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.

<u>Response - (Rev. 2)</u>

a. There are some small horizontal surfaces in the reactor containment building other than slabs between the secondary shield wall and the containment shell. Those small horizontal surfaces (① to ⑥) are modeled in the reactor containment building structural analysis model. Figure 1 depicts the horizontal surfaces in the reactor containment building comparing to those in DCD Tier 2, Figure 1.2-2.

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Figure 1. Section View of RCB internal structure

Figure 2 shows a sketch of the concrete slab and steel beam between containment wall and SSW. The concrete slab is supported by the 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 the beam is welded on the beam seat. The restraint on the SSW side and containment side are discussed as follows:

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Figure 2. 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)).

The R_m for slabs/containment and slabs/SSW are 6.7% and 6.2%, respectively. Table 1 shows the natural frequency of concrete slab, internal structure, and RCB wall. The R_f for reactor containment and internal structure are shown in Table 2.

Table 1. Frequency of slabs

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In Table 2, the frequency ratios of slab/containment and slab/SSW satisfy the decoupling criteria. For the containment wall, 50% of slab mass was lumped to the containment wall to consider the slab. The slab does not induce additional moments to the containment wall.

Therefore, considering the behavior of connection between slab and containment wall, the decoupling method of slab for containment does not affect the integrity of containment wall.

Table 2. Check Result of Frequency Ratio

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As mentioned before, the slabs between the containment wall and SSW are not included in the overall FEM; separate local analyses were performed for the design of the slabs.

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. To incorporate the proper seismic load on each slab, the response spectrum analyses are performed using the FRS which envelope containment shell side and secondary shield wall side at each elevation. In addition, the seismic anchor movement is considered in the seismic design case for concrete slabs. Based on the enveloped results of FE analysis, the slab is designed for all member forces as recommended in ACI 349. The thickness of the slab is generally determined by the requirements of radiation shielding, missile protection, and structural integrity.

There are various analysis models for the local slabs depending on the elevation and thickness. Among them, the representative model which is a 3-ft thick operating floor slab at EL.156'-0" is as follows;

Local Slab Analysis

For design of concrete slabs, a refined mathematical model is built and analyzed for static and seismic loadings utilizing GTSTRUDL.

The structural analysis model for the slab at EL. 156'-0" consists of:

Concrete Slab : SBHQ6 (plate element)

Steel Beam : BW21x166

The supports at the secondary shield wall side are considered to be fixed - on the other hand, those at the containment wall side are considered as support for the vertical translation. Both sides of slab are developed as y-direction restraint joints since 3 ft slab and 2 ft SIT lateral support slab are located next to 3 ft slab at each side.

The concrete slabs and steel beams are linked by an offset of steel beams in the GT STRUDL program.

Model 1 - one edge fixed, the other edge hinge (Figure. 3)

3D FE model is developed by using GTSTRUDL version 31. The summary of geometries is as follows :

Number of Joints	: 689
Number of Members	: 154
Number of Plate elements	: 630

The complete analytical models are as shown in Figure 5 and the local axes of elements are presented in Figure 4.

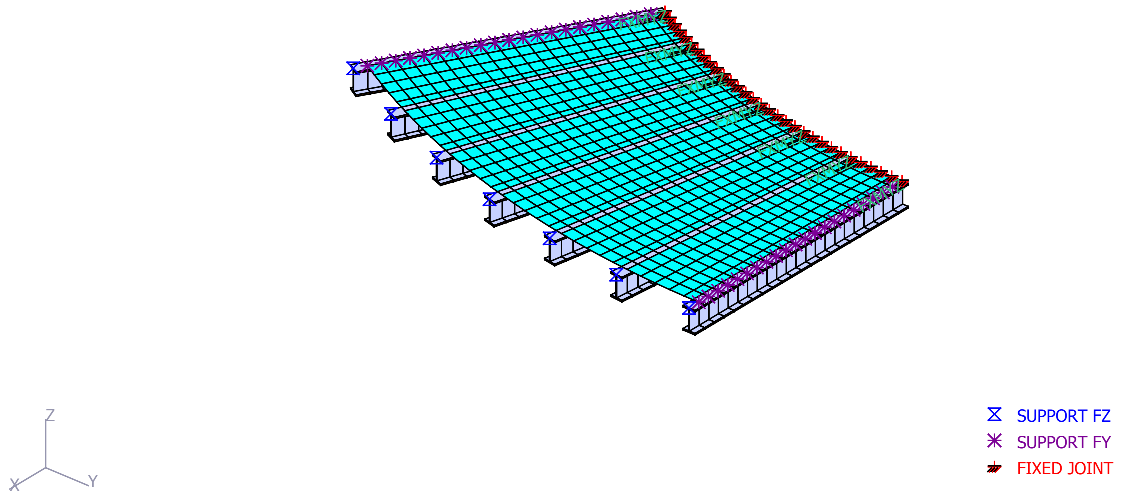

Figure 3. GTSTRUDL Analysis Model 1

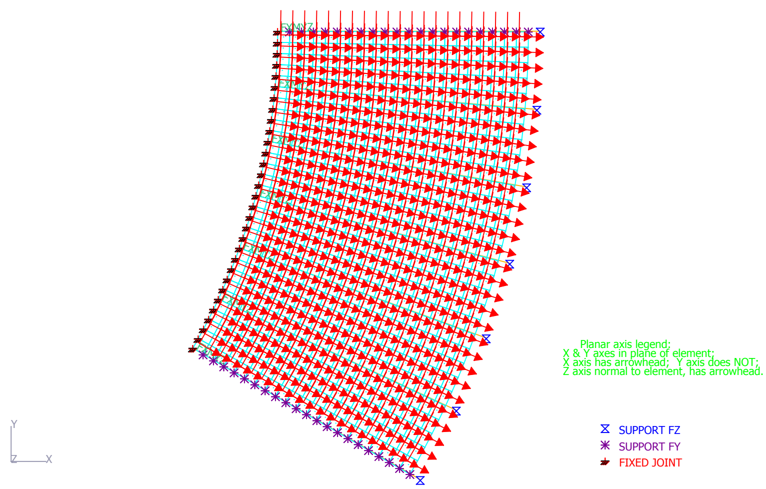

Figure 4. Local Axes of Elements

The slab deformations of the major mode for each direction are shown in Figure 5 through Figure 7.

