3G.3 *FUEL BUILDING*

3G.3.1 Objective and Scope

The objective of this subsection is to document the structural design details, inputs and analytical results from the analysis of the FB of the standard ESBWR plant. The scope includes the design and analysis of the structure for normal, severe environmental, extreme environmental, and construction loads.

3G.3.2 Conclusions

The following are the major summary conclusions on the design and analysis of the FB.

- *Based on the results of finite element analyses performed in accordance with the design conditions identified in Subsection 3G.3.5, stresses in concrete and reinforcement are less than the allowable stresses per the applicable regulations, codes or standards listed in Section 3.8.4.*
- *The factors of safety against floatation, sliding, and overturning of the structure under various loading combinations are higher than the required minimum.*
- *The thickness of the roof slabs and exterior walls are more than the minimum required to preclude penetration, perforation or spalling resulting from impact of design basis tornado missiles.*

3G.3.3 Structural Description

The FB is integrated with the RB, sharing a common wall between the RB and the FB and a large common foundation mat (see Subsection 3.8.4.1.3). The FB houses the spent fuel pool facilities and their supporting system, and HVAC equipment. The FB is a Seismic Category I structure except for the penthouse that covers HVAC equipment. The penthouse is a Seismic Category II structure.

The FB is a reinforced concrete box type shear wall structure consisting of walls and slabs and is supported by a foundation mat. Concrete framing (steel beams can be used partially) is composite with concrete slab and used to support the slabs for vertical loads. The FB is a shear wall structure designed to accommodate all seismic loads with its walls and the connected floors. Therefore, frame members such as beams or columns are designed to accommodate deformations of the walls in case of earthquake conditions.

The key dimensions of the FB are summarized in Table 3.8-8. Figures 3G.1-1 through 3G.1-4 and Figure 3G.1-6. show the outline plans of the FB.

3G.3.4 Analytical Models

Because the FB is integrated with the RB, the finite element model which integrates the RB and FB is used for the stress analysis of the FB. The analysis model is described in Subsection 3G.1.4.1.

3G.3.5 Structural Analysis and Design

3G.3.5.1 Site Design Parameters

The key site design parameters are referenced in Subsection 3G.1.5.1.

3G.3.5.2 Design Loads, Load Combinations, and Material Properties

3G.3.5.2.1 Design Loads

This section presents only the loads which are applied to the FB directly. Other loads which are applied to the RCCV only but have effects on FB structures because of common foundation mat, like P_a and T_a, are also considered in the FB design. The containment hydrodynamic loads are also considered but their effects are negligibly small on the FB design.

3G.3.5.2.1.1 Dead Load (D) and Live Load (L and L_o)

The weights of structures are evaluated using the following unit weights.

- *reinforced concrete: 23.5 kN/m^3 (150 lbf/ft^3)*
- *steel: 77.0 kN/m^3 (490 lbf/ft^3)*

Weights of major equipment, miscellaneous structures, piping, and commodities are summarized in Tables 3G.3-1 and 3G.3-2.

Live loads on the FB floor and roof slabs are described in Subsection 3.8.4.3.3.

3G.3.5.2.1.2 Snow and Rain Load

The snow and rain load is applied to the roof slab and is taken as shown in Table 3G.1-2.

3G.3.5.2.1.3 Lateral Soil Pressure at Rest

The lateral soil pressure at rest is applied to the walls below grade and is based on soil properties given in Table 3G.1-2. Pressures to be applied to the walls are provided in Figure 3G.1-19..

3G.3.5.2.1.4 Wind Load (W)

The wind load is applied to the roof slab and external walls above grade and is based on basic wind speed given in Table 3G.1-2.

3G.3.5.2.1.5 Tornado Load (W_t)

The tornado load is applied to roof slab and external walls above grade and its characteristics are given in Table 3G.1-2. The tornado load, Wt is further defined by the combinations described in Subsection 3G.1.5.2.1.5.

3G.3.5.2.1.6 Thermal Load

Thermal loads for the FB are evaluated for the normal operating conditions and accident conditions. The accident thermal load, T_a, includes the thermal effects in the spent fuel pool which may occur

due to loss of the Fuel and Auxiliary Pools Cooling System (FAPCS). The effect is included in the load combination Nos. 8 and 9 in Table 3.8-15. Figure 3G.3-1. shows the section location for temperature distributions for various structural elements of the FB, and Table 3G.3-3 shows the magnitude of equivalent linear temperature distribution.

The evaluation method of temperature effect on the concrete design is based on ACI 349-01 Commentary Figure RA.1.

Two cases, winter and summer, are considered in the analysis.

Stress-free temperature is 15.5°C (60°F).

3G.3.5.2.1.7 Design Seismic Loads

The design seismic loads applied to the FB are provided in Subsection 3G.1.5.2.1.13.

Seismic lateral soil pressure for the FB is provided in Subsection 3G.1.5.2.1.13.

3G.3.5.2.2 Load Combinations and Acceptance Criteria

Load combinations and acceptance criteria for the FB concrete structures are described in Subsections 3.8.4.3.3 and 3.8.4.5.3, respectively. Based on previous experience, critical load combinations are selected for the FB design. They are mainly combinations including LOCA loads and seismic loads as shown in Table 3G.3-4. The acceptance criteria for the selected combinations are also included in Table 3G.3-4.

3G.3.5.2.3 Material Properties

Properties of the materials used for the FB design analyses are the same as those for the RB, and they are described in Subsection 3G.1.5.2.3.

3G.3.5.3 Stability Requirements

The stability requirements for the FB foundation are the same as the RB and are described in Subsections 3G.1.5.3 and 3G.1.5.5.

3G.3.5.4 Structural Design Evaluation

The evaluation of the seismic Category I structures in the FB is performed with the same procedure as the RB, which is described in Subsection 3G.1.5.4.

Figure 3G.3-2. shows the location of the sections that are selected for evaluation. They are selected, in principle, from the center and both ends of wall and slab, where it is reasonably expected that the critical stresses appear based on engineering experience and judgment. Tables 3G.3-5 through 3G.3-9 show the forces and moments at the selected sections from NASTRAN analysis. Element forces and moments listed in the tables are defined with relation to the element coordinate system shown in Figure 3G.3-3.. Tables 3G.3-10 through 3G.3-12 show the

combined forces and moments in accordance with the selected load combinations listed in Table 3G.3-4.

Figures 3G.3-4 and 3G.3-5 present the design drawings used for the evaluation of the FB structural design. Table 3G.3-13 lists the sectional thicknesses and rebar ratios used in the evaluation.

Tables 3G.3-14 through 3G.3-16 show the rebar and concrete stresses at these sections for the representative elements. Table 3G.3-17 summarizes evaluation results for transverse shear in accordance with ACI 349, Chapter 11.

3G.3.5.4.1 Shear Walls and Spent Fuel Pool Walls

The maximum rebar stress of 322.8 MPa (46.82 ksi) is found in the vertical rebar at Section 2 due to the load combination FB-9 as shown in Table 3G.3-16. The maximum horizontal rebar stress is found to be 316.9 MPa (45.96 ksi) at Section 2 for the combination FB-9. The maximum transverse shear force is found to be 3.91 MN/m (22.3kips/in) against the shear strength of 5.96 MN/m (34.0 kips/in) at Section 4, Spent Fuel Pool wall.

3G.3.5.4.2 Floor Slabs

The maximum rebar stress of 156.2 MPa (22.65 ksi) is found due to the load combination FB-9 as shown in Table 3G.3-16. The maximum transverse shear force is found to be 1.08 MN/m (6.17 kips/in) against the shear strength of 4.44 MN/m (25.4 kips/in).

3G.3.5.4.3 Foundation Mat

The maximum rebar stress is found to be 333.0 MPa (48.30 ksi) due to the load combination FB-9 as shown in Table 3G.3-16. The maximum transverse shear force is found to be 11.99 MN/m (68.50 kips/in) against the shear strength of 16.29 MN/m (93.00 kips/in).

3G.3.5.5 Foundation Stability

The FB shares the foundation mat with the RB. Evaluation results of the foundation stability are described in Subsection 3G.1.5.5.

3G.3.5.6 Tornado Missile Evaluation

The minimum thickness required to prevent penetration, concrete spalling and scabbing is evaluated. The methods and procedures are shown in Subsection 3.5.3.1.1. The minimum thickness required is less than the minimum 1000 mm (39.4 in) and 700 mm (27.6 in) thickness provided for the FB external walls and slab at EL 22500, respectively.

