the seismic sloshing effect on the dynamic response of the spent fuel 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

Based on the methodology in TID-7024 (Reference 1), "Nuclear Reactors and Earthquakes", the water height excluding the effect of the dynamic fluid pressure on the tank bottom is calculated as 3/8 times the height of the water surface above the bottom of the tank. For the APR1400, the spent fuel pool (SFP) water level is maintained at a normal depth of 12 meters (39 ft). The calculated vertical distance excluding the effect of the dynamic fluid pressure is approximately 4.45 meters (14.6 ft) above the bottom of the spent fuel pool (SFP).
The fuel racks, including pedestals, rest on the bottom of the SFP and are approximately 4.78 meters (15.7 ft) tall. Only the upper 0.3 meters (13 inches) of the racks, which represents 6.9% of the overall rack height, is extended above the constrained water mass. At the top of the fuel racks, the sloshing effect would be almost non-existent.

Therefore, the seismic sloshing effect by the SFP water does not influence the dynamic response of the spent fuel racks.

(*) Reference 1. TID-7024, Nuclear Reactors and Earthquakes, Chapter 6, U. S. Atomic Energy Commission, August 1963.

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

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Application Section:	**9.1.2**
Date of RAI Issue:	**11/02/2015**

Question No. 09.01.02-32

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 3.1.2.1 (2) "General Considerations" the applicant included the pedestal-to-bearing pad interface in the dynamic model of the rack for the impact loads. However, the staff did not find any acceptance criteria for the bearing pad. 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 provide a sketch showing the bearing pad dimensions and a layout of bearing pad with respect to the rack pedestal and the pool floor and acceptance criteria for the bearing pads including the maximum calculated and allowable bearing stress. 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-HN-NR-14012-P, Rev.0, as appropriate.

Response

In the designing of spent fuel storage racks for the APR1400, bearing pads are not used. The spent fuel storage rack modules are free standing on embedments in the pool floor as specified on DCD Tier 2 Subsection 9.1.2.2.2.
Therefore, the paragraph of Section 3.1.2.1(2) of technical report APR1400-H-N-NR-14012-P will be corrected from "~ interfaces for the pedestal-to-bearing pad interface ~" to "~interfaces for the pedestal-to-embedments interface ~".

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 3.1.2.1(2) will be revised as shown in the attachment.

(2) Impact Phenomena

Compression-only spring elements, with gap capability, are used to provide opening and closing of interfaces for the pedestal-to-~~bearing pad~~ embedments interface, the fuel assembly-to-cell wall interface, and the rack-to-rack and rack-to-pool wall potential contact.

(3) Fuel Loading

The dynamic analyses are performed for the condition that all fuel assemblies are fully loaded in the racks.

(4) Fluid Coupling

If an external load like earthquake occurs, spent fuel storage rack is influenced by fluid movement as well as by mechanical contact because it is submerged in water. This phenomenon is called fluid coupling effect. As the objects adjoin closer to each other, the fluid coupling gives greater effect. Because the racks are densely arranged in the spent fuel pool, the fluid coupling effect strongly acts on adjacent racks by the water of the pool. The formula for a hydrodynamic effect of the adjacent storage racks due to a storage rack in the spent fuel pool (Reference 4) is adopted. This formula is based on the potential flow theory of Fritz (Reference 5) and calculates the values of hydrodynamic mass of two objects in the fluid.

Fritz's classical two-body fluid coupling model (Reference 5) is extended to multiple bodies and used to perform a three-dimensional multi-rack analysis. This technology is incorporated in the whole pool multi-rack (WPMR) analysis, which permits simultaneous simulation of all racks in the pool. In its simplest form, fluid coupling effect can be explained by considering the proximate motion of two bodies (for example, a rack and a wall) under water. If one body (mass M_1) vibrates adjacent to a second body (mass M_2), and both bodies are submerged in frictionless fluid, Newton's equations of motion for the two bodies are as follows:

$-M_H A_1 + (M_1 + M_H) A_2$ = Fluid reaction forces on mass M_1, and
$(M_1 + M_H) A_1 - (M_1 + M_2 + M_H) A_2$ = Fluid reaction forces on mass M_2,

where,

M_1 = Mass of fluid displaced by the inner body,
M_2 = Mass of fluid inside the outer body in the absence of the inner body,
A_1, A_2 = Absolute accelerations of masses M_1 and M_2, respectively, and
M_H = Hydrodynamic mass that depends on the fluid flow when the two bodies move relative to each other.