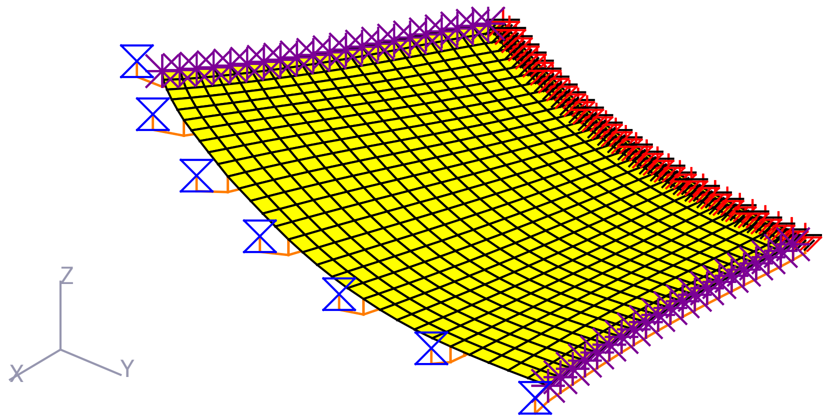

Figure 5. Major Mode Deformation for X(EW) direction (89.6 Hz)

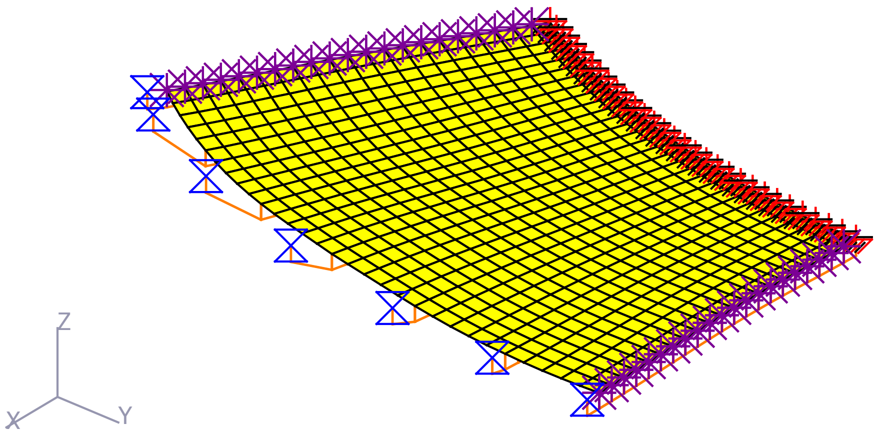

Figure 6. Major Mode Deformation for Y(NS) direction (134.8 Hz)

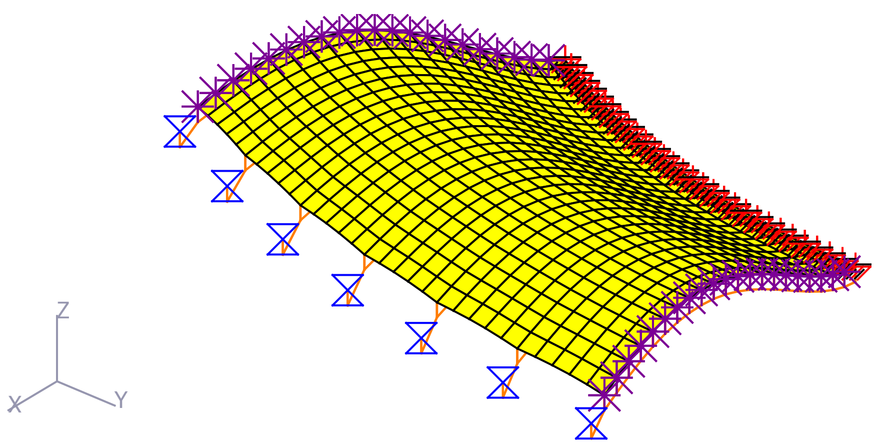

Figure 7. Major Mode Deformation for Z(Vertical) direction (40.1 Hz)

b. 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 SSW side connection at the secondary shield wall and a sliding connection at the containment wall. The beam seat supports vertical load at SSW side connection. The sliding connection at the containment wall is composed of a beam seat, lower key bumper 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 lower key bumper supports the vertical upward load. The friction forces are considered for design of the beam seat and beam and welding of the beam seat. The information for the coefficient of friction will be added into DCD section 3.8A.1.4.3.4.3 as indicated on the attached markup. 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".

Figure 8 shows how to calculate the gap. The gap between the end of the steel beam and the containment wall is sum of the displacements of containment wall, SSW, post-tensioning, the thermal expansion of max steel and the erection tolerance of steel. All values are positive regardless of direction. The beam length is considered the as-built condition of both containment and SSW.

The minimum gap =1) + 2) + 3) + 4) + 5)

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Figure 8. Concrete slab and steel beam between containment and SSW

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Figure 9. Displacement due to thermal expansion

Based on the results of 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.

The structural analysis of the CIS was re-performed to apply the reaction forces (Fx, Fy, Fz, Mx, My and Mz) obtained from separate local analysis of the three slabs, which were applied to the containment internal structure (CIS).

The comparison of maximum member forces used in the design was performed for all of the design sections. The ratios between original and new analysis for the design sections are shown in Table 3.

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Table 3. Comparison of Maximum Member Forces

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The load generated from friction at the beam seat is not considered since the load is negligibly small. To verify this approach, a combined model, which is composed of containment, CIS and slabs, was prepared and response spectrum analysis was performed. The EL. 156'-0" slab is connected as a fixed condition at the SSW side and containment side to represent completely monolithic behavior of the slabs between containment and CIS.

The analysis results were compared to the results of the current model applied to the design of the CIS as shown in Table 4. The comparison of maximum member forces was performed for all of the design sections.

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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. To show the shell element model of the SSW, part (b) of Figure 3.8A-24 is revised in DCD Rev.1.

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) are revised in DCD Rev.1. DCD Tier 2, Section 3.8.3.4.1, 3.8A.1.4.3.4.3, Table 3.8A-18, Table 3.8A-20 through Table 3.8A-22, Table 3.8A-24, Table 3.8A-25, Table 3.8A-43 and Table 3.8A-44 will be revised and Figure 3.8A-61 through Figure 66 will be added 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.

dead loads. In addition, potential loads during construction or operating periods are treated as live loads.

The vertical and lateral pressures of liquids inside containment are treated as dead loads. Structures supporting fluid loads during normal operation and accident conditions are designed for the hydrostatic as well as hydrodynamic loads.

The thermal stress analysis is carried out by inputting the normal operating thermal load into the corresponding FEM of internal structure. During the thermal analysis, the equivalent uniform temperature gradient is input directly in the ANSYS model at the appropriate nodes. In the containment internal structure, the equivalent linear temperature profile for normal operating conditions is more severe than those of the accident conditions since the temperature difference between the inside and the outside surface of the containment internal structure during accident conditions is negligibly small. Therefore, the normal operating thermal load is conservatively applied for design of internal structures in case of normal operating and accident conditions.

The compartment pressures on internal structures are the result of a pipe break inside containment. In addition, branch line pipe break (BLPB) loads are dynamic reactions caused by the combined effects of branch line nozzle reactions or thrust due to pipe break, jet impingement on RCS equipment, or subcompartment pressure effects on RCS equipment. These loads are applied to the ANSYS model with pressure and concentrated loads.

Response spectrum analysis is performed for the two horizontal and one vertical seismic load directions using the methodology described in Subsection 3.7.2.

← Insert the paragraph in the next page

3.8.3.4.2 Structural Design

The forces and moments resulting from the applied static and dynamic loads are used to design the walls, slabs, beams, and columns that make up the internal structure. The design and reinforcement are performed using ACI 349 or AISC N690 described in Subsection 3.8.4.4.

The walls and floors of internal structure are provided with anchor bolts for the mounting or attachment of RCS equipment. The jurisdictional boundary between supports and the building structure is defined by ASME Section III, Division 1, Subsection NF. According to the jurisdictional boundary of ASME Code, the component support and building

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Regarding the analysis of subelements, the concrete slabs at elevations 114'-0", 136'-6", and 156'-0" between secondary shield wall and containment wall are 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. To incorporate the proper seismic load on each slab, the response spectrum analyses are performed using the FRS which envelope containment shell side and secondary shield wall side at each elevation. In addition, the seismic anchor movement is considered in the seismic design case for concrete slabs.

