REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

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

Docket No. 52-046

RAI No.:	**208-8245**
SRP Section:	**03.08.03 – Concrete and Steel Internal Structures of Steel or Concrete Containments**
Application Section:	**03.08.03**
Date of RAI Issue:	**09/14/2015**

Question No. 03.08.03-5

10 CFR 50.55a and Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50, provide the regulatory requirements for the design of the containment internal structures. Standard Review Plan (SRP) 3.8.3, Section II specifies analysis and design procedures normally applicable to internal concrete structures, with emphasis on the extent of compliance with American Concrete Institute (ACI) 349-01, "Code Requirements for Nuclear Safety Related Concrete Structures," with additional guidance provided in Regulatory Guide 1.142, and ANSI/AISC N690-1994, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities," including Supplement 2.

DCD Tier 2, Section 3.8A.1.4.3.1.3, "Analysis Methods and Results"

a. APR1400 DCD Tier 2, Section 3.8A.1.4.3.1.3 describes the analysis methods and results for the containment internal concrete structures. It states that, "Operating concrete floor slabs are modeled to mass in a finite element model (FEM), such as slabs between the SSWs and containment shell." Per 10 CFR 50.55a; Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50; and SRP 3.8.3, the applicant is requested to clarify if this meant to say that the operating floor slabs between the secondary shield walls (SSWs) and the containment shell are included as masses in the FEM. If this is the case, then explain why it is acceptable to decouple these slabs from the overall FEM analysis of the internal structures and how is the analysis and design for such subelements performed for all of the various loadings.

b. Additionally, DCD Section 3.8A.1.4.3.1.3 indicates that fifty percent of the weights and equipment weights on the floor between the containment shell and the SSW are assumed to be distributed to the containment shell and the SSW, respectively. This implies that there is a connection between the containment internal floors and the containment. Per 10 CFR 50.55a; Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50; and SRP 3.8.3, the applicant is requested to explain in what directions (radial, tangential, and/or vertical) are the connections made and the details of how they are designed. Also, identify the gap provided between the containment and the floor slabs/connections to prevent impact/interaction and describe how the relative displacements between the containment and the floor slabs/connections from all loads including thermal and seismic were determined to demonstrate the gap is adequate.

c. This DCD Section also indicates that Figure 3.8A-23 shows the full FEM for the containment internal structures and Figure 3.8A-24 shows the solid element model (PSW, IRWST, and fill concrete), shell element model (SSW), and beam element model (RCS). The staff notes that part (b) of Figure 3.8A-24, which is labelled Shell Element Model (SSW), does not show the shell elements of the SSW. The applicant is requested to clarify why not.

d. DCD Section 3.8A.1.4.3.1.3 states that, “An equivalent uniform temperature gradient is input directly in the ANSYS model at the appropriate nodes. The temperature profiles during normal operating condition are more severe than those of the accident condition, thus represent the limiting temperature for all the plant conditions.” Per 10 CFR 50.55a; Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50; and SRP 3.8.3, the applicant is requested to provide the technical basis for this conclusion.

Response - (Rev.1)

a. Figure 1 depicts the sketch of concrete slab and steel beam between containment wall and SSW. The concrete slab is supported by steel beam and beam seats attached on the walls. The steel beam at the containment side is laid on the beam seat with a lower key bumper and at the SSW side by a weld on the beam seat.

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Figure 1. Concrete slab and steel beam between containment and SSW

Operating floor slabs between the secondary shield walls (SSWs) and the containment shell are included as masses in the FEM. The decoupling criteria in SRP 3.7.2 allow decoupling if the mass ratio of the substructure is less than 0.1 but above 0.01 (0.01 ≤ mass ratio (R_m) ≤ 0.1), and if the frequency ratio of the substructure is less than 0.8 or above 1.25 (frequency ratio (R_f) ≤ 0.8 or 1.25 ≤ frequency ratio (R_f)).

TS

b. Regarding the analysis and design of subelements, the concrete slabs at elevations 114'-0", 136'-6", and 156'-0" between secondary shield wall and containment wall are structurally analyzed using the FE (Finite Element) analysis program GTSTRUDL. A separate analysis model simulating each floor level is prepared and evaluated for each specified design load condition. The span direction for concrete slabs is considered in determining the tributary areas. In order to incorporate the proper seismic load on each slab, the response spectrum analyses are performed with the FRS which envelope containment shell side and secondary shield wall side at each elevation. The thickness of the slab is generally determined by the requirements of radiation shielding, missile protection, and structural integrity. Based on the enveloped results of FE analysis, the slab is designed for all member forces recommended in ACI 349.