Table 3G.3-1 Miscellaneous Structures and Commodities in Spent Fuel Pool

Description	Weight
Fuel Pool	
a. Spent Fuel Storage Racks	102 kN/m^2
b. Floor Liner	1.6 kN/m^2
c. Wall Liner	1.0 kN/m^2
d. Water (14.35 m)	141 kN/m^2
Pool Gate	
a. Spent Fuel Pool Gate	70 kN
b. Cask Pit Gate	70 kN
Spent Fuel Cask Pool	
a. Spent Fuel Cask	120 kN/m^2
b. Floor Liner	1.6 kN/m^2
c. Wall Liner	1.0 kN/m^2
d. Water (14.35 m)	141 kN/m^2
e. Cask Lid	100 kN
f. Cask bearing Plate	20 kN
Inclined Fuel Transfer Tube Pool	
a. Floor Liner	1.6 kN/m^2
b. Wall Liner	1.0 kN/m^2
c. Water (14.35 m)	141 kN/m^2
d. Transfer Tube Equipment	160 kN

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 kN = 224.809 lbf
1 kN/m^2 = 20.885 psf
1 m = 3.28 ft

Table 3G.3-2 Miscellaneous Structures, Piping, and Commodity Load on FB Floor

Elevation (mm)	Area Load
22,500	2.4 kN/m^2 (50psf)
4,650	2.4 kN/m^2 (50psf)
-1,000	2.4 kN/m^2 (50psf)
-6,400	2.4 kN/m^2 (50psf)
-11,500	2.4 kN/m^2 (50psf)

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 kN = 224.809 lbf
1 kN/m^2 = 20.885 psf
1 m = 3.28 ft

Table 3G.3-3 Equivalent Linear Temperature Distributions at Various Sections

Section(1)	Side(2)		Equivalent Linear Temperature(3) (°C)			
			Normal Operation (Winter)		Accident Condition (Winter)(4)	
	1	2	T_d	T_g	T_d	T_g
W1	FP	RM	32.1	33.6	48.7	83.1
W2	FP	RM	31.6	34.6	44.7	81.7
W3	FP	GR	32.2	33.4	44.7	79.6
W4	FP	GR	32.2	33.4	39.1	66.2

(1) See Figure 3G.3-1. for the location of sections.

(2) FP: Spent Fuel Pool, RM: FB Room, GR: Ground

(3) T_d: Average Temperature, T_g: Surface Temperature Difference (positive when temperature at Side 1 is higher)

(4) These temperatures correspond to the spent fuel pool temperature at 100°C (212°F), which is slightly less than the 104°C (219°F) water boiling temperature specified in Subsection 3.8.4.3.3. The slight 4% increase in the spent fuel pool temperature is negligible to the design of the spent fuel pool structure. This is because there are sufficient stress margins in accordance with Tables 3G.3-16 and 3G.3-17, even if the total combined stresses were increased by 4%, which would be very conservative since stresses other than thermal in the load combination do not increase.

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1°C = (°F - 32)/1.8

Table 3G.3-4 *Selected Load Combinations for the FB*

Category	Load Combination											Acceptance Criteria[1]
	No.[2]	D	L	P_a[3]	T_o	T_a[3]	E'[4]	W	R_a[4]	SRV[4]	Chugging[4]	
Severe Environmental	FB-4	1.05	1.3		1.3			1.3				U
LOCA (1.5P_a) 72 hours	FB-8	1.0	1.0	1.5		1.0			1.0	1.25	1.5	U
LOCA + SSE 72 hours	FB-9	1.0	1.0	1.0		1.0	1.0		1.0	1.0	1.0	U

(1) *U = Envelope of "Allowable Stress as in ASME B&PV Code Section III, Div. 2, Subsection CC-3420 for Factored Load Combination" and "Required section strength based on the strength design method per ACI 349-01."*

(2) *Based on Table 3.8-15.*

(3) *P_a and T_a are accident pressure load within the containment and thermal load generated by LOCA, respectively. T_a includes the thermal effects in the spent fuel pool due to loss of FAPCS cooling function.*

P_a and T_a are indirect loads, but their effects are considered in the FB design.

(4) *In load combinations that combine SSE with SRV, Chugging and CO, the loads are combined by SRSS.*

Table 3G.3-5 Results of NASTRAN Analysis: Dead Load

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1 Exterior Wall and Pool Wall Bottom	60011	-0.479	-1.785	-0.532	-0.160	-1.149	-0.028	-0.097	-0.366
	60219	0.337	-1.565	-0.302	-0.653	-0.826	-0.169	0.032	0.289
	70201	0.298	-0.173	0.002	0.499	-0.014	0.116	-0.273	0.072
	70204	0.424	-1.004	0.031	-0.227	-0.052	0.121	-0.003	-0.358
	110718	0.324	-1.355	-0.066	-0.050	0.084	0.008	0.036	0.190
2 Exterior Wall @ EL4.65 to 6.60m	62011	0.088	-1.037	0.069	0.043	0.146	0.010	0.010	0.056
	62019	0.125	-0.627	-0.190	-0.032	0.048	-0.031	-0.001	0.021
	72001	0.110	-0.171	0.108	0.106	0.020	-0.006	-0.015	-0.005
	72004	0.146	-0.451	0.200	-0.038	0.004	0.001	-0.016	0.014
3 Exterior Wall @ EL22.50 to 24.60m	64011	0.099	-0.287	-0.092	-0.111	-0.534	-0.004	-0.005	0.075
	64019	-0.108	-0.369	-0.064	-0.061	-0.371	0.053	0.063	0.063
	74001	-0.015	-0.050	0.092	0.049	-0.045	-0.046	-0.020	-0.030
	74004	-0.050	-0.212	0.088	-0.078	-0.336	-0.061	0.019	-0.069
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	0.603	-1.253	-0.492	-1.105	-0.818	-0.249	-0.006	-0.070
	70801	0.676	-0.156	0.012	1.074	0.074	-0.015	-0.548	0.031
	70804	0.581	-0.750	0.133	-0.561	-0.466	0.064	-0.097	0.045
	110748	0.225	-1.009	-0.441	-0.184	-0.081	-0.008	0.073	-0.025
5 Basemat	90306	-1.089	-0.434	0.519	0.939	-0.124	0.175	-0.535	1.186
	90310	-0.134	-0.121	-0.043	-0.153	-0.152	-0.696	0.171	-0.067
	90410	-0.454	-0.918	0.533	-0.712	0.164	1.499	1.396	-0.066
5 Basemat @ Spent Fuel Pool	90486	0.294	0.023	0.095	3.606	2.368	0.278	-0.180	0.125
	90490	0.430	0.193	0.284	1.432	1.257	0.506	1.197	0.261
	90526	0.517	0.487	0.018	1.983	2.122	0.126	-0.227	-0.794
6 Slab EL4.65m	93306	0.189	0.018	0.025	0.048	-0.003	0.005	0.031	-0.099
	93310	0.039	0.055	0.231	0.032	0.008	0.034	-0.023	0.006
	93410	0.313	0.318	-0.450	0.013	0.013	-0.069	0.001	-0.010

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.3-6 Results of NASTRAN Analysis: Thermal Load (Winter)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1 Exterior Wall and Pool Wall Bottom	60011	-1.384	0.477	-0.339	1.280	1.116	0.111	-0.386	-0.113
	60219	0.346	-3.904	1.390	-22.210	-29.543	-0.705	0.040	-3.334
	70201	1.886	3.103	-2.082	-9.857	-9.800	0.485	0.113	0.812
	70204	0.054	1.309	-1.353	-8.600	-9.704	0.357	0.163	0.084
	110718	-5.215	-5.510	-2.744	-4.390	-4.955	0.047	0.412	-0.504
2 Exterior Wall @ EL4.65 to 6.60m	62011	5.792	2.205	0.857	-1.050	-1.212	0.013	-0.038	-0.053
	62019	8.979	0.020	-2.349	-1.303	-1.808	-0.089	0.056	-0.166
	72001	6.347	-1.049	3.952	0.062	-0.998	0.052	-1.303	0.473
	72004	8.900	0.584	3.462	-1.667	-2.299	0.138	-0.101	0.338
3 Exterior Wall @ EL22.50 to 24.60m	64011	4.711	0.191	0.358	-0.959	-0.381	-0.033	-0.012	-0.085
	64019	5.437	1.415	1.717	-1.028	-0.428	0.049	0.002	-0.056
	74001	2.923	-0.822	-3.513	-0.721	-0.452	0.098	-0.293	0.081
	74004	4.106	0.207	-3.618	-0.945	-0.256	-0.054	0.039	0.093
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	-2.264	-4.358	-0.357	-18.258	-17.484	-1.137	-0.079	-1.940
	70801	-0.192	3.118	-0.554	-9.534	-8.830	0.036	0.338	0.094
	70804	-1.696	0.628	0.018	-8.487	-8.519	0.490	0.004	0.347
	110748	-1.028	-5.130	-1.753	-3.188	-4.057	-0.239	0.788	-0.280
5 Basemat	90306	-0.891	-0.104	0.374	1.773	0.777	0.094	-0.041	0.263
	90310	0.146	0.250	0.330	1.230	1.339	0.636	0.137	-0.030
	90410	-0.178	-1.176	0.355	0.552	2.044	0.015	-0.255	-0.326
5 Basemat @ Spent Fuel Pool	90486	-4.328	-1.550	0.543	-31.929	-31.367	2.927	-0.234	0.718
	90490	-4.114	1.286	0.657	-38.413	-34.888	0.923	2.994	2.034
	90526	5.653	0.288	-0.632	-32.497	-12.815	0.082	-1.429	2.332
6 Slab EL4.65m	93306	-0.809	-0.029	-1.613	-0.049	0.041	-0.014	0.079	-0.032
	93310	-2.213	-2.170	-3.182	-0.748	-0.783	-0.241	0.266	0.291
	93410	-0.508	-2.745	-0.501	-0.023	-0.030	0.015	-0.142	-0.048