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: $1.4D + 1.4L_h + 1.7L + 1.7R_o$ and $1.1D + 1.1L_h + 1.3L + 1.2T_o + 1.3R_o$

b. Abnormal: $1.0D + 1.0L_h + 1.0L + 1.4P_a + 1.0T_a + 1.0R_a$

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

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

Pipe break reaction (Y_r), jet impingement loads (Y_j), missile impact loads (Y_m), reactions of pipe, cable tray and duct (R_o), and pipe accident reactions (R_a) do not act on the PSW. So, these loads are not applied to the design of the PSW.

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 between the SSWs and containment shell are included as ~~masses~~ reaction forces obtained from local analyses to represent dynamic amplification in the finite element model (FEM).

 RAI 248-8295 - Question 03.08.05-1_Rev.2

The concrete slab and steel beams are analyzed separately. The loads on the slab and slab weight are applied on the steel beam by line load.

containment wall and secondary shield wall at El. 114 ft 0 in, El. 136 ft 6 in, and El. 156 ft 0 in supporting the concrete slabs and grating area. Typical steel beam, beam connection, and beam seat on each level are designed for highest load case.

3.8A.1.4.3.4.2 Load Combinations Considered

Replaced with Part A in the next page

In sixteen load combinations given in Table 3.8-7B, only the governing load cases are considered as defined herein. ~~Load combination No. 5 is used for design of normal condition. Load combination No. 13 of extreme environmental load condition governs over combinations No. 14 and 15. This load combination referred to as "SSE" is used as input for the analysis by computer program and it is investigated for all structural members.~~

3.8A.1.4.3.4.3 Analysis and Design Methods

The computer program GTSTRUDL, which is used for structural analysis, is a software for creation of model, modification of the model, execution of analysis, check of the analysis, and optimization of design. The steel beam structures for design load cases are analyzed using 3-dimensional frame elements. The GTSTRUDL prints the detailed output of results including the stress. After the analysis, the stresses of steel structure are checked according to the allowable values in AISC N690. The allowable stresses in AISC N690 are used for stress acceptance criteria.

Insert Part B in the next page

Replaced with Part C in the next page

Connections are designed based on the reactions from the GTSTRUDL analysis. The capacities of the various connection components are computed. ~~Each end of the steel beams has 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 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 and horizontal displacements due to seismic and thermal loads.~~

3.8A.1.4.3.4.4 Conclusion

The design of steel beam and connections is performed to maintain adequate design margins. The summary of design results is shown in Table 3.8A-47.

The details of the steel beam, concrete slab, and connection are shown in Figure 3.8A-60.

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Part A

The load case 5 (LC5) governs over the construction conditions (LC1, LC2, LC3), the test condition (LC4), and the normal condition (LC6), and the severe environmental conditions (LC7, LC8, LC9). The load case 13 (LC13) governs over the abnormal conditions (LC10, LC11, LC12), extreme environmental conditions (LC14, LC15) and abnormal/extreme environmental conditions (LC16). The load of To, Ta are not considered since the sliding connections are provided in the steel design to relieve the thermal stresses. The loads of W, H are not considered since the loads do not exist inside of the containment. The loads of Pa, Ra, Yr, Yj, Ym, Yf, Ma, Wt, Hs are not considered since the loads do not affect the steel structures. The load combinations considered are used as input for the analysis by computer program, and they are investigated for all structural members.

Part B

For design of steel beam, uniform floor loads are distributed to all beams based on tributary areas. The span direction for concrete slabs on metal deck is considered in determining the tributary areas. Response spectrum analysis is used to design steel member with the FRS that envelop the containment side and SSW side at each level. The steel beam model is built and analyzed for static and seismic loads utilizing GTSTRUDL.

Part C

For design, the SSW side connection is composed of a beam seat and welding between the beam and beam seat. The beam seat and stiffener support downward vertical load and the welding between the beam and beam seat support upward vertical load. The axial and horizontal load and torsional moment are supported by concrete slab.

The sliding connection at the containment wall is composed of a beam seat, lower key bumper and gaps (between the end of the steel beam and the containment wall, between the lower key bumper and beam seat). The gap between the end of the steel beam and the containment wall is to allow radial movement. The other gap between the lower key bumper and beam seat is to allow horizontal movement due to seismic and thermal loads. The beam seat support downward vertical load and the lower key bumper support upward vertical load.

Friction force are considered for steel connection design. The friction coefficient of 0.35 is used as recommended in Commentary on the AISC 360-05 chapter J and the type of steel surface is class A.

Table 3.8A-18

Design Forces and Moments for PSW

Unit: kips/ft, kips-ft/ft

Location	M_φ	M_θ	N_φ	N_θ	Q_φ	Q_θ	Q_T	$M_{\varphi\theta}$
North Wall	157.9 (-195.9)	111.3 (-77.9)	26.5	60.0	-74.8	-89.2	127.4	-117.6
South Wall	680.7 (-616.1)	352.1 (-351.4)	108.8	184.5	-139.7	-135.2	99.6	-213.9
East Wall	162.4 (-144.2)	46.6 (-64.0)	33.0	50.6	-76.3	-74.5	108.5	-106.3

Where,

M_φ: Meridional Moment around Horizontal Axis
M_θ: Hoop Moment around Vertical Axis
N_φ: Meridional Axial Force (+: Tension, -: Compression)
N_θ: Hoop Axial Force (+: Tension, -: Compression)
Q_φ: Meridional Transverse Shear Force
Q_θ: Hoop Transverse Shear Force
Q_T: Tangential Shear Force (In-plane Shear Force)
$M_{\varphi\theta}$: Torsion Moment

Replace this table with Table 3.8A-18 in the next page

Table 3.8A-18

Design Forces and Moments for PSW

Unit: kips/ft, kips-ft/ft

Location	M_φ	M_θ	N_φ	N_θ	Q_φ	Q_θ	Q_T	$M_{\varphi\theta}$
North Wall	188.9 (-202.4)	92.1 (-100.3)	110.6	78.3	250.9	-152.2	282.7	-319.2
South Wall	698.2 (-619.9)	456.5 (-466.2)	177.3	212.8	-268.7	-187.8	173.0	-359.4
East Wall	211.5 (-192.9)	104.1 (-112.3)	76.5	92.2	-202.9	-102.0	209.5	-190.9

Where,

M_φ: Meridional Moment around Horizontal Axis
M_θ: Hoop Moment around Vertical Axis
N_φ: Meridional Axial Force (+: Tension, -: Compression)
N_θ: Hoop Axial Force (+: Tension, -: Compression)
Q_φ: Meridional Transverse Shear Force
Q_θ: Hoop Transverse Shear Force
Q_T: Tangential Shear Force (In-plane Shear Force)
$M_{\varphi\theta}$: Torsion Moment