The fluid adds mass to the body (M_H to mass M_1), and may be considered an inertial force proportional to acceleration of the adjacent body (mass M_2). Thus, acceleration of one body affects the force on another. This force is a function of a gap between bodies. Lateral motion of a fuel assembly inside a storage location is subject to this effect. Generally, the fluid coupling is always present when a series of closely spaced bodies (for example, fuel racks) undergo transient motion in a submerged environment of SFP. Therefore, the kinematics phenomenon of the storage rack in the spent fuel pool is indicated by analysis which includes a hydrodynamic effect. However, the NFSRs have no hydrodynamic effect because it is installed in air.

3.1.2.2 Details for Rack and Fuel Assembly

The dynamic analysis model of new fuel storage rack is shown in the Figure 3-1. Figure 3-2 is whole pool multi-rack analysis model of spent fuel storage rack. It is overall dynamic analysis model of spent fuel storage rack created by combining the model shown in the Figure 3-3 for Region I and Region II.

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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. 09.01.02-34

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, Subsections 3.2.2.1 and 3.2.2.2, the applicant provided the acceptance criteria for normal and upset conditions, Service Level A and Service Level B respectively, but did not discuss or provide the evaluation results for the normal and upset conditions. In accordance with SRP 3.8.4 Appendix D I (6), the applicant is requested to provide its evaluation results for the normal and upset conditions. 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

As described in DCD 3.7.1, the APR1400 seismic Category I SSCs are designed for the safe shutdown earthquake (SSE). The SSE is defined as the maximum potential vibratory ground motion at the generic plant site. Since the operating basis earthquake (OBE) is defined as one third the SSE, the design of the APR1400 seismic Category I SSCs based on OBE are not required in accordance with Appendix S of 10 CFR Part 50. Moreover thermal loads applied to the racks are not included in the stress combinations involving seismic loadings; since the thermal stresses are a secondary stress, and have no stipulated stress limits for Class 3 structures or components when acting in concert with seismic loadings.

Therefore, the primary stress evaluation for the normal and upset conditions is performed for dead weight, which includes only of the racks and the fuel assembly weight, in accordance with Table 3-1 of technical report APR1400-H-N-NR-14012-P.
Technical report APR1400-H-N-NR-14012-P will be revised to include the evaluation results for the normal condition of the pedestal and cell wall of the 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

APR1400-H-N-NR-14012-NP, Table 3-12 will be revised as shown in the attachment.

Table 3-12 Maximum Stress Factors of Rack

Rack		Pedestal Stress Factors			Cell Wall Stress Factors			COF
		FACT1	FACT2	FACT3	FACT1	FACT2	FACT3	
NFSRs		0.476	0.538	0.389	0.05	0.054	0.031	0.8
SFSRs	Region I Racks	0.41	0.436	0.219	0.149	0.16	0.032	0.8
SFSRs	Region II Racks	0.337	0.357	0.236	0.295	0.314	0.07	0.8

Notes:
(1) Dimensionless stress factors, FACT1, FACT2, and FACT3, are stated on subsection 3.2.3.

[Insert]

Service Level	Rack		Pedestal Stress Factors			Cell Wall Stress Factors		
			FACT1	FACT2	FACT3	FACT1	FACT2	FACT3
A	NFSRs		0.061	0.046	-	0.031	0.033	-
A	SFSRs	Region I Racks	0.063	0.046	-	0.046	0.049	-
A	SFSRs	Region II Racks	0.058	0.043	-	0.057	0.062	-
D	NFSRs		0.476	0.538	0.389	0.05	0.054	0.031
D	SFSRs	Region I Racks	0.41	0.436	0.219	0.149	0.16	0.032
D	SFSRs	Region II Racks	0.337	0.357	0.236	0.295	0.314	0.07

Notes:
(1) Dimensionless stress factors, FACT1, FACT2, and FACT3, are stated on subsection 3.2.3.