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.3-7 Results of NASTRAN Analysis: Seismic Load (Horizontal: North to South Direction)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1 Exterior Wall and Pool Wall Bottom	60011	-4.974	-4.132	-0.842	-0.159	-1.012	-0.064	0.041	-0.353
	60219	-4.331	-5.856	-1.554	0.787	0.466	0.306	-0.110	0.204
	70201	0.098	-1.657	-2.673	-0.129	-0.589	-0.046	-0.254	0.097
	70204	1.149	-4.630	-5.158	-0.556	-1.110	-0.136	-0.019	0.242
	110718	1.846	-2.400	1.147	-0.012	0.047	-0.020	0.025	-0.081
2 Exterior Wall @ EL4.65 to 6.60m	62011	0.817	-1.295	-0.355	0.134	0.666	0.005	-0.018	0.279
	62019	0.763	-1.209	-2.124	0.042	0.223	-0.121	0.037	0.083
	72001	-0.117	-1.352	-3.519	-0.073	-0.058	0.010	-0.006	0.052
	72004	-0.286	-1.706	-4.128	-0.025	-0.029	-0.001	0.017	0.006
3 Exterior Wall @ EL22.50 to 24.60m	64011	3.618	-0.192	-0.226	-0.054	-0.114	0.010	0.003	-0.157
	64019	2.638	0.004	-0.653	-0.049	-0.130	0.137	0.039	-0.014
	74001	0.144	-0.106	-1.085	0.035	0.046	-0.047	0.037	-0.013
	74004	-1.324	-0.219	-1.583	0.033	0.018	-0.033	0.015	0.008
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	-0.913	-4.138	-2.609	0.331	0.200	0.267	0.118	0.047
	70801	-0.017	-1.691	-4.182	-0.245	-0.135	-0.132	-0.087	-0.051
	70804	0.627	-2.998	-5.007	-0.420	-0.178	-0.204	0.033	0.098
	110748	0.603	-0.359	1.101	0.041	0.094	-0.130	-0.020	0.034
5 Basemat	90306	-1.332	-1.353	5.050	2.387	-0.476	4.931	-4.168	3.147
	90310	0.229	-1.746	0.216	0.850	-0.443	-1.007	-0.684	2.156
	90410	-0.863	-9.238	-0.135	1.318	1.178	2.207	3.061	-0.507
5 Basemat @ Spent Fuel Pool	90486	-1.353	-2.884	-2.052	15.253	8.966	-2.179	-2.169	-0.054
	90490	-0.501	-8.792	0.829	5.706	7.080	0.667	4.700	-0.518
	90526	0.726	-0.593	-5.563	7.413	1.750	-6.090	-2.498	-3.773
6 Slab EL4.65m	93306	2.047	0.394	-0.788	0.335	-0.448	-0.005	-0.048	0.039
	93310	0.713	0.293	0.983	0.434	-0.367	0.012	-0.420	0.415
	93410	0.095	0.998	0.837	0.256	0.087	0.062	-0.079	0.009

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.3-8 Results of NASTRAN Analysis: Seismic Load (Horizontal: East to West Direction)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1 Exterior Wall and Pool Wall Bottom	60011	-0.106	-0.140	-6.111	-0.048	-0.651	-0.131	0.089	-0.103
	60219	0.613	6.980	-4.243	1.345	4.113	-0.307	-0.076	0.670
	70201	-0.012	2.514	-0.894	-0.093	0.289	-0.131	0.053	-0.148
	70204	0.847	7.253	0.948	0.119	0.399	-0.099	0.002	0.083
	110718	-0.397	3.726	0.193	0.338	0.757	0.044	0.044	0.453
2 Exterior Wall @ EL4.65 to 6.60m	62011	0.192	0.091	-3.939	0.030	0.060	-0.005	-0.028	0.015
	62019	-0.299	1.564	-2.102	0.020	0.016	0.007	-0.004	-0.003
	72001	-0.053	1.982	-0.527	-0.080	-0.083	-0.082	-0.017	0.031
	72004	-0.162	2.433	0.328	-0.013	-0.308	-0.065	-0.016	0.169
3 Exterior Wall @ EL22.50 to 24.60m	64011	-0.165	-0.013	-2.022	0.000	-0.012	0.010	0.004	0.003
	64019	-0.602	0.128	-1.312	0.005	0.014	-0.020	-0.009	-0.002
	74001	-0.170	0.249	0.183	-0.099	-0.019	0.112	0.009	0.027
	74004	-1.056	0.192	0.792	0.035	0.004	0.071	-0.035	-0.123
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	-0.667	4.624	-3.578	1.101	1.127	-0.074	-0.069	0.331
	70801	-0.408	2.734	-0.990	-0.491	-0.030	-0.031	0.296	-0.070
	70804	-0.379	4.938	0.402	0.273	0.250	-0.064	0.025	-0.063
	110748	-0.573	1.976	0.272	-0.059	-0.145	-0.057	0.106	0.055
5 Basemat	90306	-7.362	-1.887	2.309	4.493	1.341	1.350	-2.147	4.891
	90310	-1.100	-0.668	0.422	-0.184	0.640	-1.514	1.882	0.117
	90410	0.099	0.337	4.867	-0.357	-1.797	7.909	-0.067	-3.731
5 Basemat @ Spent Fuel Pool	90486	1.939	1.517	0.910	-15.652	-16.364	-0.601	0.601	-1.861
	90490	0.971	3.631	4.022	0.429	-7.892	4.397	-6.383	-1.813
	90526	5.573	0.814	1.711	-11.621	-5.948	1.135	1.546	5.652
6 Slab EL4.65m	93306	1.734	0.127	-0.674	0.335	-0.163	-0.027	0.105	0.081
	93310	0.348	0.464	0.447	-0.137	0.095	-0.014	0.131	-0.075
	93410	-0.271	0.703	0.410	0.094	-0.067	0.121	-0.217	-0.007

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.3-9 Results of NASTRAN Analysis: Seismic Load (Vertical: Upward Direction)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1 Exterior Wall and Pool Wall Bottom	60011	0.347	1.444	0.295	0.151	0.929	0.026	0.063	0.284
	60219	0.028	1.529	0.165	0.479	0.708	0.106	-0.021	-0.150
	70201	-0.036	0.252	-0.081	-0.321	0.046	-0.078	0.190	-0.076
	70204	-0.074	1.039	-0.038	0.142	0.070	-0.087	-0.001	0.233
	110718	-0.173	1.169	0.284	0.063	-0.016	-0.035	-0.020	-0.093
2 Exterior Wall @ EL4.65 to 6.60m	62011	-0.051	0.992	-0.111	-0.057	-0.254	-0.012	-0.009	-0.085
	62019	-0.052	0.677	0.047	0.017	-0.116	0.045	-0.002	-0.038
	72001	-0.056	0.232	-0.064	-0.083	-0.016	0.003	0.005	0.002
	72004	-0.058	0.481	-0.097	0.021	-0.027	-0.011	0.010	-0.004
3 Exterior Wall @ EL22.50 to 24.60m	64011	0.055	0.424	0.030	0.184	0.895	0.006	0.006	-0.122
	64019	0.151	0.524	0.057	0.106	0.631	-0.084	-0.102	-0.100
	74001	0.013	0.028	-0.112	-0.083	0.074	0.075	0.037	0.049
	74004	0.074	0.313	-0.072	0.132	0.561	0.097	-0.029	0.114
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	-0.130	1.235	0.305	0.809	0.422	0.189	-0.011	0.076
	70801	-0.114	0.355	-0.035	-0.737	-0.067	0.018	0.367	-0.018
	70804	-0.140	0.742	-0.091	0.356	0.296	-0.048	0.066	-0.040
	110748	-0.119	0.789	0.347	0.104	0.033	0.013	-0.047	0.033
5 Basemat	90306	0.831	0.342	-0.377	-0.717	0.087	-0.126	0.414	-0.937
	90310	0.113	0.081	0.038	0.113	0.109	0.556	-0.161	0.055
	90410	0.352	0.666	-0.331	0.551	-0.129	-1.083	-1.131	-0.053
5 Basemat @ Spent Fuel Pool	90486	0.223	0.456	0.032	-3.144	-2.174	-0.332	0.173	-0.142
	90490	0.289	0.317	-0.118	-0.405	-1.037	-0.309	-1.235	-0.234
	90526	0.239	0.271	0.059	-1.710	-1.031	-0.079	0.226	0.886
6 Slab EL4.65m	93306	-0.124	0.014	-0.053	-0.040	-0.064	-0.010	-0.027	0.132
	93310	-0.021	-0.040	-0.208	-0.041	-0.028	-0.042	0.018	0.002
	93410	-0.284	-0.289	0.275	-0.088	-0.020	0.074	0.047	0.017

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.3-10 Combined Forces and Moments: Selected Load Combination FB-4