The floors are supported by structural steel beams which span the secondary shield wall and the containment wall. Each end of the steel beams have a fixed connection at the secondary shield wall and a sliding connection at the containment wall. The fixed connection is composed of a beam seat and a web angle connection. The beam seat supports vertical load and is designed considering the friction. The load generated from friction is negligible because the axial load generated from friction is so small. The web angle connection supports vertical and axial load. The sliding connection at the containment wall is composed of a beam seat and a gap between the end of the steel beam and the containment wall to allow radial displacements due to seismic and thermal loads. The gap between the end of the steel beam and the containment wall is 2 1/16" which is larger than the maximum displacement of 2.04".

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Figure 2. Concrete slab and steel beam between containment and SSW

Based on the results of the FE analysis of containment shell & dome, containment wall displacements by earthquake and post-tensioning are determined. Thermal displacement is thermal expansion of steel beam in RCB under design basis accident condition of LOCA. Installation tolerance is also determined according to tolerances on structural steel fabrication. In addition to the gap between the end of the steel beam and the containment wall, the gap between the edge of concrete floors and the containment wall is 2 1/2". Therefore, the gap is adequate to allow the relative displacements between the containment internal floors and the containment wall.

c. Part (b) of Figure 3.8A-24 shows the solid element model of the PSW, the IRWST, and the fill concrete due to an editorial error. In order to show the shell element model of the SSW, part (b) of Figure 3.8A-24 will be revised as indicated on the attached markup.

d. According to ACI 349, the actual non-linear temperature distribution can be converted to an equivalent linear temperature distribution for use in design of concrete structures. In containment internal structure, the equivalent linear temperature profiles of normal operating condition is more severe than those of the accident condition. A detailed explanation is provided in KHNP's response to RAI 208-8245, Question 03.08.03-4.

Impact on DCD

DCD Tier 2, Section 3.8A.1.4.3.1.3 and Figure 3.8A-24, part (b) will be revised as indicated on 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 Environmental Report.

d. Abnormal/extreme: $1.0D + 1.0L_h + 1.0L + 1.0P_a + 1.0T_a + 1.0Y_r + 1.0E_s$

3.8A.1.4.3.1.3 Analysis Methods and Results

The containment internal concrete structures are interconnected at various elevations. Significant lateral loads from the reactor coolant system (RCS) supports are applied at several elevations. In order to properly account for the load distribution in structures, an overall structural model representing containment internal concrete structures is prepared. Operating concrete floor slabs ~~are modeled to mass in a finite element model (FEM), such as slabs between the SSWs and containment shell.~~ between the SSWs and containment shell are included as masses in the finite element model (FEM).

The ANSYS program is used to perform structural analysis using the containment internal structure full model. The FEM consists of a total of 50,496 nodes. The numbers of shell, solid, and beam elements are 5,522, 41,689, and 827, respectively. The following containment internal structures are included in the analysis model:

Solid Elements

a. PSW

b. IRWST and fill concrete

Shell Elements

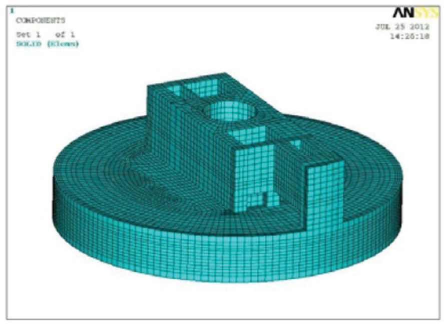
a. SSW

b. Refueling pool wall and slab

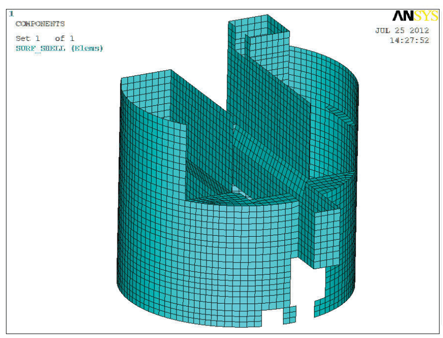
c. Pressurizer (PZR) enclosure wall and slab

d. Steam generator (SG) enclosure wall

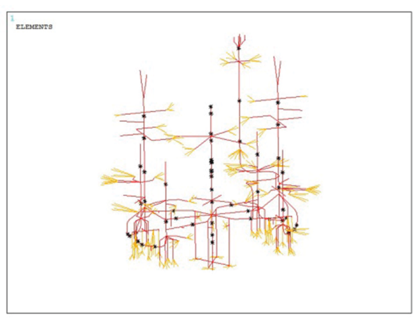
e. Operating floor slab between SSW and refueling pool wall



(a) Solid Element Model (PSW, IRWST, and Fill Concrete)



(b) Shell Element Model (SSW)



(c) Beam Element Model (RCS)

Figure 3.8A-24 Solid, Shell, and Beam Element Model for RCB Internal Structure