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Question No. 09.01.02-35

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 3.2.2.2, “Upset Conditions (Level B)”, the Service Level B acceptance criteria states that “allowable stress of Level A is used for Level B for conservatism”. The staff notes that in Section 4.3.5, “Methodology for Stuck Fuel Accident”, the applicant did not use the allowable stress of Level A but instead increased the Service Level A allowable in shear to Service Level B allowable. In accordance with SRP 3.8.4 Appendix D I (6), the applicant is requested to clarify the apparent inconsistency in the implementation of its Service Level B acceptance criteria for the stuck fuel assembly scenario. The applicant is also requested to provide the results of its evaluation and safety factors for the cell wall tensile stress, cell to cell weld shear stress, and the base metal shear stress for this accident scenario. 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 technical report APR1400-H-N-NR-14012-P, Section 3.2.2.2, the sentence "The stress limit factors for Level B are larger than those for Level A. However, allowable stress of Level A is used for Level B for conservatism" will be deleted to be consistent with the Section 4.3.5, “Methodology for Stuck Fuel Accident”.

For the stuck fuel accident analysis, the critical location for load application is to have the uplift load applied near the top of the rack along a single cell wall. This set of assumptions induces the maximum tensile stress in the cellular region of the rack due to the vertical force. The stress calculations are performed manually using the strength of materials formula and the results of the stuck fuel assembly are summarized in the table below:

Region	Stress Category	Calculated Stress MPa (psi)	Allowable Stress(1) MPa (psi)	Safety Factor
Cell Wall	Tensile	36.9 (5,354)	117.7 (17,077)	2.9
Cell-to-Cell Weld	Shear	8.9 (1,294)	136.7 (19,830)	15.3
Base Metal	Shear	8.9 (1,294)	78.5 (11,385)	8.8

Note)
(1) Per Appendix D of SRP 3.8.4, the allowable stresses for Level B service condition were applied to the stuck fuel assembly load.

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 3.2.2.2, 4.3.5 and 4.5(4) will be revised as shown in the attachment.

f_a = Direct compressive stress in the section,
f_{bx} = Maximum bending stress along x-axis,
f_{by} = Maximum bending stress along y-axis,
C_{mx} = 0.85,
C_{my} = 0.85,
D_x = $1 - (f_a/F'_{ex})$,
D_y = $1 - (f_a/F'_{ey})$,
F'_{ex}, F'_{ey} = $(\pi^2 E)/(2.15\ (kl/r)_{x,y}^2)$,
and subscripts x and y reflect the particular bending plane.

(6) Combined Stress (Combined Flexure and Tension Loads)

Combined flexure and tension/compression load on a net section satisfies the following equation given in NF-3322.1(e).

$$(f_a/0.6\ S_y) + (f_{bx}/F_{bx}) + (f_{by}/F_{by}) < 1.0$$

(7) Welds

The allowable maximum shear stress on the net section of a weld (F_w) is given in Table NF-3324.5(a)-1.

$$F_w = 0.3\ S_u$$

Where, S_u is the material ultimate strength at temperature. For the area in contact with the base metal, the shear stress on the gross section is limited to 0.4 S_y.

3.2.2.2 Upset Conditions (Level B)

The stress limits for Level B are those for Level A multiplied by the stress limit factor specified in Table NF-3312.1(b)-1 (Reference 8). ~~The stress limit factors for Level B are larger than those for Level A. However, allowable stress of Level A is used for Level B for conservatism.~~

3.2.2.3 Faulted (Abnormal) Conditions (Level D)

Article F-1334 of ASME Code Section III, Appendix F (Reference 8) states that the limits for the Level D condition are the smaller of 2 or 1.167 S_u/S_y times the corresponding limits for the Level A condition if $S_u >$ 1.2 S_y, or 1.4 if S_u is less than or equal to 1.2 S_y except for requirements specifically listed below. S_u and S_y are the ultimate strength and the yield strength at the specified rack design temperature.