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1 Exterior Wall and Pool Wall Bottom	60011	OTHR	-2.758	-2.156	-0.833	-0.154	-1.181	0.019	-0.066	-0.940
		TEMP	-1.399	0.244	-0.150	1.389	1.248	0.082	-0.323	-0.124
	60219	OTHR	-2.519	-1.987	-0.576	0.103	-0.752	0.146	0.026	-0.857
		TEMP	2.141	-3.473	1.526	-16.532	-22.653	-0.638	-0.009	-2.744
	70201	OTHR	-0.927	-0.381	0.021	-1.345	-0.893	-0.609	0.588	-0.045
		TEMP	2.590	3.915	-1.049	-5.504	-5.911	0.402	-0.198	0.757
	70204	OTHR	-1.295	-1.774	-0.209	0.449	-1.950	-0.415	-0.086	1.941
		TEMP	1.973	1.474	-0.981	-5.183	-6.088	0.322	0.084	0.078
	110718	OTHR	-0.744	-1.072	-0.846	-0.079	0.018	0.047	0.072	0.103
		TEMP	-2.857	-4.097	-1.806	-2.527	-2.904	0.015	0.243	-0.324
2 Exterior Wall @ EL4.65 to 6.60m	62011	OTHR	-0.206	-1.133	-0.108	0.033	0.189	0.008	0.000	0.075
		TEMP	7.429	2.426	0.697	-1.402	-1.563	0.008	-0.029	-0.075
	62019	OTHR	-0.339	-0.713	-0.077	0.018	0.120	-0.030	0.012	0.059
		TEMP	10.022	0.294	-2.625	-1.562	-1.942	-0.063	0.045	-0.137
	72001	OTHR	-0.073	-0.262	-0.055	-0.268	-0.039	0.054	0.145	0.026
		TEMP	5.610	-1.657	3.481	-0.530	-1.166	0.047	-0.963	0.332
	72004	OTHR	-0.277	-0.665	-0.069	0.390	0.266	0.053	0.061	-0.165
		TEMP	8.962	1.077	3.662	-1.724	-2.091	0.110	-0.068	0.213
3 Exterior Wall @ EL22.50 to 24.60m	64011	OTHR	0.261	-0.308	-0.066	-0.123	-0.586	0.002	-0.002	0.068
		TEMP	5.619	0.223	0.312	-1.261	-0.544	-0.026	-0.006	-0.099
	64019	OTHR	0.005	-0.413	-0.082	-0.069	-0.408	0.056	0.067	0.054
		TEMP	6.640	1.810	1.921	-1.323	-0.590	0.031	-0.009	-0.068
	74001	OTHR	-0.023	-0.057	0.119	0.057	-0.051	-0.042	-0.032	-0.029
		TEMP	3.770	-0.975	-4.229	-0.993	-0.606	0.162	-0.381	0.129
	74004	OTHR	-0.024	-0.227	0.085	-0.084	-0.383	-0.062	0.018	-0.061
		TEMP	5.254	0.289	-4.060	-1.230	-0.396	-0.031	0.029	0.115
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	OTHR	-2.105	-1.486	-0.681	0.638	1.076	0.113	0.184	-0.012
		TEMP	-2.782	-4.484	-0.289	-13.307	-12.914	-1.206	-0.062	-1.487
	70801	OTHR	-1.408	-0.700	-0.086	-3.528	-0.259	-0.424	2.180	-0.351
		TEMP	0.397	4.656	-0.384	-5.261	-5.277	0.027	0.021	-0.027
	70804	OTHR	-1.218	-1.095	-0.090	2.790	1.830	-0.341	0.325	0.256
		TEMP	-0.972	0.944	0.201	-5.140	-5.323	0.365	-0.042	0.181
	110748	OTHR	-0.545	-0.664	-0.428	-0.053	-0.042	-0.068	0.102	-0.059
		TEMP	-0.574	-3.683	-1.399	-1.735	-2.298	-0.112	0.476	-0.198
5 Basemat	90306	OTHR	-4.303	-3.072	0.792	0.964	-0.800	0.428	-0.607	1.572
		TEMP	-0.551	-0.079	0.609	2.135	1.086	0.301	-0.278	0.264
	90310	OTHR	-2.506	-2.554	0.254	-0.649	-0.532	-0.047	0.392	0.183
		TEMP	0.239	0.313	0.518	1.691	1.777	0.959	0.054	-0.064
	90410	OTHR	-3.284	-5.447	0.721	-2.048	-0.018	1.721	1.708	-0.343
		TEMP	-0.173	-0.844	0.141	0.811	2.381	-0.132	-0.103	-0.121
5 Basemat @ Spent Fuel Pool	90486	OTHR	-3.441	-5.730	-0.324	3.049	1.537	-0.129	-0.140	-0.216
		TEMP	-4.244	-2.720	0.470	-24.557	-25.455	2.673	-0.139	0.534
	90490	OTHR	-3.543	-4.698	0.200	-1.337	0.792	0.349	1.532	-0.327
		TEMP	-3.300	3.303	0.448	-29.781	-29.188	0.728	2.617	2.051
	90526	OTHR	-4.261	-6.627	-0.403	0.647	-5.564	-0.297	-0.207	-1.875
		TEMP	3.535	0.045	-0.194	-25.792	-9.116	0.463	-1.405	2.015
6 Slab EL4.65m	93306	OTHR	0.041	-0.230	-0.085	0.099	0.165	0.016	0.034	-0.158
		TEMP	-1.235	-0.073	-1.154	-0.070	0.029	-0.024	0.086	-0.038
	93310	OTHR	-0.038	-0.035	0.139	0.092	0.042	0.011	-0.050	0.004
		TEMP	-2.819	-2.798	-3.576	-0.996	-1.005	-0.291	0.362	0.365
	93410	OTHR	-0.052	-0.174	0.009	0.221	0.058	-0.047	-0.099	-0.017
		TEMP	-0.718	-3.379	-0.128	-0.172	-0.035	0.000	-0.089	-0.038

OTHR: Loads other than thermal loads
TEMP: Thermal loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.3-11 Combined Forces and Moments: Selected Load Combination FB-8

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1 Exterior Wall and Pool Wall Bottom	60011	OTHR	-2.174	-2.012	-0.749	-0.156	-1.171	0.013	-0.079	-0.817
		TEMP	-1.384	0.477	-0.339	1.280	1.116	0.111	-0.386	-0.113
		HYDR	0.343	0.293	0.291	0.021	0.118	0.009	0.011	0.040
	60219	OTHR	-1.833	-1.807	-0.485	-0.058	-0.764	0.069	0.027	-0.605
		TEMP	0.346	-3.904	1.390	-22.210	-29.543	-0.705	0.040	-3.334
		HYDR	0.317	0.588	0.207	0.084	0.203	0.013	0.007	0.035
	70201	OTHR	-0.655	-0.305	0.030	-0.934	-0.688	-0.446	0.399	-0.021
		TEMP	1.886	3.103	-2.082	-9.857	-9.800	0.485	0.113	0.812
		HYDR	0.010	0.175	0.191	0.016	0.053	0.003	0.023	0.017
	70204	OTHR	-0.910	-1.539	-0.121	0.304	-1.512	-0.294	-0.067	1.423
		TEMP	0.054	1.309	-1.353	-8.600	-9.704	0.357	0.163	0.084
		HYDR	0.094	0.569	0.366	0.044	0.100	0.012	0.002	0.023
	110718	OTHR	-0.528	-1.089	-0.693	-0.070	0.032	0.037	0.062	0.118
		TEMP	-5.215	-5.510	-2.744	-4.390	-4.955	0.047	0.412	-0.504
		HYDR	0.159	0.275	0.063	0.016	0.037	0.002	0.004	0.018
2 Exterior Wall @ EL4.65 to 6.60m	62011	OTHR	-0.166	-1.130	-0.068	0.029	0.147	0.007	0.002	0.055
		TEMP	5.792	2.205	0.857	-1.050	-1.212	0.013	-0.038	-0.053
		HYDR	0.101	0.076	0.187	0.003	0.012	0.001	0.004	0.003
	62019	OTHR	-0.258	-0.686	-0.077	0.008	0.087	-0.026	0.008	0.040
		TEMP	8.979	0.020	-2.349	-1.303	-1.808	-0.089	0.056	-0.166
		HYDR	0.061	0.126	0.193	0.003	0.011	0.001	0.001	0.002
	72001	OTHR	-0.044	-0.183	-0.013	-0.199	-0.029	0.034	0.117	0.018
		TEMP	6.347	-1.049	3.952	0.062	-0.998	0.052	-1.303	0.473
		HYDR	0.023	0.198	0.270	0.007	0.005	0.001	0.002	0.004
	72004	OTHR	-0.200	-0.583	-0.013	0.302	0.201	0.036	0.044	-0.113
		TEMP	8.900	0.584	3.462	-1.667	-2.299	0.138	-0.101	0.338
		HYDR	0.052	0.190	0.321	0.004	0.006	0.001	0.001	0.001
3 Exterior Wall @ EL22.50 to 24.60m	64011	OTHR	-0.006	-0.326	-0.057	-0.121	-0.598	0.001	-0.002	0.083
		TEMP	4.711	0.191	0.358	-0.959	-0.381	-0.033	-0.012	-0.085
		HYDR	0.344	0.002	0.133	0.005	0.015	0.002	0.001	0.002
	64019	OTHR	-0.160	-0.426	-0.136	-0.067	-0.419	0.052	0.067	0.067
		TEMP	5.437	1.415	1.717	-1.028	-0.428	0.049	0.002	-0.056
		HYDR	0.254	0.011	0.101	0.005	0.011	0.004	0.002	0.002
	74001	OTHR	-0.036	-0.042	0.156	0.045	-0.056	-0.036	-0.028	-0.028
		TEMP	2.923	-0.822	-3.513	-0.721	-0.452	0.098	-0.293	0.081
		HYDR	0.020	0.018	0.092	0.009	0.004	0.004	0.005	0.003
	74004	OTHR	-0.105	-0.239	0.176	-0.084	-0.400	-0.055	0.014	-0.080
		TEMP	4.106	0.207	-3.618	-0.945	-0.256	-0.054	0.039	0.093
		HYDR	0.118	0.009	0.173	0.003	0.004	0.004	0.001	0.001
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	OTHR	-1.496	-1.381	-0.595	0.277	0.635	0.027	0.139	-0.023
		TEMP	-2.264	-4.358	-0.357	-18.258	-17.484	-1.137	-0.079	-1.940
		HYDR	0.057	0.403	0.247	0.083	0.054	0.022	0.009	0.015
	70801	OTHR	-0.949	-0.537	-0.044	-2.507	-0.190	-0.332	1.569	-0.269
		TEMP	-0.192	3.118	-0.554	-9.534	-8.830	0.036	0.338	0.094
		HYDR	0.028	0.219	0.302	0.036	0.010	0.009	0.012	0.005
	70804	OTHR	-0.811	-0.983	-0.028	2.046	1.302	-0.251	0.231	0.205
		TEMP	-1.696	0.628	0.018	-8.487	-8.519	0.490	0.004	0.347
		HYDR	0.051	0.378	0.366	0.033	0.015	0.017	0.003	0.010
	110748	OTHR	-0.380	-0.726	-0.446	-0.079	-0.049	-0.053	0.092	-0.050
		TEMP	-1.028	-5.130	-1.753	-3.188	-4.057	-0.239	0.788	-0.280
		HYDR	0.060	0.095	0.068	0.010	0.010	0.015	0.002	0.006