Table 3.8A-20

<u>Design Forces and Moments for SSW</u>

Unit: kips/ft, kips-ft/ft

Type	M_φ	M_θ	N_φ	N_θ	Q_φ	Q_θ	Q_T	$M_{\varphi\theta}$
SSW (1)	130.9 (-119.8)	240.3 (-130.3)	88.4	154.4	-35.3	54.0	-128.2	-71.2
RFP (2)	1521.6 (-1304.2)	949.7 (-1038.2)	215.6	344.1	232.5	415.5	-158.8	673.6
RFP (3)	89.1 (-74.3)	306.8 (-255.6)	40.4	365.6	32.7	-72.3	-108.9	53.5
SG (4)	430.3 (-335.7)	492.3 (-407.3)	399.2	199.4	114.1	92.2	61.7(7) -111.4(8)	-220.2(7) 280.3(8)
SG (5)	743.5 (-685.3)	703.4 (-603.5)	85.1	211.5	-171.4	-149.5	57.2(7) 116.5(8)	-446.0(7) -324.0(8)
PZR (6)	21.2 (-15.7)	178.8 (-244.7)	173.7	89.6	-1.2	-92.3	135.7(7) 95.2(8)	16.3(7) -69.7(8)

(1) Secondary Shield Wall (Thickness 4 ft)
(2) South/North Wall of Refueling pool (thickness 6 ft 2 in)
(3) West Wall of Refueling pool (Thickness 5 ft)
(4) Circular Wall of Steam Generator (SG) Enclosure (Thickness 4 ft)
(5) Straight Wall of Steam Generator (SG) Enclosure (Thickness 5 ft)
(6) Pressurizer (PZR) Enclosure Wall (Thickness 2 ft 9 in)
(7) These forces are considered with Nφ and Mφ when designing vertical re-bar.
(8) These forces are considered with Nθ and Mθ when designing horizontal re-bar.

Where:

M_φ: Vertical Moment around Horizontal Axis
M_θ: Horizontal Moment around Vertical Axis
N_φ: Vertical Axial Force (+: Tension, -: Compression)
N_θ: Horizontal Axial Force (+: Tension, -: Compression)
Q_φ: Vertical Transverse Shear Force
Q_θ: Horizontal Transverse Shear Force
Q_T: In-plane Shear Force
$M_{\varphi\theta}$: Torsion Moment

Replace this table with Table 3.8A-20 in the next page

Table 3.8A-20

Design Forces and Moments for SSW

Unit: kips/ft, kips-ft/ft

Type	M_φ	M_θ	N_φ	N_θ	Q_φ	Q_θ	Q_T	$M_{\varphi\theta}$
SSW (1)	299.6 (-227.8)	283.6 (-176.4)	159.5	235.1	-64.5	-65.2	-227.9	115.1
RFP (2)	1,479.3 (-1,242.2)	1,009.0 (-1,026.6)	256.9	382.9	-440.3	412.1	-341.9	662.1
RFP (3)	138.7 (-131.2)	330.6 (-325.9)	48.1	505.8	-50.5	103.6	155.9	78.2
SG (4)	473.8 (-337.7)	490.9 (-428.5)	353.1	249.0	129.6	-98.1	-184.2	276.1
SG (5)	1,026.8 (-880.7)	758.7 (-708.3)	198.3	250.4	181.2	-147.1	238.3	-425.6
PZR (6)	79.3 (-75.9)	318.7 (-308.8)	216.3	230.9	-59.0	-109.1	165.4	78.8

(1) Secondary Shield Wall (Thickness 4 ft)

(2) South/North Wall of Refueling pool (thickness 6 ft 2 in)

(3) West Wall of Refueling pool (Thickness 5 ft)

(4) Circular Wall of Steam Generator (SG) Enclosure (Thickness 4 ft)

(5) Straight Wall of Steam Generator (SG) Enclosure (Thickness 5 ft)

(6) Pressurizer (PZR) Enclosure Wall (Thickness 2 ft 9 in)

Where:

M_φ: Vertical Moment around Horizontal Axis
M_θ: Horizontal Moment around Vertical Axis
N_φ: Vertical Axial Force (+: Tension, -: Compression) N_θ:
Horizontal Axial Force (+: Tension, -: Compression) Q_φ:
Vertical Transverse Shear Force
Q_θ: Horizontal Transverse Shear Force
Q_T: In-plane Shear Force
$M_{\varphi\theta}$: Torsion Moment

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Table 3.8A-21

Typical Rebar Arrangement for PSW

Location	Meridional Direction	Hoop Direction	Shear Reinforcement
North Wall	Inside : #18 & #14 @ 4.5° Outside : #18 & #14 @ 12″	Inside : #14 & #14 @ 12″ Outside : #14 & #14 @ 12″	#8 @ 24" Vert. @ 4.5° Horiz.
East Wall	Inside : 2-#18(Bundled) & #14 @ 4.5° Outside : #18 & #18 & #14 @ 12″	Inside : #18 & #14 @ 12″ Outside : #18 & #14 @ 12″	#8 @ 24" Vert. @ 4.5° Horiz.
South Wall	Inside : #18 & #14 @ 4.5° Outside : #18 & #14 @ 12″	Inside : #14 & #14 @ 12″ Outside : #14 & #14 @ 12″	#8 @ 24" Vert. @ 4.5° Horiz.

Replace this table with Table 3.8A-21 in the next page

Table 3.8A-21

Typical Rebar Arrangement for PSW

Location	Meridional Direction	Hoop Direction	Shear Reinforcement
North Wall	Inside : #18 & #18 @ 4.5° Outside : #18 & #18 @ 12″	Inside : #18 & #18 @ 12″ Outside : #18 & #18 @ 12″	#8 @ 12" Vert. @ 4.5° Horiz.
East Wall	Inside : 2-#18(Bundled) & #14 @ 4.5° Outside : #18 & #18 & #14 @ 12″	Inside : #18 & #18 @ 12″ Outside : #18 & #18 @ 12″	#8 @ 12" Vert. @ 4.5° Horiz.
South Wall	Inside : #18 & #14 @ 4.5° Outside : #18 & #14 @ 12″	Inside : #18 & #14 @ 12″ Outside : #18 & #14 @ 12″	#8 @ 12" Vert. @ 4.5° Horiz.

Table 3.8A-22

Margins of Safety for Primary Shield Wall

Rebar

Section	Meridional/Vertical Direction			Hoop/Horizontal Direction		
	Stress (ksi)		Ratio (1)	Stress (ksi)		Ratio (1)
	Allowable	Rebar		Allowable	Rebar	
North Wall	54	32.3	1.67	54	41.9	1.29
East Wall	54	32.7	1.65	54	43.2	1.25
South Wall	54	32.0	1.69	54	34.1	1.58

Concrete

Location	Meridional/Vertical Direction			Hoop/Horizontal Direction		
	Stress (ksi)		Ratio (1)	Stress (ksi)		Ratio (1)
	Allowable	Concrete		Allowable	Concrete	
North Wall	3.57	1.11	3.20	3.57	1.00	3.56
East Wall	3.57	1.23	2.90	3.57	0.97	3.68
South Wall	3.57	1.10	3.24	3.57	0.89	4.02

(1) Ratio = Allowable Stress / Maximum Stress

Replace this table with Table 3.8A-22 in the next page

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Table 3.8A-22

Margins of Safety for Primary Shield Wall

Location	Meridional/Vertical Direction			Hoop/Horizontal Direction		
	Reinforcement		Ratio (1)	Reinforcement		Ratio (1)
	Required (in^2)	Provided		Required (in^2)	Provided	
North Wall	6.96	#18 & #18@4.5° ($8.00in^2$)	1.15	6.36	#18 & #18@12" ($8.00in^2$)	1.26
East Wall	7.75	2-#18 & #14@4.5° ($10.38in^2$)	1.34	7.07	#18 & #18@12" ($8.00in^2$)	1.13
South Wall	5.18	#18 & #14@4.5° ($6.28in^2$)	1.21	4.89	#18 & #14@12" ($6.25in^2$)	1.28