Exceptions to the above general multiplier are the following:

(1) The tensile stress on the net section shall not exceed the lesser of 1.2 S_y and 0.7 S_u.

(2) The shear stress on the gross section shall not exceed the lesser of 0.72 S_y or 0.42 S_u. In the case of the austenitic stainless steel material used here, 0.72 S_y governs.

(3) Combined axial compression and bending - The equations for Level A conditions shall apply except that F_a = 2/3 x Buckling Load, and F'_{ex} and F'_{ey} may be increased by the factor 1.65.

(4) For welds, the Level D allowable weld stress is not specified in Appendix F of the ASME Code. Therefore, a limit for weld throat stress is used conservatively as follows:

$$F_w = (0.3\ S_u) \times \text{Factor}$$

where, Factor = (Level D shear stress limit)/(Level A shear stress limit)

F_{Uplift} : Uplift force applied to the rack,
τ_y : Allowable in shear of cell wall for Level B limit (=1.33 x 0.4 x S_y), and
t_{cell} : Cell wall thickness.

(2) Vertical uplift along length of cell

The cell wall stress (σ) due to vertical uplift force along length of cell is determined as follows:

$$\sigma = \frac{F_{Uplift}}{D_{cell} \cdot t_{cell}}$$

If the calculated stress using above equation is below the Level B limit (=1.33 x 0.6 x Sy) of rack cell, the damage of the cell will not occur.

where,
D_{cell} : Cell Inside dimension.

~~If the calculated stress using above equation is below the yield strength of rack cell, the permanent damage of the cell will not occur.~~

(3) Horizontal and vertical force (45 degree inclined force)

If the load is applied inclined at 45 degrees, then there is a horizontal load that must be supported. Realistically, this load can only be applied at the top of the rack. Therefore, any damage is confined to a region above the active fuel area. The depth (h_{sf}) of the damaged region is obtained from the following equation to determine the amount of area needed to support the forces.

$$h_{sf} = \frac{F_{Uplift}}{2 \cdot \sqrt{2} \cdot \tau_y \cdot t_{cell}}$$

The damaged region by tear out of a cell wall shall be less than the distance from the rack top to the edge of the neutron absorber material.

4.4 Assumptions

(1) The trajectory of the dropped objects is vertical, which minimizes the fluid drag. This assumption increases the impact velocity and results in higher energy impacts.

(2) The ultimate load that can be sustained by a cell wall is based on the load carrying capacity of thin plate sections.

(3) The energy absorbed through failure of connecting welds is ignored in the analysis.

4.5 Results of Analyses

The postulated drop accidents analyses are conservatively performed based on the bounding impact energy and configuration. The impact velocities for mechanical accident scenarios 1, 2 and 3 are summarized in Table 4-1. The following results are determined based on the methodologies, which are discussed on section 4.3, and the detailed calculations are described in the mechanical accident analysis report (Reference 18).

(1) Straight Shallow Drop (Scenario 1)

In the straight shallow drop of a fuel assembly along with the handling tool, it is demonstrated that the permanent damage to any fuel storage cell is limited to the maximum depth of 64.3 mm (2.53 in) below the top of the rack. This is less than the distance from the top of the rack to the beginning of the active fuel region, 0.61 m (2 ft). Therefore, there will be no effect on the configuration and subcriticality of the fuel in the adjacent cells due to this accident.

(2) Straight Deep Drop (Scenario 2)

During a straight deep drop accident away from the pedestal locations, the baseplates of the new and the spent fuel storage racks do not experience gross failure (puncture) because the deformed depth of the baseplate is smaller than the baseplate thickness of 25 mm (0.984 in). Furthermore, the deformation amounts of the baseplates of the new and the spent fuel storage racks are calculated as 138.9 mm (5.47 in) and 117.1 mm (4.61 in), respectively. These values are less than the minimum distances between the baseplate and the liner, which are 210 mm (8.27 in) and 185 mm (7.28 in) for the new and the spent fuel storage racks, respectively. Therefore, a dropped fuel assembly along with the handling tool will not cause the result that the rack baseplate impacts the pool liner.