Table 3G.3-11 Combined Forces and Moments: Selected Load Combination FB-8 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
5 Basemat	90306	OTHR	-3.553	-2.445	0.667	0.917	-0.660	0.318	-0.535	1.428
		TEMP	-0.891	-0.104	0.374	1.773	0.777	0.094	-0.041	0.263
		HYDR	0.379	0.165	0.412	0.357	0.091	0.349	0.331	0.408
	90310	OTHR	-1.959	-1.980	0.183	-0.545	-0.443	-0.171	0.345	0.118
		TEMP	0.146	0.250	0.330	1.230	1.339	0.636	0.137	-0.030
		HYDR	0.052	0.139	0.022	0.062	0.063	0.144	0.111	0.142
	90410	OTHR	-2.639	-4.291	0.681	-1.812	-0.001	1.618	1.590	-0.271
		TEMP	-0.178	-1.176	0.355	0.552	2.044	0.015	-0.255	-0.326
		HYDR	0.071	0.650	0.200	0.146	0.116	0.471	0.230	0.146
5 Basemat @ Spent Fuel Pool	90486	OTHR	-2.601	-4.362	-0.196	3.036	1.609	0.001	-0.098	-0.152
		TEMP	-4.328	-1.550	0.543	-31.929	-31.367	2.927	-0.234	0.718
		HYDR	0.158	0.207	0.127	1.680	1.236	0.208	0.129	0.088
	90490	OTHR	-2.642	-3.498	0.202	-0.805	0.804	0.383	1.388	-0.178
		TEMP	-4.114	1.286	0.657	-38.413	-34.888	0.923	2.994	2.034
		HYDR	0.057	0.699	0.167	0.334	0.711	0.173	0.524	0.090
	90526	OTHR	-3.184	-4.998	-0.258	0.875	-3.886	-0.137	-0.182	-1.581
		TEMP	5.653	0.288	-0.632	-32.497	-12.815	0.082	-1.429	2.332
		HYDR	0.271	0.062	0.398	0.923	0.352	0.426	0.198	0.477
6 Slab EL4.65m	93306	OTHR	0.053	-0.186	-0.138	0.087	0.129	0.012	0.034	-0.142
		TEMP	-0.809	-0.029	-1.613	-0.049	0.041	-0.014	0.079	-0.032
		HYDR	0.184	0.036	0.234	0.034	0.041	0.003	0.008	0.008
	93310	OTHR	-0.037	-0.027	0.108	0.078	0.036	0.013	-0.045	0.002
		TEMP	-2.213	-2.170	-3.182	-0.748	-0.783	-0.241	0.266	0.291
		HYDR	0.035	0.026	0.060	0.032	0.030	0.004	0.034	0.031
	93410	OTHR	-0.016	-0.085	-0.074	0.165	0.045	-0.049	-0.073	-0.015
		TEMP	-0.508	-2.745	-0.501	-0.023	-0.030	0.015	-0.142	-0.048
		HYDR	0.017	0.128	0.106	0.023	0.007	0.012	0.016	0.001

OTHR: Loads other than thermal and hydrodynamic loads
TEMP: Thermal loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.3-12 Combined Forces and Moments: Selected Load Combination FB-9

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
1 Exterior Wall and Pool Wall Bottom	60011	OTHR	-2.173	-2.002	-0.745	-0.154	-1.158	0.012	-0.076	-0.809
		TEMP	-1.384	0.477	-0.339	1.280	1.116	0.111	-0.386	-0.113
		SEIS	5.340	4.432	6.312	0.268	1.599	0.163	0.152	0.708
		HYDR	0.241	0.207	0.204	0.015	0.085	0.007	0.008	0.029
	60219	OTHR	-1.833	-1.806	-0.485	-0.058	-0.764	0.071	0.027	-0.605
		TEMP	0.346	-3.904	1.390	-22.210	-29.543	-0.705	0.040	-3.334
		SEIS	5.241	9.790	4.701	2.774	5.361	0.727	0.311	2.090
		HYDR	0.224	0.415	0.145	0.059	0.141	0.008	0.005	0.024
	70201	OTHR	-0.655	-0.308	0.033	-0.935	-0.688	-0.446	0.400	-0.021
		TEMP	1.886	3.103	-2.082	-9.857	-9.800	0.485	0.113	0.812
		SEIS	0.521	3.113	3.160	1.159	1.102	0.682	0.583	0.327
		HYDR	0.007	0.122	0.136	0.011	0.038	0.002	0.016	0.012
	70204	OTHR	-0.915	-1.537	-0.118	0.305	-1.510	-0.295	-0.067	1.422
		TEMP	0.054	1.309	-1.353	-8.600	-9.704	0.357	0.163	0.084
		SEIS	2.326	9.215	5.539	0.822	2.462	0.477	0.077	1.441
		HYDR	0.067	0.403	0.260	0.031	0.071	0.008	0.001	0.016
	110718	OTHR	-0.527	-1.086	-0.689	-0.070	0.031	0.038	0.062	0.117
		TEMP	-5.215	-5.510	-2.744	-4.390	-4.955	0.047	0.412	-0.504
		SEIS	3.270	4.733	2.813	0.389	0.835	0.103	0.088	0.532
		HYDR	0.114	0.194	0.045	0.011	0.026	0.002	0.003	0.013
2 Exterior Wall @ EL4.65 to 6.60m	62011	OTHR	-0.164	-1.119	-0.067	0.030	0.151	0.008	0.002	0.056
		TEMP	5.792	2.205	0.857	-1.050	-1.212	0.013	-0.038	-0.053
		SEIS	1.289	1.695	4.101	0.198	0.724	0.030	0.041	0.303
		HYDR	0.072	0.054	0.130	0.002	0.008	0.000	0.003	0.002
	62019	OTHR	-0.257	-0.685	-0.076	0.008	0.089	-0.026	0.009	0.040
		TEMP	8.979	0.020	-2.349	-1.303	-1.808	-0.089	0.056	-0.166
		SEIS	1.107	2.253	3.383	0.249	0.470	0.146	0.051	0.144
		HYDR	0.043	0.088	0.135	0.002	0.008	0.001	0.000	0.001
	72001	OTHR	-0.044	-0.199	-0.005	-0.199	-0.029	0.034	0.117	0.018
		TEMP	6.347	-1.049	3.952	0.062	-0.998	0.052	-1.303	0.473
		SEIS	0.741	2.589	4.297	0.472	0.159	0.128	0.214	0.078
		HYDR	0.016	0.138	0.191	0.005	0.004	0.001	0.001	0.003
	72004	OTHR	-0.197	-0.588	0.000	0.302	0.201	0.036	0.044	-0.113
		TEMP	8.900	0.584	3.462	-1.667	-2.299	0.138	-0.101	0.338
		SEIS	1.039	3.209	4.682	0.481	0.640	0.091	0.085	0.336
		HYDR	0.037	0.133	0.227	0.002	0.004	0.001	0.001	0.001
3 Exterior Wall @ EL22.50 to 24.60m	64011	OTHR	0.046	-0.326	-0.060	-0.123	-0.604	0.001	-0.002	0.084
		TEMP	4.711	0.191	0.358	-0.959	-0.381	-0.033	-0.012	-0.085
		SEIS	3.879	0.468	2.053	0.194	0.906	0.035	0.018	0.201
		HYDR	0.242	0.001	0.092	0.004	0.011	0.001	0.001	0.001
	64019	OTHR	-0.130	-0.425	-0.116	-0.068	-0.422	0.052	0.067	0.068
		TEMP	5.437	1.415	1.717	-1.028	-0.428	0.049	0.002	-0.056
		SEIS	2.950	0.539	1.577	0.118	0.656	0.185	0.114	0.103
		HYDR	0.178	0.008	0.070	0.004	0.008	0.002	0.002	0.002
	74001	OTHR	-0.032	-0.047	0.145	0.046	-0.055	-0.037	-0.029	-0.028
		TEMP	2.923	-0.822	-3.513	-0.721	-0.452	0.098	-0.293	0.081
		SEIS	0.238	0.290	1.163	0.139	0.098	0.175	0.075	0.060
		HYDR	0.014	0.013	0.064	0.006	0.003	0.003	0.003	0.002
	74004	OTHR	-0.081	-0.240	0.152	-0.085	-0.401	-0.056	0.014	-0.080
		TEMP	4.106	0.207	-3.618	-0.945	-0.256	-0.054	0.039	0.093
		SEIS	1.903	0.434	1.829	0.141	0.564	0.135	0.055	0.175
		HYDR	0.083	0.006	0.121	0.002	0.003	0.003	0.001	0.001

