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 Containment**
Application Section:	
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Question No. 03.08.03-3

Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50, provides the regulatory requirements for the design of the containment internal structures. Standard Review Plan (SRP) 3.8.3, Section II discusses the loads and load combinations normally applicable to containment internal 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 .

APR1400 DCD Tier 2, Section 3.8.3.3, "Loads and Load Combinations," indicates that the typical loads and load combinations used for the internal structures are detailed in Section 3.8.4.3. Then it lists loads that the internal structures are designed for. A comparison of these loads listed in DCD Section 3.8.3.3 with those of DCD Section 3.8.4.3 shows that some loads are not included like operating pressure loads, construction loads, and internal flooding. Per 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 confirm that all applicable loads described in DCD Section 3.8.4.3 are used for internal structures, or explain why not. This issue of consideration of all applicable loads also applies to the list of loads identified in DCD Section 3.8.3.4.1 – Analysis Procedures.

In addition, DCD Appendix 3.8A.1.4.3.1.2, "Load Combinations Considered," identifies load combinations that are critical for the analysis and design of the primary shield wall (PSW). It is not clear to the staff whether only these load combinations were evaluated or all load combinations were evaluated, and only these were critical. This should be explained. In addition, there are some loads that are not included in these critical load combinations such as R_o in load combination labelled a. and c., R_a in load combination b., and R_a, Y_j, Y_m, and Y_f in load combination d. This should be explained. The applicant is also requested to address the above items for the other containment internal structures (e.g., IRWST and SSW).

Response – (Rev. 1)

Some of the loads described in DCD Section 3.8.4.3 are used for the design of internal structures- the appropriate loads for the design of internal structures are considered. DCD Section 3.8.3.3 will be revised to state applicable loads used for the design of the containment internal structure (CIS), as indicated on the attached markup.

As shown on the attached markup, except for M_o, W, and H, which are not applied to the CIS, the load combination (LC) No. 4 and 5 in DCD Table 3.8-9A can be represented as LC No. 1 through No. 9. Also, except for M_a, W_t, and H_s, which are not applied to the CIS, the LC No. 11 and 12 in DCD Table 3.8-9A can be representative as LC No. 10 through No. 14.

There are no R_o and R_a at the primary shield wall (PSW). Based on the ACI 349 Appendix C, impactive and impulsive effects are treated separately because of the nature of the effects as well as the response characteristics of the structural members subjected to these loads. Y_j and Y_m act on the local area of the internal structures. So, Y_j and Y_m are evaluated with the design margin of the arranged reinforcement in the local area after design with load combinations. For the containment internal structures, Y_f is offset by acting equally on both sides of the internal wall. So, Y_f is not included in the load combination. The above discussion regarding Y_j,Y_m, and Y_f are also applicable to the other containment internal structures (e.g., IRWST and SSW).

Internal flooding load (H_a) described in DCD Section 3.8.4.3.2 is an editorial error since H_a acts on the containment shell. Therefore, the associated description in the DCD will be deleted as shown on the attached markup.

For above mentioned items, DCD Section 3.8.3.3, 3.8.4.3.1, 3.8.4.3.2, 3.8A.1.4.3.1.2, 3.8A.1.4.3.2.2, 3.8A.1.4.3.3.2 will be revised to clarify as indicated on the attached markup.

Impact on DCD

DCD Section 3.8.3.3, 3.8.4.3.1, 3.8.4.3.2, 3.8A.1.4.3.1.2, 3.8A.1.4.3.2.2, 3.8A.1.4.3.3.2 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.

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3.8.3.1.11 Interior Concrete Fill Slab

The interior concrete fill slab is located on the surface of liner plate of the reactor containment building basemat for protection of pressure boundary structures.

3.8.3.1.12 Polar Crane Supports

A large capacity of polar crane is supported by brackets installed in the containment shell, and the bracket is a steel structure consisting of cantilever beam.

3.8.3.2 Applicable Codes, Standards, and Specifications

The following codes, standards, and specifications are applied to the design of internal concrete and steel structures.

3.8.3.2.1 Design Codes and Standards

The design codes, standards, and regulations are listed in Table 3.8-1.

3.8.3.2.2 NRC Regulatory Guides

Conformance to each NRC RG is described in Section 1.9. The NRC RGs applicable to the design of the concrete and steel structures are 1.60, 1.61, 1.92, 1.122, 1.142, and 1.199 (References 22 through 27).

3.8.3.2.3 Industry Standards

Nationally recognized industry standards, such as those published by ASTM, will be used whenever possible to describe material properties, testing procedures, and fabrications and construction methods.