(1) Ratio = Provided Rebar / Required Rebar

Table 3.8A-24

Typical Rebar Arrangement for SSW

Location		Meridional/Vertical Direction	Hoop/Horizontal Direction	Shear Reinforcement
Secondary Shield Wall		#14 & #11 @ 0.9° Each Face	#18 & #14 @ 12″ Each Face	#8 @ 12″ Vert. @ 1°48′ Horiz.
Refueling Pool Wall	South/ North	2-#18(Bundled) & #14 @ 12″ Each Face	2-#18(Bundled) & #18 @ 12″ Each Face	2-#8 @ 12″ Vert. @ 9″ Horiz.
	West	#11 & #11 @ 12″ Each Face	#18 & #18 @ 12″ Each Face	#6 @ 12″ Vert. @ 12″ Horiz.
SG Enclosure Wall	Circular	#18 & #18 @ 0.9° Each Face	2-#14 & #18 @ 12″ Each Face	2-#7 @ 12″ Vert. @ 1° Horiz.
	Straight	#18 & #18 @ 12″ Each Face	2-#14 #18 @ 12″ Each Face	2-#7 @ 12″ Vert. @ 12″ Hor.
PZR Enclosure Wall		2-#11(Bundled) & #11 @ 12″ Each Face	#18 & #14 @ 12″ Each Face	#8 @ 12″ Vert. @ 12″ Hor.

Replace this table with Table 3.8A-24 in the next page

Table 3.8A-24

Typical Rebar Arrangement for SSW

Location		Meridional/Vertical Direction	Hoop/Horizontal Direction	Shear Reinforcement
Secondary Shield Wall		#18 & #14 @ 0.9° Each Face	#18 & #18 @ 12″ Each Face	#7 @ 12″ Vert. @ 0.9° Horiz.
Refueling Pool Wall	South/ North	2-#18(Bundled) & 2-#18(Bundled) @ 12″ Each Face	2-#18(Bundled) & 2-#18(Bundled) @ 12″ Each Face	2-#8 @ 12″ Vert. @ 6″ Horiz.
	West	#14 & #11 @ 12″ Each Face	#18 #14 & #18 @ 12″ Each Face	#8 @ 12″ Vert. @ 12″ Horiz.
SG Enclosure Wall	Circular	#18 #14 & #18 @ 0.9° Each Face	#18 #14 & #18 @ 12″ Each Face	2-#7 @ 12″ Vert. @ 0.9° Horiz.
	Straight	2-#18(Bundled) & 2-#18(Bundled) @ 12″ Each Face	2-#18 & #18 @ 12″ Each Face	2-#8 @ 12″ Vert. @ 12″ Hor.
PZR Enclosure Wall		2-#14(Bundled) & #14 @ 12″ Each Face	#18 #14 & #18 @ 12″ Each Face	2-#8 @ 12″ Vert. @ 12″ Hor.

Table 3.8A-25

Margins of Safety for Secondary Shield Wall

Rebar

Structure	Meridional/Vertical Direction			Hoop/Horizontal Direction		
	Stress (ksi)		Ratio (1)	Stress (ksi)		Ratio (1)
	Allowable	Rebar		Allowable	Rebar	
SSW	54	38.6	1.39	54	40.3	1.34
Refueling Pool North/South	54	52.1	1.04	54	51.3	1.05
Refueling West	54	36.8	1.47	54	43.6	1.24
SG Circular	54	46.5	1.16	54	47.1	1.15
SG Straight	54	51.7	1.04	54	49.1	1.10
PZR	54	37.7	1.43	54	42.3	1.28

Concrete

Location	Meridional/Vertical Direction			Hoop/Horizontal Direction		
	Stress (ksi)		Ratio (1)	Stress (ksi)		Ratio (1)
	Allowable	Concrete		Allowable	Concrete	
SSW	3.57	0.82	4.34	3.57	1.07	3.35
Refueling Pool North/South	3.57	2.52	1.42	3.57	1.98	1.81
Refueling West	3.57	0.41	8.71	3.57	0.24	14.63
SG Circular	3.57	2.12	1.68	3.57	2.09	1.71
SG Straight	3.57	3.28	1.09	3.57	1.97	1.81
PZR	3.57	1.12	3.19	3.57	2.13	1.68

(1) Ratio = Allowable Stress / Maximum Stress

Replace this table with Table 3.8A-25 in the next page

Table 3.8A-25

Margins of Safety for Secondary Shield Wall

Location	Meridional/Vertical Direction			Hoop/Horizontal Direction		
	Reinforcement		Ratio (1)	Reinforcement		Ratio (1)
	Required (in^2)	Provided		Required (in^2)	Provided	
SSW	6.68	#18 & #14@0.9° ($7.81in^2$)	1.17	7.29	#18 & #18@12" ($8.00in^2$)	1.10
RPW North/South	14.06	2-#18 & 2-#18@12" ($16.00in^2$)	1.14	14.09	2-#18 & 2-#18@12" ($16.00in^2$)	1.14
RPW West	3.00	#14 & #11@12" ($3.81in^2$)	1.27	8.39	#18#14 & #18@12" ($10.25in^2$)	1.22
SG Circular	9.99	#18#14 & #18@0.9° ($12.81in^2$)	1.28	9.14	#18#14 & #18@12" ($10.25in^2$)	1.12
SG Straight	12.41	2-#18 & 2-#18@12" ($16.00in^2$)	1.29	10.40	2-#18 & #18@12" ($12.00in^2$)	1.15
PZR	5.50	2-#14 & #14@12" ($6.75in^2$)	1.23	7.76	#18#14 & #18@12" ($10.25in^2$)	1.32

(1) Ratio = Provided Rebar / Required Rebar

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Table 3.8A-43

Design Forces and Moments for Slab in RCB

Location	Thick-ness	Direction	Design Force and Moments	N_{xx} (kip/ft)	N_{yy} (kip/ft)	N_{xy} (kip/ft)	M_{xx} (kip-ft/ft)	M_{yy} (kip-ft/ft)	M_{xy} (kip-ft/ft)	V_{out} (kip/ft)
Operating Floor slab at El. 156'-0"	2ft	Radial	Top(1)	11.29	-	-1.27	152.50	-	2.11	11.30
			Top(2)	40.66	-	-25.31	46.03	-	-21.79	
			Bottom (1)	58.22	-	14.48	-189.57	-	-1.57	
			Bottom (2)	-56.35	-	22.38	-90.59	-	-2.38	
		Tangential	Top	-	-11.70	-25.31	-	43.00	-21.79	
			Bottom	-	-1.50	-31.34	-	-41.65	-43.24	
	3ft	Radial	Top(1)	222.04	-	45.29	56.33	-	-19.25	23.52
			Top(2)	98.57	-	-4.34	36.64	-	5.59	
			Bottom (1)	154.21	-	26.76	-144.74	-	-29.18	
			Bottom (2)	-13.04	-	-23.45	-148.01	-	-11.93	
		Tangential	Top	-	-15.37	-18.00	-	50.05	-34.49	
			Bottom	-	62.72	-25.66	-	-0.88	-29.18	

(1) These forces are considered when designing the rebar for the connection area between slab and SSW.