(3) Straight Deep Drop (Scenario 3)

In the straight deep drop accident over a pedestal, the resulting impact transmits a load of 31,877 kgf (70,276 lbf) to the concrete pool slab through the embedment plate under the pedestal of racks. The compressive stress due to this impact load on concrete pool slab is calculated as 4.0 MPa (581 psi) by using a classical strength of materials equation, which is less than allowable stress limit of 16.4 MPa (2,375 psi). Therefore, the compressive stress on concrete due to dropping mass is less than the allowable stress limit.

(4) Stuck Fuel Assembly (Scenario 4)

[Insert]
tensile stress, cell to cell weld shear stress, and the base metal shear stress

The fuel racks are adequate to withstand the uplift force of 2,268 kgf (5,000 lbf) due to a stuck fuel assembly. The maximum depth of the damaged cell wall for the vertical uplift force at top of cell is found to be limited to within 56.9 mm (2.24 in) below the top of the rack. The damaged region by tear out of a cell wall for the 45 degrees inclined force would occur within the 40.1 mm (1.58 in) of the cell length. These are less than the distance from the top of the rack to the beginning of the active fuel region, 0.61 m (2 ft). In addition, the cell wall ~~stress~~ due to vertical uplift force along length of cell of 36.9 MPa (5,354 psi) is less than the ~~yield strength of 78.5 MPa (21,400 psi)~~. Therefore, the stuck fuel accident analysis demonstrates that the damage of the cell wall would only occur above the neutron absorber and the permanent deformation of cell does not occur.

allowable stress as shown on Table 4-2.

Table 4-1 Impact Evaluation Data

Rack	Cases	Drop Weight(*), kgf (lbf)	Drop Height, m (in)	Impact Velocity, m/sec (in/sec)
NFSR	Straight Deep Drop (Away from Pedestal)	1,100 (2,425)	5.18 (203.9)	10.1 (396.8)
SFSR	Straight Shallow Drop	1,100 (2,425)	0.61 (24.0)	3.14 (123.6)
	Straight Deep Drop (Away from Pedestal)	1,100 (2,425)	5.2 (204.7)	7.68 (320.2)
	Straight Deep Drop (Over a Pedestal)	1,100 (2,425)	5.2 (204.7)	7.18 (282.6)

(*) Drop Weight = Fuel assembly along with the handling pool

[Insert]

Table 4-2 Stress Evaluation for Stuck fuel Asselbly

Region	Stress Category	Calculated Stress MPa (psi)	Allowable Stress(1) MPa (psi)	Safety Factor
Cell Wall	Tensile	36.9 (5,354)	117.7 (17,077)	2.9
Cell-to-Cell Weld	Shear	8.9 (1,294)	136.7 (19,830)	15.3
Base Metal	Shear	8.9 (1,294)	78.5 (11,385)	8.8

Note)
(1) Per Appendix D of SRP 3.8.4, the allowable stresses for Level B service condition were applied to the stuck fuel assembly load.

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Question No. 09.01.02-37

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, Table 3-9, “Maximum Loads on single Pedestal”, the applicant provided the pedestal forces for the new and spent fuel racks. In accordance with SRP 3.8.4 Appendix D I (5), the applicant is requested to provide the details how the pedestal forces were converted to the bending moment and shear force at the bottom baseplate-to-pedestal interface. 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 dynamic simulations of the racks give results for the vertical and two horizontal forces (i.e. east-west and north-south directions) at that instant. From those values, the maximum axial force of the vertical direction and the maximum shear forces of the two horizontal directions per pedestal are determined. The resultant shear force is conservatively calculated by combining the maximum horizontal loads (i.e. east-west and north-south directions) on a single pedestal in Table 3-9 of technical report APR1400-H-N-NR-14012-P using the square root of the sum of the squares (SRSS) method. The maximum bending moment at the bottom baseplate-to-pedestal interface is computed by multiplying the maximum shear force and the distance from the bottom baseplate to the liner plate of the new fuel storage rack and the spent fuel storage racks, which is 185 mm (7.28 inches) and 160 mm (6.3 inches) as shown in Tables 2-1 and 2-2 of technical report APR1400-H-N-NR-14012-P, respectively.