3.8.3.3 Loads and Load Combinations

~~described~~

The ~~typical~~ loads and load combinations ~~used for the internal structures are detailed in~~ Subsection 3.8.4.3.

for the CIS are obtained from

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The internal structures are designed for the following loads:

a. Dead load

b. Equipment operating loads and other live loads

c. Pipe break reactions

d. Seismic load

e. Internal missiles (the ~~internal structure is designed to withstand~~ internal missiles, as described in Section 3.5 ~~)~~. This included pipe break missle.)

f. Pipe rupture jet impingement

g. Compartment accident pressure

h. The greatest pipe rupture loads from (1) pipe breaks not eliminated by leak-before-break, (2) the largest through-wall leakage crack in a high-energy line (minimum 37.9 L/min (10 gpm)), whether or not consideration of dynamic effects is eliminated by leak-before-break for the line, or (3) the largest leak from another leak source, such as a valve or pump seal.

i. Operating and accident temperatures

j. Hydrostatic and dynamic loads (IRWST)

Seismic Category I concrete structures are designed for impulsive and impactive loads in accordance with the ACI 349 Code, and special provisions of Appendix C of the same code, with exceptions given in NRC RG 1.142. Impactive and impulsive loads are considered concurrent with seismic and other loads (i.e., dead and live loads) in determining the load resistance of structural elements.

Subcompartment pressure loads are the result of postulated high-energy pipe ruptures. In determining an appropriate equivalent static load for Y_r, Y_j, and Y_m, elasto-plastic behavior is acceptable with appropriate ductility ratios, provided excessive deflections do not result in loss of function of any safety-related system.

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j. Hydrostatic and Hydrodynamic loads (POSRV load for IRWST)

k. Pipe, cable tray, duct, and ties

l. Pipe accident reaction

Miscellaneous loads (Mo, Ma), wind loads (W), precipitation loads (H, Hs), and tornado loads (Wt) of the loads in DCD Table 3.8-9A do not affect the design of the containment internal structures (CIS) because the CIS is protected by the concrete containment and there is no column, transformer, belt, etc. Therefore, these loads are not applied to the design of the CIS. There is no large crane supported by the CIS. Jip cranes are evaluated in the local affected area.

Reactions of pipe, cable tray and duct (Ro) and pipe accident reactions (Ra) are evaluated in local affected area after the load informations are provided from the responsible design group and/or the supplier.

Flooding loads (Yf) are not applied because it is offset by acting equally on both sides of the CIS. During operation, there is little to no pressure (Po) acting on the CIS.

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normal loading condition is 12.0 kN/m^2 (250 psf). Any loading conditions that result in soil surcharge loads greater than these minimum values are checked on an individual basis.

2) Hydrostatic load (L_h)

Hydrostatic loads are due to weight and pressures of fluids with well-defined densities and controllable maximum heights or related internal moment and forces.

3) Snow load (L_s)

Based on the assumed site-related parameters, the 100-year snowpack roof load is considered to be 2.873 kN/m^2 (60 psf).

c. Thermal operating load – (T_o)

Thermal operating load is thermal load effect from the most critical transient or steady-state thermal condition at normal operation or shutdown conditions. This also includes thermal effects such as frictional loads due to expansion.

d. Pipe, cable tray, duct ~~supports~~, and ties – (R_o)

This includes their dead load, live load, thermal load, seismic load, thrust load, and unbalanced internal pressure under normal and severe environmental conditions.

R_{os} – Self-weights, including contents

R_{ot} – Transient or steady-state thermal loading conditions during normal operation and shutdown conditions

For the test loading condition, this includes piping reactions due to test cleanup and blowdown conditions.

R_{op} – Effects of unbalanced pressure and thrust construction. SEI/ASCE 37-02 (Reference 8) is considered to be supplemental guidance.

3.8.4.3.2 Abnormal Loads

a. Accident pressure – (P_a)

Accident pressure is applied to external or internal air, gas, or liquid pressure loads during abnormal operating conditions. Examples of this are excursion pressures within gas ducts due to fan or damper type failures and differential air pressure on a building wall due to a postulated pipe break including annulus pressurization effects and flooding loads. An appropriate dynamic factor to account for the dynamic response of the structure and the time dependency of the load is included.

1) Main steam valve house

The compartmental accident pressures due to main steam and feedwater line breaks are considered.

2) Other areas

Accident pressures in other areas of seismic Category I structures are defined during plant layout and design.

b. Accident temperature – (T_a)

Accident temperature is thermal load effects during abnormal operating conditions. Accident temperatures in other areas of seismic Category I structures are defined during plant layout and design.

c. Accident reactions of pipe, cable tray, ~~and~~ duct, ~~supports~~ and ties – (R_a)

R_a is reactions of pipe, cable tray, ~~and~~ duct, ~~supports~~ and ties. This includes their dead load, live load, thermal load, seismic load, thrust load, and transient

g. Flooding load – (Y_f)

Y_f is the load within or across a compartment and/or building due to flooding generated by a postulated pipe break. These loads are calculated considering the design basis flood heights.

h. Miscellaneous abnormal loads – (M_a)

M_a includes other miscellaneous site-related accidents such as blast, aircraft impact, or internally generated equipment missiles.