(2) These forces are considered when designing the rebar for the central area of slab.

Replace this table with Table 3.8A-43 in the next page

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Table 3.8A-43

Design Forces and Moments for Slab in RCB

Location	Thick -ness	Direction	Design Force and Moments	N_{xx} (kip/ft)	N_{yy} (kip/ft)	N_{xy} (kip/ft)	M_{xx} (kip-ft/ft)	M_{yy} (kip-ft/ft)	M_{xy} (kip-ft/ft)	V_{out} (kip/ft)
Operating Floor Slab at El. 156'-0"	2ft	Radial	at SSW Area (1)	165.56	-	8.24	145.31	-	-1.55	34.31
			at Central Area (2)	35.75	-	7.58	88.44	-	-3.71	
		Tangential	All Areas	-	3.67	-65.54	-	9.58	-49.27	
	3ft	Radial	at SSW Area (1)	53.93	-	3.60	287.49	-	-14.96	28.43
			at Central Area (2)	38.72	-	2.92	192.15	-	-19.05	
		Tangential	All Areas	-	-64.97	10.34	-	-65.69	30.36	

(1) These forces are considered when designing the rebar for the connection area between slab and SSW.

(2) These forces are considered when designing the rebar for the central area of slab.

Table 3.8A-44

Slab Reinforcement and Margins of Safety at Each Critical Section in RCB

Location	Thick-ness	Direction	Top Rebar Arrangement			Bottom Rebar Arrangement		
			Required Rebar (in^2)	Provided Rebar	Ratio[(1)]	Required Rebar (in^2)	Provided Rebar	Ratio[(1)]
Operating Floor slab at El. 156'-0"	2 ft	Radial (at SSW Area)	2.45	2-#11@0˚45′ (4.50 in^2)	1.84	3.61	2-#11@0˚45′ (4.50 in^2)	1.25
		Radial (at Central Area)	1.59	#11@0˚45′ (2.17 in^2)	1.36	2.09	#11@0˚45′ (2.17 in^2)	1.04
		Tangential	1.20	#11@12" (1.56 in^2)	1.30	1.45	#11@12" (1.56 in^2)	1.08
	3 ft	Radial (at SSW Area)	3.08	2-#11@0˚45′ (4.50 in^2)	1.46	3.10	2-#11@0˚45′ (4.50 in^2)	1.45
		Radial (at Central Area)	1.29	#11@0˚45′ (2.17 in^2)	1.68	1.64	#11@0˚45′ (2.17 in^2)	1.32
		Tangential	0.96	#11 @12" (1.56 in^2)	1.63	1.05	#11@12" (1.56 in^2)	1.49

(1) Ratio = Provided Rebar / Required Rebar

Replace this table with Table 3.8A-44 in the next page

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Table 3.8A-44

Slab Reinforcement and Margins of Safety at Each Critical Section in RCB

Location	Thick-ness	Radial Direction				Tangential Direction		
		Area	Required Rebar (in^2)	Provided Rebar	Ratio(1)	Required Rebar (in^2)	Provided Rebar	Ratio(1)
Operating Floor slab at El. 156'-0"	2ft	at SSW Area	3.81	2-#11@0°45′ (4.50in^2)	1.18	1.41	#11@12" (1.56in^2)	1.11
		at Central Area	1.75	#11@0°45′ (2.17in^2)	1.24			
	3ft	at SSW Area	3.05	2-#11@0°45′ (4.50in^2)	1.48	1.44	#11@12" (1.56in^2)	1.08
		at Central Area	2.12	#11@0°45′ (2.17in^2)	1.02			