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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Question No. 09.01.02-38

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 (3) "Cell-to-Cell Weld" provides a general description of the forces considered in the evaluation of cell-to-cell welds but did not provide any descriptions of how the stresses in the weld were calculated. In accordance with SRP 3.8.4 Appendix D I (3, 4, 5, 6), the applicant is requested to provide details of how the stresses in the cell-to-cell welds were determined, including a free-body diagram explaining how the loads were transferred and used to evaluate the cell-to-cell welds. 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

Cell-to-cell connections are a series of connecting welds along the cell height. Stresses in the storage rack cell to cell welds develop due to fuel assembly impacts with the cell wall. Weld stress is calculated based on the maximum fuel-to-cell impact load and shear stress, which is obtained by using the cell wall shear stress coefficient under Level D conditions from the dynamic analysis results. The maximum fuel-to-cell impact load (= 25,000 lbf) is taken from Table 3-10 of technical report APR1400-H-N-NR-14012-P. The shear stress on the cell wall is calculated by multiplying shear allowable stress under Level D conditions and the cell wall stress coefficient, FACT3= 0.07, per Table 3-12 of technical report APR1400-H-N-NR-14012-P.

The total shear stress acting on the weld is calculated by combining the shear stress acting on cell wall with the fuel-to-cell impact stress using the square root of the sum of the squares (SRSS) method. Then the safety factors of the storage rack cell-to-cell weld and base material adjacent to the weld are calculated as summarized in Table 3-13 of technical report APR1400-H-N-NR-14012-P. Below are figures that show a free-body diagram explaining how the loads were transferred and used to evaluate the cell-to-cell welds.

TS

In summary, the stress on the cell-to-cell weld is calculated using the following formula.

1) Stress calculation of base metal adjacent to weld due to impact load:

$$S_{impact} = \frac{Impact_{sse}}{A_{weld}}$$

Where, $Impact_{sse}$ is the maximum cell to fuel assembly impact load in Table 3-10 of technical report APR1400-H-N-NR-14012-P and A_{weld} is the total area of weld.

2) Shear stress calculation on the cell wall:

$$S_{shear} = StressFactor \cdot V_{sse}$$

Where, StressFactor is the shear stress factor of cell wall in Table 3-12 of technical report APR1400-H-N-NR-14012-P and V_{sse} is the allowable stress of cell wall under Level D condition.

3) Total shear stress calculation acting at cell-to-cell weld:

$$S_{combined} = \sqrt{(S_{impact}{}^2 + S_{shear}{}^2)}$$

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. 09.01.02-39

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(2) "Baseplate-to-Pedestal Weld", it is stated that "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". In accordance with SRP 3.8.4 Appendix D I (3, 4, 5, 6), the applicant is requested to provide details of the finite element analysis performed, including the finite element computer program, the computer model, and the loads considered in the weld stress analysis. 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 stress evaluation of the welds between the pedestal and the rack baseplate were performed using the finite element analysis program, ANSYS and manual calculations.

An ANSYS model as shown below was used to develop the load along the welds surrounding the pedestal. The maximum horizontal loads on a single pedestal are applied to the top of the beam element.

TS

The weld stress is derived from the simultaneous application of the maximum tensile force, as obtained from ANSYS, and the maximum pedestal friction forces in the horizontal directions (Fxs=756.2 kN (170,000 lbf) and Fys= 660.1 kN (148,400 lbf)), as determined by dynamic analysis. This is conservative, since these maximum loads may not occur at the same pedestal or at the same time instant. The maximum pedestal friction forces in any single direction are reported in Table 3-9 of technical report, APR1400-H-N-NR-14012-P. Therefore, stress on the weld is calculated by combining the horizontal load due to dynamic analysis and maximum tensile load, which is obtained from the ANSYS program.