~~i. Internal flooding – (H_a)~~

~~H_a includes loads on the containment resulting from internal flooding other than from pipe breaks.~~

3.8.4.3.3 <u>Severe Environmental Loads</u>

a. Wind loads – (W)

W is the equivalent static load generated by the design wind velocity, and is calculated in accordance with ASCE 7 (Reference 33) and described in Subsection 3.3.1. Seismic Category I structures are designed for a 100-year recurrence interval wind, and for tornado and hurricane winds and missiles as described in Subsections 3.3.2 and 3.5.1.4.

For seismic Category I structures, an importance factor I of 1.15 is used with 50-year, 3-second gust speed at exposure Category C, as defined in ASCE 7, Section 6.5.

b. Design flood/precipitation – (H)

Flood loads on seismic Category I structures are determined based on the maximum site flood levels specified in Chapter 2.

3.8A.1.4.3 Internal Structures

3.8A.1.4.3.1 Primary Shield Wall

3.8A.1.4.3.1.1 Description

The PSW is a massive rectangular concrete structure, 18.80 m (61 ft 8 in.) long by 11.43 m (37 ft 6 in) wide, with cavities consisting of the following:

a. Vertical chase, 2.03 m (6 ft 8 in.) by 5.18 m (17 ft 0 in.), for in-core instrumentation (ICI) guide tubes from the seal table at the bottom of the refueling pool, El. 130 ft 0 in, down to the bottom of the ICI tunnel at El. 69 ft 0 in.

b. Horizontal chase, 5.51 m (18 ft 3/4 in.) wide 4.27 m (14 ft 0 in.) high, from below the seal table to below the reactor vessel for the ICI guide tubes.

c. A cavity to enclose and support the reactor vessel from the top of the PSW at El. 130 ft 0 in to the bottom of the ICI horizontal chase.

d. Openings to allow installation and access to the main coolant loop piping from the reactor vessel to the steam generators and the RCPs back to the reactor vessel.

e. A laydown area for the upper guide structure that is a part of the fuel handing system. This opening is 5.18 m (17 ft 0 in.) by 5.16 m (16 ft 11 in.) and extends from the bottom of the refueling pool down to El. 106 ft 6-3/8 in.

3.8A.1.4.3.1.2 Load Combinations Considered

The following loading combinations are critical for the analysis and design of the PSW:

a. Normal: $1.4D + 1.4L_h + 1.7L$ + 1.7 Ro and $1.1D + 1.1L_h + 1.3L + 1.2T_o$ + 1.3 Ro

b. Abnormal: $1.0D + 1.0L_h + 1.0L + 1.4P_a + \cancel{1.2}$ 1.0 T_a + 1.0 Ra

c. Extreme environmental: $1.0D + 1.0L_h + 1.0L + 1.0T_o + 1.0E_s$ + 1.0 Ro

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

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.

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

Pipe break reaction (Yr), jet impingement loads (Yj), missile impact loads (Ym), reactions of pipe, cable tray and duct (Ro), and pipe accident reactions (Ra) do not act on the PSW. So, these loads are not applied to the design of the PSW.

3.8A.1.4.3.2.2 Load Combinations Considered

The following loading combinations are critical for the analysis and design of the IRWST wall:

a. Normal: $1.4D + 1.4L_h + 1.7L$ + 1.7 Ro and ~~or~~ $1.1D + 1.1L_h + 1.3L + 1.2T_o$ + 1.3 Ro and
$1.4D + 1.4L_h + 1.7L + 1.4P_s + 1.2T_o$

b. Abnormal: $1.0D + 1.0L_h + 1.0L + 1.4P_s + 1.2T_a$ + 1.0 Ra

c. Extreme environmental: $1.0D + 1.0L_h + 1.0L + 1.0T_o + 1.0E_s$ + 1.0 Ro

d. Abnormal/extreme environmental: $1.0D + 1.0L_h + 1.0L + 1.0P_s + 1.0T_a$ + 1.0 Ra + 1.0 Yr + 1.0 Yj + 1.0 Ym $+ 1.0E_s$

P_s is the air-clearing load, which is the hydrodynamic load generated by the expulsion of air in POSRV discharge lines during the POSRV discharge following the water clearing phenomena in the sparger.