Table 3G.3-12 Combined Forces and Moments: Selected Load Combination FB-9 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	OTHR	-1.497	-1.379	-0.595	0.276	0.636	0.030	0.139	-0.023
		TEMP	-2.264	-4.358	-0.357	-18.258	-17.484	-1.137	-0.079	-1.940
		SEIS	2.656	6.814	4.604	5.026	2.489	0.669	0.362	0.792
		HYDR	0.039	0.284	0.174	0.058	0.037	0.016	0.006	0.011
	70801	OTHR	-0.950	-0.543	-0.038	-2.509	-0.190	-0.332	1.570	-0.269
		TEMP	-0.192	3.118	-0.554	-9.534	-8.830	0.036	0.338	0.094
		SEIS	1.892	3.601	4.599	3.498	0.454	0.671	2.033	0.503
		HYDR	0.019	0.153	0.214	0.025	0.007	0.006	0.009	0.003
	70804	OTHR	-0.818	-0.980	-0.018	2.046	1.302	-0.251	0.231	0.205
		TEMP	-1.696	0.628	0.018	-8.487	-8.519	0.490	0.004	0.347
		SEIS	2.282	6.197	5.211	2.893	1.577	0.494	0.308	0.468
		HYDR	0.036	0.267	0.261	0.023	0.011	0.012	0.002	0.007
	110748	OTHR	-0.380	-0.723	-0.443	-0.078	-0.049	-0.053	0.092	-0.050
		TEMP	-1.028	-5.130	-1.753	-3.188	-4.057	-0.239	0.788	-0.280
		SEIS	1.832	2.310	2.172	0.219	0.198	0.216	0.130	0.104
		HYDR	0.043	0.066	0.049	0.007	0.007	0.011	0.001	0.004
5 Basemat	90306	OTHR	-3.543	-2.443	0.668	0.916	-0.652	0.320	-0.537	1.426
		TEMP	-0.891	-0.104	0.374	1.773	0.777	0.094	-0.041	0.263
		SEIS	7.568	2.347	5.652	5.383	2.007	5.199	4.883	6.009
		HYDR	0.266	0.117	0.292	0.253	0.065	0.246	0.234	0.289
	90310	OTHR	-1.959	-1.978	0.184	-0.542	-0.440	-0.170	0.344	0.114
		TEMP	0.146	0.250	0.330	1.230	1.339	0.636	0.137	-0.030
		SEIS	1.160	1.886	0.486	1.285	1.047	2.093	2.187	2.493
		HYDR	0.036	0.099	0.016	0.044	0.045	0.102	0.078	0.100
	90410	OTHR	-2.629	-4.289	0.675	-1.785	0.001	1.614	1.583	-0.271
		TEMP	-0.178	-1.176	0.355	0.552	2.044	0.015	-0.255	-0.326
		SEIS	0.937	9.268	5.001	2.443	2.322	8.518	3.315	3.953
		HYDR	0.050	0.457	0.140	0.106	0.081	0.332	0.163	0.102
5 Basemat @ Spent Fuel Pool	90486	OTHR	-2.595	-4.368	-0.203	3.007	1.602	-0.006	-0.107	-0.148
		TEMP	-4.328	-1.550	0.543	-31.929	-31.367	2.927	-0.234	0.718
		SEIS	2.384	3.292	2.327	23.723	19.662	2.721	2.561	2.077
		HYDR	0.113	0.145	0.089	1.198	0.875	0.148	0.090	0.061
	90490	OTHR	-2.642	-3.498	0.201	-0.806	0.803	0.375	1.387	-0.183
		TEMP	-4.114	1.286	0.657	-38.413	-34.888	0.923	2.994	2.034
		SEIS	1.131	9.545	4.262	12.359	11.532	4.673	8.620	2.290
		HYDR	0.040	0.495	0.117	0.237	0.504	0.121	0.370	0.063
	90526	OTHR	-3.186	-4.998	-0.260	0.863	-3.884	-0.142	-0.183	-1.579
		TEMP	5.653	0.288	-0.632	-32.497	-12.815	0.082	-1.429	2.332
		SEIS	5.718	1.045	5.949	15.115	11.110	6.772	3.246	7.506
		HYDR	0.192	0.044	0.282	0.655	0.248	0.301	0.141	0.339
6 Slab EL4.65m	93306	OTHR	0.051	-0.187	-0.110	0.086	0.128	0.012	0.034	-0.141
		TEMP	-0.809	-0.029	-1.613	-0.049	0.041	-0.014	0.079	-0.032
		SEIS	2.686	0.414	1.040	0.523	0.628	0.036	0.125	0.195
		HYDR	0.129	0.026	0.171	0.024	0.029	0.002	0.005	0.006
	93310	OTHR	-0.034	-0.026	0.124	0.076	0.036	0.014	-0.043	0.002
		TEMP	-2.213	-2.170	-3.182	-0.748	-0.783	-0.241	0.266	0.291
		SEIS	0.796	0.550	1.111	0.582	0.441	0.065	0.528	0.489
		HYDR	0.024	0.018	0.044	0.023	0.022	0.003	0.024	0.022
	93410	OTHR	-0.010	-0.086	-0.080	0.163	0.045	-0.050	-0.072	-0.015
		TEMP	-0.508	-2.745	-0.501	-0.023	-0.030	0.015	-0.142	-0.048
		SEIS	0.404	1.269	0.975	0.532	0.150	0.196	0.294	0.022
		HYDR	0.013	0.091	0.076	0.017	0.005	0.008	0.011	0.001

OTHR: Loads other than thermal, seismic and hydrodynamic loads
TEMP: Thermal loads
SEIS: Seismic loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = $6.852x10^4$ lbf/ft
1 MNm/m = $2.248x10^5$ lbf-ft/ft

Table 3G.3-13 Sectional Thicknesses and Rebar Ratios Used in the Evaluation

Location	**Element ID**	**Thickness (m)**	Primary Reinforcement					**Shear Tie**	
			Position	Direction 1[*1]		Direction 2[*1]			
				Arrangement[*2]	Ratio (%)	Arrangement[*2]	Ratio (%)	Arrangement	Ratio (%)
1 Exterior Wall *and Pool Wall Bottom*	60011	2.0	Inside	3-#11@200	0.755	1-#11@100 +3-#11@200	1.258	#6@200x200	0.710
			Outside	1-#11@100 +3-#11@200	1.258	2-#11@100 +2-#11@200	1.510		
	60219	3.6	Inside	6-#11@200	0.839	6-#11@200	0.839	#6@200x200	0.710
			Outside	1-#11@100 +7-#11@200	1.258	1-#11@100 +7-#11@200	1.258		
	70201 70204	2.0	Inside	3-#11@100 +1-#11@200	1.761	3-#11@100 +1-#11@200	1.761	#6@200x200	0.710
			Outside	3-#11@100 +1-#11@200	1.761	5-#11@100	2.516		
	110718	1.5	Inside	2-#11@200	0.671	3-#11@200 (+1-#11@200)	1.342	#6@400x200	0.355
			Outside	2-#11@200	0.671	3-#11@200 (+1-#11@200)	1.342		
2 Exterior Wall *@ EL4.65 to 6.60m*	62011 62019	1.0	Inside	2-#11@200	1.006	2-#11@200	1.006	#5@400x400	0.125
			Outside	3-#11@200	1.510	3-#11@200	1.510		
	72001	1.0	Inside	2-#11@200	1.006	2-#11@200	1.006	#5@400x200	0.250
			Outside	3-#11@200	1.510	3-#11@200	1.510		
	72004	1.0	Inside	2-#11@200	1.006	2-#11@200 (+1-#11@200)	1.510	#5@400x400	0.125
			Outside	3-#11@200	1.510	3-#11@200	1.510		
3 Exterior Wall *@ EL22.50 to 24.60m*	64011	1.0	Inside	2-#11@200	1.006	2-#11@200	1.006	#5@400x400	0.125
			Outside	2-#11@200 (+1-#11@200)	1.510	2-#11@200 (+1-#11@200)	1.510		
	64019	1.0	Inside	2-#11@200	1.006	2-#11@200	1.006	#5@400x400	0.125
			Outside	2-#11@200	1.006	2-#11@200	1.006		
	74001 74004	1.0	Inside	2-#11@200	1.006	2-#11@200	1.006	#5@400x400	0.125
			Outside	3-#11@200	1.510	3-#11@200	1.510		