(1) Ratio = Provided Rebar / Required Rebar

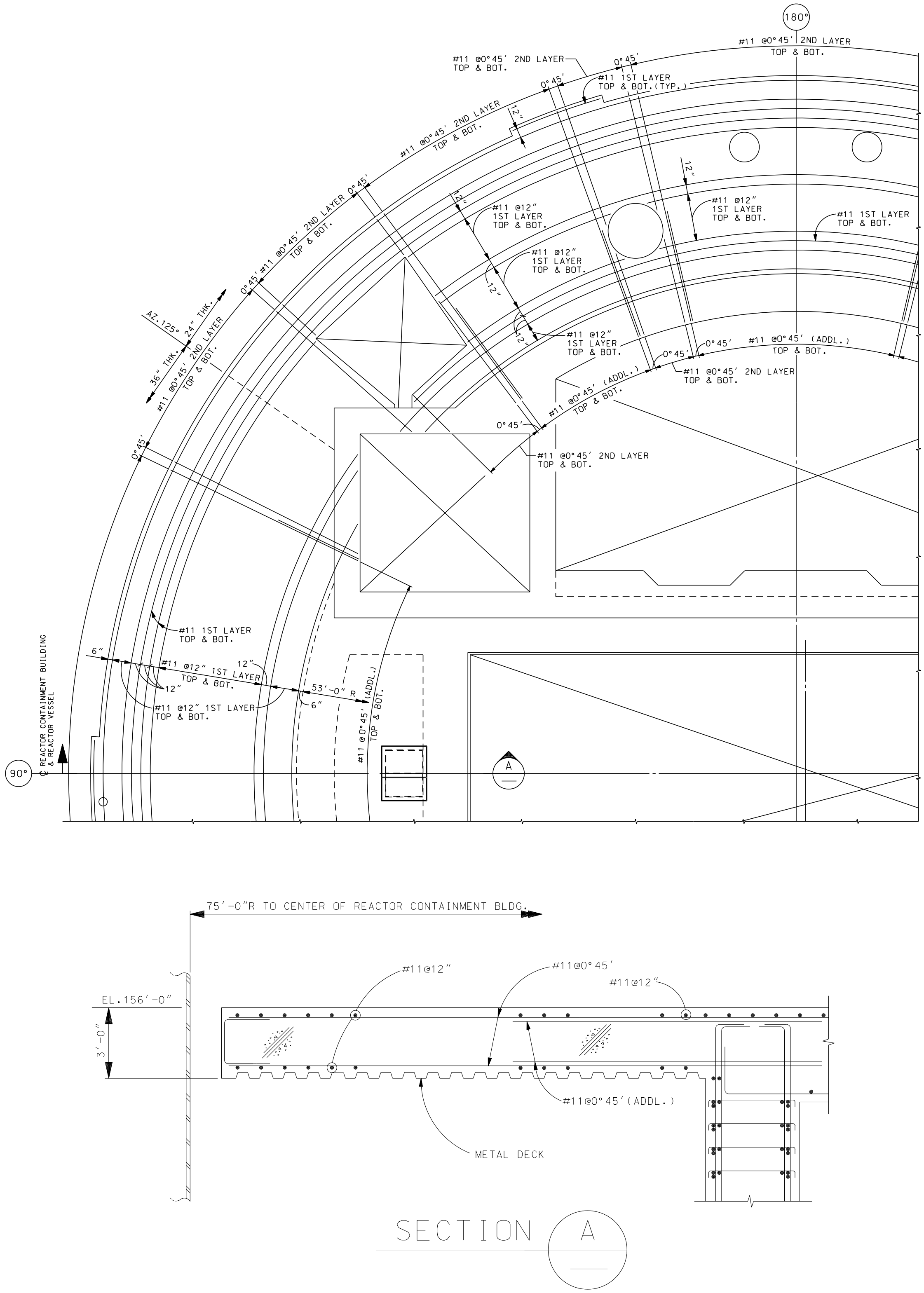

Figure 3.8A-61 Slab Reinforcements for Operating Floor in RCB

Figure added

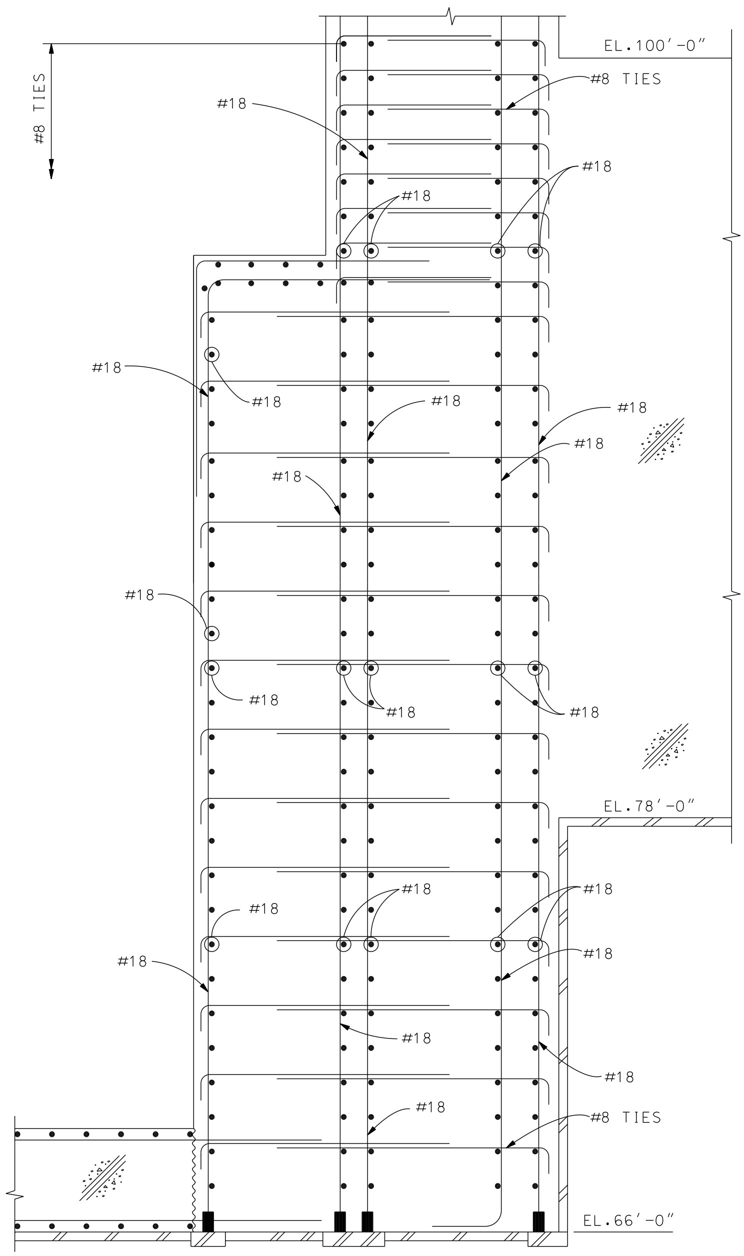

Figure 3.8A-62 Reinforcement Arrangement for Primary Shield Wall

Figure added

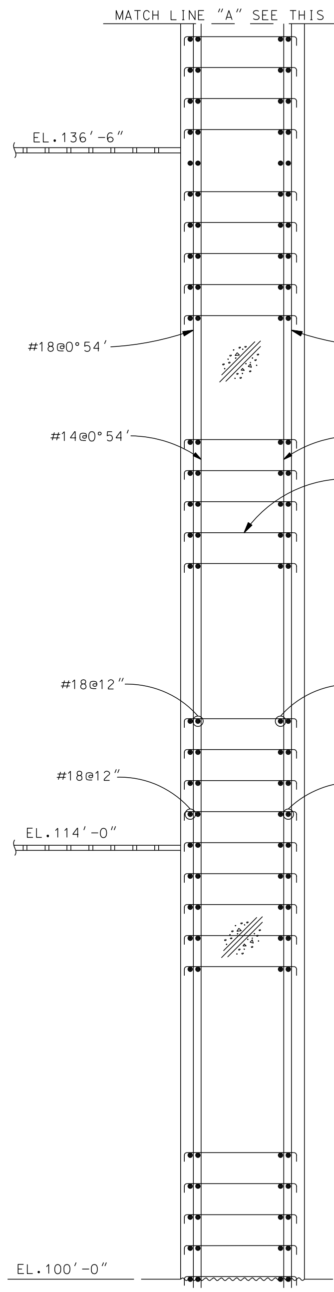

Figure 3.8A-63 Reinforcement Arrangement for Secondary Shield Wall

Figure added

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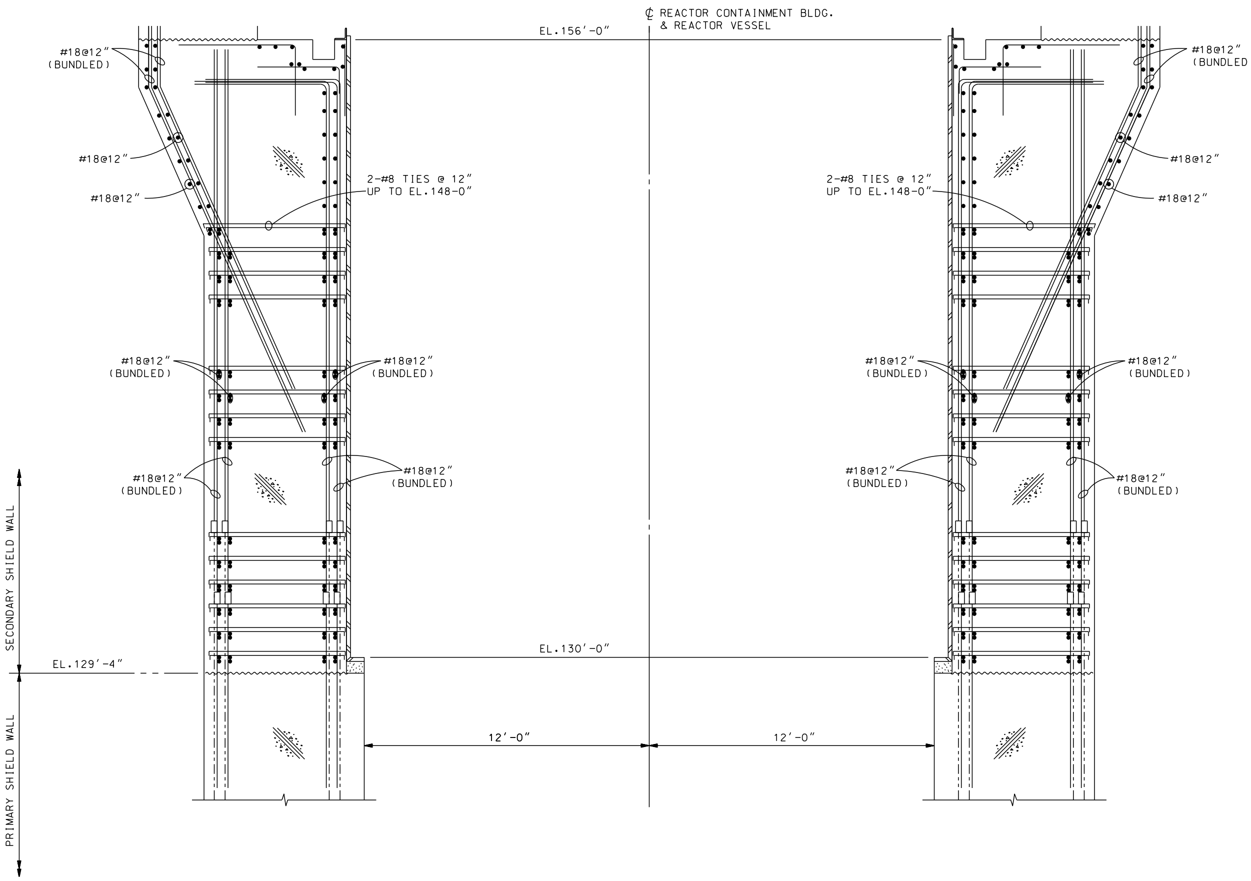