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 3.7.3.3(2) will be revised as shown in the attachment.

3.7.3.2 Pedestal Thread Stress Evaluation

The integrity for the support pedestal thread is evaluated for the maximum load of support pedestal in vertical direction as shown in Table 3-9. Using this load, the maximum shear stress of thread in the engagement region is calculated. The allowable shear stress of SA-240 Type 304L material for Level D condition is the lesser of 0.72 S_y = 106.2 MPa (15,408 psi) or 0.42 S_u = 191.4 MPa (27,762 psi) as stated on subsection 3.2.2. Therefore, the former criteria controls, and the calculated shear stress of pedestal thread is as shown on Table 3-13.

3.7.3.3 Stresses on Welds

Weld locations of the NFSRs subjected to SSE loading are at the bottom of the rack at the cell-to-baseplate connection, and at the top of the pedestal support at the baseplate connection. In addition, weld locations for the SFSRs are at the bottom of the rack at the cell-to-baseplate connection, at the top of the pedestal support at the baseplate connection, and at cell-to-cell connections. The maximum values of resultant loads are used to evaluate the structural integrity of these welds. The calculated stresses on welds of rack are summarized in Table 3-13.

(1) Cell-to-Baseplate Weld

As given in ASME Code Section III, Subsection NF, for Level A or B conditions, an allowable shear stress of a weld is 0.3 S_u = 136.7 MPa (19,830 psi) conservatively based on the base metal material. As stated in subsection 3.2.2, the allowable weld stress may be increased for Level D by the ratio of 1.8, giving an allowable of 0.54 S_u = 246.1 MPa (35,694 psi).

Weld stresses on the cell-to-baseplate are determined through the use of a simple conversion factor (ratio) applied to the corresponding stress factor in the adjacent rack material. This stress factor is discussed in section 3.2, and given in the Table 3-12. The conversion factor (ratio) values are developed from consideration of the differences in material thickness and length versus weld throat dimension and length, as follows:

Ratio = [(220 + 2.5) x 2.5)] / (180 x 2.5 x 0.707) = 1.75 (for the SFSRs)

where, Inner cell dimension (220 mm (8.66 in)), Cell wall thickness (2.5 mm (0.098 in)), Weld length (180 mm (7.09 in)), and Weld thickness (= 2.5 x 0.707 = 1.767 mm (0.069 in)) are used.

For the NFSRs, the cell wall thickness and weld thickness are 6.0 mm (0.236 in) and 4.24 mm (0.167 in), respectively. The conversion factor (ratio) for the NFSRs is calculated as 1.54.

The highest predicted cell-to-baseplate weld stress is conservatively calculated based on the highest FACT2 for the rack cell region tension stress factor and FACT3 for the rack cell region shear stress factor. The maximum stress factors used do not all occur at the same time instant and the shear stress factors are the maximum for all load conditions. These cell wall stress factors are converted into actual stress on the weld of cell-to-cell as follows:

(FACT2 + FACT3) x (2 x 0.6 x S_y) x Ratio= (0.314 + 0.07) x (2 x 0.6 x 147.55) x 1.75 = 119.0 MPa (17,257 psi)

The 2.0 multiplier value is used to adjust the Level A allowable to the Level D allowable, as discussed in subsection 3.2.2. The calculated stress value is less than the allowable weld stress value of 246.1 MPa (35,694 psi). Therefore, all weld stresses between the cell wall and the baseplate are acceptable.

(2) Baseplate-to-Pedestal Weld

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.

The weld stress is derived from the simultaneous application of the maximum tensile force, as obtained from ANSYS, and the maximum pedestal friction forces in the horizontal directions (Fxs=756.2 kN (170,000 lbf) and Fys= 660.1 kN (148,400 lbf)), as determined by dynamic analysis and the calculated