Table 3G.3-13 Sectional Thicknesses and Rebar Ratios Used in the Evaluation

Location	Element ID	Thickness (m)	Primary Reinforcement					Shear Tie	
			Position	Direction 1[*1]		Direction 2[*1]			
				Arrangement[*2]	Ratio (%)	Arrangement[*2]	Ratio (%)	Arrangement	Ratio (%)
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	3.6	Inside	6-#11@200	0.839	6-#11@200	0.839	#6@200x200	0.710
			Outside	1-#11@100 +7-#11@200	1.258	1-#11@100 +7-#11@200	1.258		
	70801 70804	2.0	Inside	3-#11@100 +1-#11@200	1.761	3-#11@100 +1-#11@200	1.761	#6@200x200	0.710
			Outside	3-#11@100 +1-#11@200	1.761	5-#11@100	2.516		
	110748	1.5	Inside	2-#11@200	0.671	3-#11@200	1.006	#6@400x400	0.177
			Outside	2-#11@200	0.671	3-#11@200	1.006		
5 Basemat	90306 90310 90410	4.0	Top	4-#11@200	0.503	4-#11@200	0.503	#11@400x400	0.629
			Bottom	5-#11@200	0.629	5-#11@200	0.629		
6 Basemat @ Spent Fuel Pool	90486	5.5	Top	4-#11@200 (+2-#11@200)	0.549	4-#11@200 (+2-#11@200)	0.549	#11@600x400	0.419
			Bottom	5-#11@200	0.457	5-#11@200	0.457		
	90490 90526	5.5	Top	4-#11@200 (+2-#11@200)	0.549	4-#11@200 (+2-#11@200)	0.549	#11@400x400	0.629
			Bottom	5-#11@200	0.457	5-#11@200	0.457		
7 Slab EL4.65m	93306 93310 93410	1.3	Top	2-#11@200	0.774	2-#11@200	0.774	#5@200x200	0.500
			Bottom	2-#11@200	0.774	2-#11@200	0.774		

*Note *1.: Exterior Wall, Pool Wall — Direction 1: Horizontal, — Direction 2: Vertical*
Basemat, Slab — Direction 1: N-S, — Direction 2: E-W
*Note *1.: Rebar in parentheses indicates additional bars locally required.*
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 m = 3.28 ft

Table 3G.3-14 Rebar and Concrete Stresses: Selected Load Combination FB-4

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
1 Exterior Wall and Pool Wall Bottom	60011	-3.4	-29.3	-4.4	-19.2	-4.5	-3.3	372.2
	60219	-7.8	-29.3	-9.6	30.5	-33.2	56.7	372.2
	70201	-9.9	-29.3	-12.0	90.3	-10.1	85.1	372.2
	70204	-9.2	-29.3	-4.6	31.0	-30.4	67.6	372.2
	110718	-11.3	-29.3	-16.3	84.8	-26.2	48.4	372.2
2 Exterior Wall @ EL4.65 to 6.60m	62011	-3.0	-29.3	36.5	84.3	-11.2	27.7	372.2
	62019	-10.2	-29.3	51.9	114.9	-26.3	77.7	372.2
	72001	-9.5	-29.3	22.5	108.5	-20.1	80.1	372.2
	72004	-6.7	-29.3	62.5	44.5	5.2	26.8	372.2
3 Exterior Wall @ EL22.50 to 24.60m	64011	-8.4	-29.3	25.7	101.7	-18.6	66.4	372.2
	64019	-8.4	-29.3	41.2	152.5	-9.1	117.7	372.2
	74001	-4.6	-29.3	23.6	93.7	3.3	80.3	372.2
	74004	-7.5	-29.3	13.7	108.2	1.8	116.5	372.2
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	-5.2	-29.3	-18.5	19.2	-21.7	17.2	372.2
	70801	-11.7	-29.3	-32.2	102.5	1.9	58.7	372.2
	70804	-2.9	-29.3	-12.2	4.0	-5.7	12.9	372.2
	110748	-8.8	-29.3	0.6	57.8	-32.1	33.7	372.2
5 Basemat	90306	-2.1	-23.5	-2.5	-13.7	-5.0	-3.8	372.2
	90310	-0.8	-23.5	-2.6	-4.6	-2.1	-4.9	372.2
	90410	-2.3	-23.5	-7.7	-1.3	-5.7	-15.4	372.2
5 Basemat @ Spent Fuel Pool	90486	-4.0	-23.5	-12.9	8.3	-16.1	8.6	372.2
	90490	-4.2	-23.5	-13.2	23.1	-4.7	11.7	372.2
	90526	-3.1	-23.5	-3.2	12.8	-14.0	4.4	372.2
6 Slab EL4.65m	93306	-1.8	-29.3	18.0	3.9	41.7	4.9	372.2
	93310	-7.5	-29.3	-12.4	53.3	-14.1	56.6	372.2
	93410	-2.6	-29.3	-0.4	-1.8	-16.8	-17.3	372.2

Note: Negative value means compression.

*Note *: Exterior Wall, Pool Wall — Direction 1: Horizontal, Direction 2: Vertical*

Basemat, Slab — Direction 1: N-S, Direction 2: E-W

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MPa = 145.038 psi

Table 3G.3-15 Rebar and Concrete Stresses: Selected Load Combination FB-8

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated				
		Calculated	Allowable	Direction 1*		Direction 2*		Allowable
				In/Top	Out/Bottom	In/Top	Out/Bottom	
1 Exterior Wall and Pool Wall Bottom	60011	-3.3	-29.3	-4.0	-18.1	-5.7	-1.9	372.2
	60219	-9.9	-28.5	-16.6	55.0	-39.8	85.5	366.4
	70201	-12.7	-28.3	-20.5	113.1	-20.5	101.0	364.6
	70204	-12.3	-28.3	-16.4	69.5	-39.4	98.0	364.6
	110718	-17.9	-28.1	-32.7	146.0	-34.3	91.8	363.3
2 Exterior Wall @ EL4.65 to 6.60m	62011	-3.7	-29.3	40.2	65.6	-19.6	26.9	372.2
	62019	-10.4	-29.3	53.7	105.7	-28.0	80.0	372.2
	72001	-7.4	-29.3	40.8	92.8	-23.4	89.2	372.2
	72004	-11.3	-29.3	86.6	83.2	-49.9	99.2	372.2
3 Exterior Wall @ EL22.50 to 24.60m	64011	-8.5	-29.3	29.0	92.7	-17.8	68.7	372.2
	64019	-6.6	-29.3	37.4	94.6	-5.8	75.2	372.2
	74001	-4.0	-29.3	23.5	77.3	4.8	67.8	372.2
	74004	-6.1	-29.3	13.0	100.0	4.0	97.9	372.2
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	-6.4	-28.5	-19.4	43.7	-25.3	36.1	366.4
	70801	-14.4	-28.3	-36.3	132.6	-11.8	84.4	364.6
	70804	-7.3	-28.3	-18.7	33.6	-18.9	50.9	364.6
	110748	-13.8	-28.1	1.0	102.5	-44.9	70.3	363.3
5 Basemat	90306	-2.2	-23.5	-2.4	-14.3	-3.9	-3.3	372.2
	90310	-0.7	-23.5	-2.1	-3.9	-1.4	-4.3	372.2
	90410	-2.2	-23.5	-6.9	-0.8	-5.9	-14.9	372.2
5 Basemat @ Spent Fuel Pool	90486	-4.3	-22.9	-11.8	21.9	-12.0	19.9	367.2
	90490	-4.7	-22.9	-10.9	39.2	-6.7	18.0	367.2
	90526	-2.8	-22.9	0.4	24.4	-11.1	10.2	367.2
6 Slab EL4.65m	93306	-2.4	-29.3	49.8	27.5	70.5	33.0	372.2
	93310	-6.1	-29.3	-5.7	55.3	-7.6	59.6	372.2
	93410	-2.4	-29.3	14.9	-2.5	-12.2	-14.9	372.2

Note: Negative value means compression.

*Note *: Exterior Wall, Pool Wall — Direction 1: Horizontal, Direction 2: Vertical*

Basemat, Slab — Direction 1: N-S, Direction 2: E-W

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.3-16 Rebar and Concrete Stresses: Selected Load Combination FB-9

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
1 Exterior Wall and Pool Wall Bottom	60011	-8.5	-29.3	244.8	107.4	217.4	108.8	372.2
	60219	-13.9	-28.5	74.8	137.0	-63.4	192.8	366.4
	70201	-10.4	-28.3	-9.9	174.4	-20.5	169.1	364.6
	70204	-18.4	-28.3	36.2	150.7	84.4	202.9	364.6
	110718	-22.7	-28.1	-44.5	151.5	-55.4	90.9	363.3
2 Exterior Wall @ EL4.65 to 6.60m	62011	-9.3	-29.3	214.9	241.9	322.8	240.7	372.2
	62019	-13.2	-29.3	165.6	252.3	144.1	195.7	372.2
	72001	-15.3	-29.3	158.9	276.9	75.8	198.1	372.2
	72004	-16.1	-29.3	255.1	316.9	130.3	283.0	372.2
3 Exterior Wall @ EL22.50 to 24.60m	64011	-26.7	-29.3	161.9	301.7	91.9	274.6	372.2
	64019	-7.1	-29.3	233.3	284.5	105.5	231.4	372.2
	74001	-8.2	-29.3	68.5	103.3	52.9	89.5	372.2
	74004	-9.4	-29.3	139.1	217.4	-31.1	222.5	372.2
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	-9.5	-28.5	-30.9	83.3	-36.4	122.8	366.4
	70801	-19.0	-28.3	-47.6	228.3	29.2	157.6	364.6
	70804	-13.4	-28.3	85.5	121.0	92.6	139.7	364.6
	110748	-16.3	-28.1	9.2	114.5	-53.2	78.0	363.3
5 Basemat	90306	-10.4	-23.5	197.2	116.9	198.3	56.1	372.2
	90310	-3.2	-23.5	13.2	21.5	24.1	23.1	372.2
	90410	-11.1	-23.5	264.6	-25.0	235.6	113.2	372.2
5 Basemat @ Spent Fuel Pool	90486	-12.8	-22.9	121.5	163.6	116.2	122.0	367.2
	90490	-9.7	-22.9	94.8	127.7	268.3	41.0	367.2
	90526	-8.4	-22.9	333.0	100.3	190.0	106.8	367.2
6 Slab EL4.65m	93306	-5.5	-29.3	56.7	156.2	125.0	80.1	372.2
	93310	-9.2	-29.3	22.9	119.8	11.9	120.6	372.2
	93410	-5.8	-29.3	84.8	42.8	13.1	-19.8	372.2

Note: Negative value means compression.