3.8A.1.4.3.2.3 Analysis Methods and Results

The IRWST FEM is part of the containment internal structure full model. See Subsection 3.8A.1.4.3.1.3. The governing load to the IRWST outer wall and upper slab is the sparger discharge load. Hydrodynamic loads occur at two sparger locations (north and west). Therefore, stresses on the portions of outer wall and upper slab are investigated and critical sections are selected where the largest stress takes place. The design forces and moments for IRWST critical sections are presented in Table 3.8A-19.

The typical rebar arrangements for the IRWST are presented in the Table 3.8A-23.

3.8A.1.4.3.2.4 Conclusion

The IRWST wall/slab concrete section strengths determined from the criteria in ACI 349 are sufficient to resist the design basis loads. It is feasible to design and construct the structural components considered. The assumptions envelop the given parameters so the design is adequate for any site-specific conditions within the parameters.

Pipe break reaction (Yr), jet impingement loads (Yj), missile impact loads (Ym), reactions of pipe, cable tray and duct (Ro), and pipe accident reactions (Ra) do not act on the IRWST. So, these loads are not applied to the design of the IRWST.

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3.8A.1.4.3.3 SSW

3.8A.1.4.3.3.1 Description

The SSW is a circular reinforced concrete structure that extends up to the main operating floor. The wall is anchored to the containment basemat. The wall is integrally connected to the refueling pool at the fuel transfer tube side (east) and at the regenerative heat exchanger room (west). At other points, the SSW is connected to the refueling pool through the SG and PZR enclosure walls and RCP lateral support members, which make the SSW and the internal structures almost symmetric around the east-west centerline of the containment.

In addition to enclosing the primary loop and the internal structures, the SSW provides lateral support for the SGs, RCPs, PZR, and the operating and intermediate floors inside the containment.

The major floor elevations are as follows:

a. Base floor: El. 100 ft 0 in

b. Intermediate floor: El. 114 ft 0 in, El. 136 ft 6 in

c. Operating floor: El.156 ft 0 in

The major design dimensions of the secondary shield wall are as follows:

a. Wall thickness: 1.22 m (4 ft)

b. Inside radius: 14.94 m (49 ft)

c. Height of wall: 17.07 m (56 ft)

3.8A.1.4.3.3.2 Load Combinations Considered

The following loading combinations are critical for the analysis and design of the SSW:

a. Normal: $1.4D + 1.4L_h + 1.7L$ + 1.7 Ro and $1.1D + 1.1L_h + 1.3L + 1.2T_o$ + 1.3 Ro

b. Abnormal: $1.0D + 1.0L_h + 1.0L + 1.4P_a + \cancel{1.2}\ 1.0T_a$ + 1.0 Ra

c. Extreme environmental: $1.0D + 1.0L_h + 1.0L + 1.0T_o$ + 1.0 Ro $+ 1.0E_s$

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

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3.8A.1.4.3.3.3 Analysis Methods and Results

The SSW FEM is a part of the containment internal structure full model. See Subsection 3.8A.1.4.3.1.3. The SSWs extend from El. 100 ft 0 in up to the operating floor at El. 156 ft 0 in. The SSW from El. 100 ft 0 in to El. 114 ft 0 in is selected as the critical section because this portion of the wall includes the junction between SSW and fill concrete.

The refueling pool walls extend from the bottom of the pool at El. 130 ft 0 in up to El. 156 ft 0 in. The north, south, and west walls between these elevations are selected as critical sections.

SG enclosure walls extend from El. 156 ft 0 in up to El. 191 ft 0 in, which is the top of wall. SG enclosure walls between these elevations are selected as critical sections.

PZR enclosure walls extend from El. 133 ft 4 in up to El. 200 ft 0 in, which is the top of wall. PZR enclosure walls from El. 156 ft 0 in up to 191 ft 0 in are selected as critical sections since these portions of the wall support the PZR laterally. The design forces and moments for SSW critical sections are presented in the Table 3.8A-20. Table 3.8A-25 presents the margins of safety of rebar stress in secondary shield wall. The margin of safety is the ratio of allowable stress and actual stress.

3.8A.1.4.3.3.4 Typical Rebar Arrangement

The typical rebar arrangements for the SSW are presented in the Table 3.8A-23.

3.8A.1.4.3.3.5 Conclusion

The SSW concrete section strengths determined from the criteria in ACI 349 are sufficient to resist the design basis loads. It is feasible to design and construct the structural

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Jet impingement loads (Yj), missile impact loads (Ym), reactions of pipe, cable tray and duct (Ro), and pipe accident reactions (Ra) are evaluated in local affected area. Thermal operating load (To), and accident temperature (Ta) do not affect the design of SSW since there is no temperature difference between the inside and outside of the SSW.