Figure 3.8A-64 Reinforcement Arrangement for Refueling Pool Wall

Figure added

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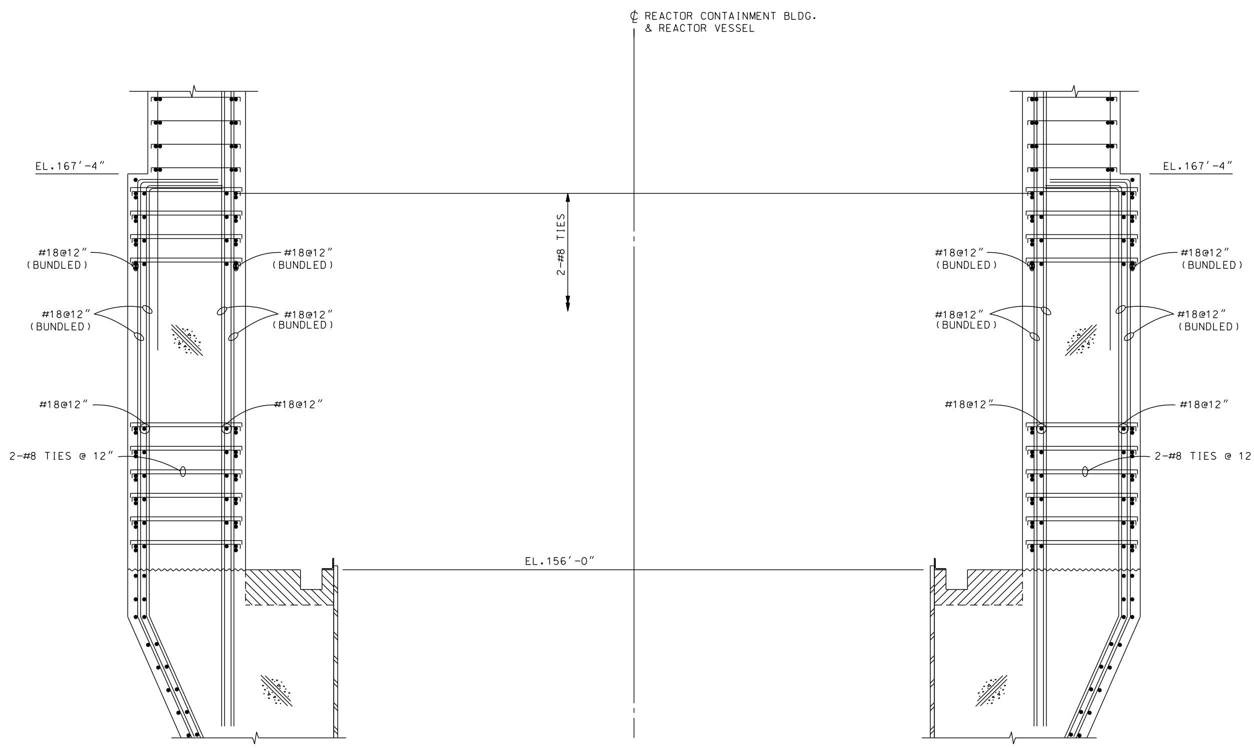

Figure 3.8A-65 Reinforcement Arrangement for SG Enclosure Wall

Figure added

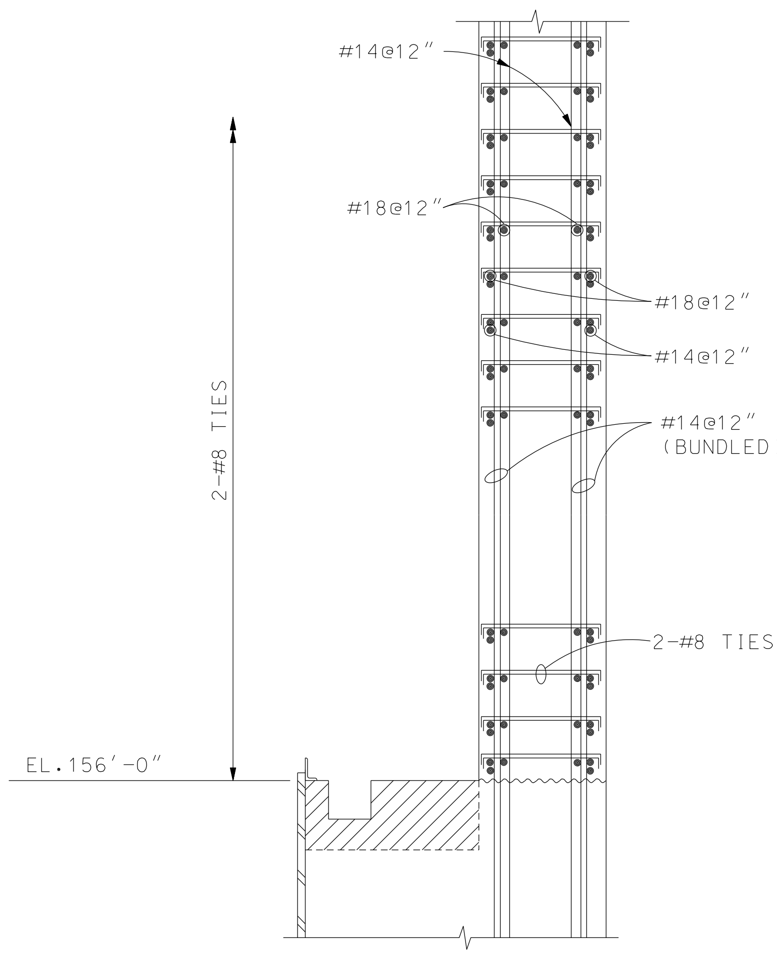

Figure 3.8A-66 Reinforcement Arrangement for PZR Enclosure Wall

Figure added