*Note *: Exterior Wall, Pool Wall — Direction 1: Horizontal, Direction 2: Vertical*
Basemat, Slab — Direction 1: N-S, Direction 2: E-W

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

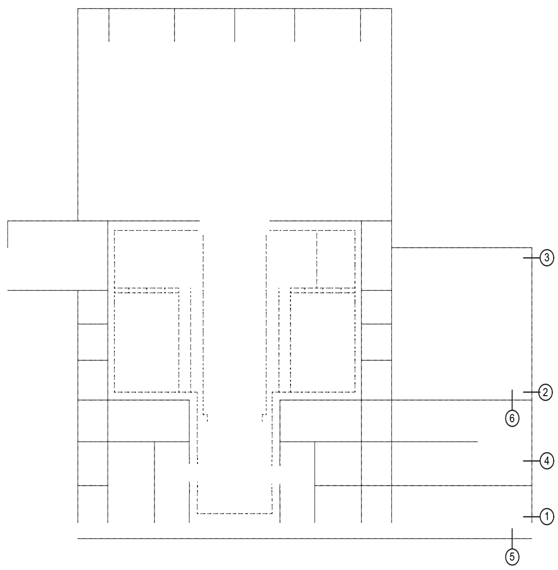
Table 3G.3-17 Transverse Shear of FB

Location	Element ID	Load ID	d (m)	pv (%)	Shear Force (MN/m) Vu	Vc	Vs	ϕVn	Vu/ϕVn
1 Exterior Wall and Pool Wall Bottom	60011	FB-9	1.73	0.710	0.38	0.00	5.07	4.31	0.087
	60219	FB-9	3.07	0.710	0.33	0.39	9.03	8.01	0.042
	70201	FB-9	1.66	0.710	1.28	1.73	4.88	5.63	0.227
	70204	FB-4	1.59	0.710	1.99	2.09	4.67	5.75	0.346
	110718	FB-9	1.10	0.355	1.02	1.41	1.61	2.56	0.397
2 Exterior Wall @ EL4.65 to 6.60m	62011	FB-9	0.78	0.125	0.27	0.23	0.40	0.54	0.499
	62019	FB-9	0.72	0.125	0.11	0.13	0.37	0.42	0.256
	72001	FB-9	0.72	0.250	0.45	0.10	0.75	0.72	0.620
	72004	FB-9	0.72	0.125	0.23	0.00	0.37	0.32	0.734
3 Exterior Wall @ EL22.50 to 24.60m	64011	FB-9	0.72	0.125	0.29	0.72	0.37	0.92	0.310
	64019	FB-9	0.80	0.125	0.24	0.00	0.41	0.35	0.680
	74001	FB-4	0.72	0.125	0.10	0.12	0.37	0.42	0.249
	74004	FB-4	0.72	0.125	0.06	0.08	0.37	0.38	0.168
4 Spent Fuel Pool Wall @ EL-5.10 to -3.30m	60819	FB-9	3.06	0.710	0.55	0.65	8.99	8.19	0.067
	70801	FB-9	1.71	0.710	3.91	1.98	5.03	5.96	0.655
	70804	FB-9	1.71	0.710	0.08	0.09	5.03	4.35	0.017
	110748	FB-9	1.22	0.177	1.09	1.38	0.89	1.93	0.563
5 Basemat	90306	FB-9	3.49	0.629	6.11	1.70	9.07	9.15	0.667
	90310	FB-9	3.48	0.629	3.70	5.75	9.06	12.59	0.294
	90410	FB-9	3.50	0.629	3.90	1.76	9.09	9.23	0.423
5 Basemat @ Spent Fuel Pool	90486	FB-9	3.92	0.419	2.91	3.66	6.79	8.89	0.327
	90490	FB-9	5.05	0.629	11.99	6.04	13.13	16.29	0.736
	90526	FB-9	3.94	0.629	6.45	3.16	10.25	11.40	0.566
6 Slab EL4.65m	93306	FB-8	1.10	0.500	0.22	0.26	2.27	2.15	0.101
	93310	FB-9	1.10	0.500	1.08	2.95	2.27	4.44	0.244
	93410	FB-9	1.10	0.500	0.46	2.15	2.27	3.75	0.121

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 m = 3.28 ft

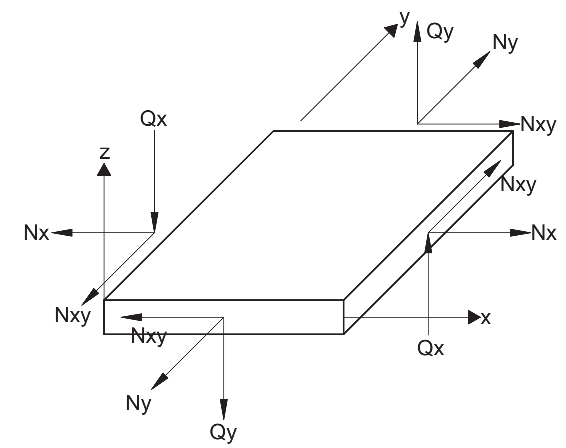
Figure 3G.3-1. Sections Where Thermal Loads Are Defined

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

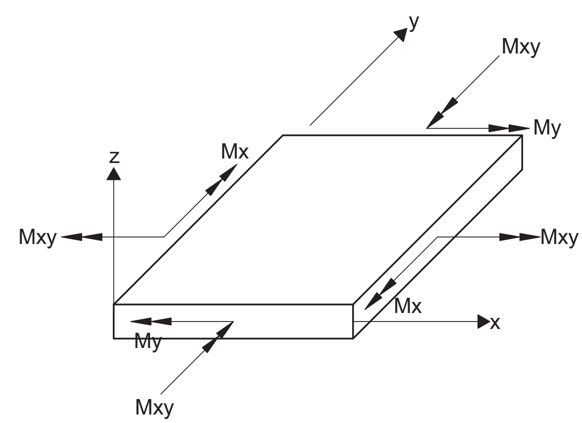


Selected Sections (FB)

Figure 3G.3-2. Section Considered for Analysis



Membrane and Shear Forces



Moments

Definition of Element Coordinate System

Structure	x	y	z
External Wall	horizontal	vertical	outward
Wall in N-S Direction	horizontal	vertical	toward West
Wall in E-W Direction	horizontal	vertical	toward South
Foundation Mat Floor Slab	toward South	toward West	downward

Figure 3G.3-3. Force and Moment in Shell Element

Figure 3G.3-4. Reinforcing Steel of Spent Fuel Pool

Note: All dimensions are in mm unless otherwise noted

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.3-5. List of FB Wall and Slab Reinforcement

Note: All dimensions are in mm unless otherwise noted

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

3G.4 FIREWATER SERVICE COMPLEX

3G.4.1 Objective and Scope

The objective of this subsection is to document the structural design details, inputs and analytical results from the analysis of the FWSC of the standard ESBWR plant. The scope includes the design and analysis of the structure for normal, severe environmental, extreme environmental, and construction loads.

3G.4.2 Conclusion

The following are the major summary conclusions on the design and analysis of the FWSC.

- *Based on the results of finite element analyses performed in accordance with the design conditions identified in Subsection 3G.4.3, stresses in concrete and reinforcement are less than the allowable stresses per the applicable regulations, codes and standards listed in Section 3.8.*
- *The factors of safety against floatation, sliding, and overturning of the structure under various loading combinations are higher than the required minimum.*
- *The thickness of the roof slabs and exterior walls are more than the minimum required to preclude penetration, perforation and spalling resulting from impact of design basis tornado missiles.*

3G.4.3 Structural Description

The FWSC consists of two Firewater Storage Tanks (FWS) and a Fire Pump Enclosure (FPE) that share a common basemat. Each FWS is capable of storing 2082 m^3 (550000 gallons) of water. The FPE provides enclosure and protection for the Electric Pump, RPV Makeup Water Pump, Diesel Pump, Tank Recirculation Pump, and Diesel Fuel Oil Storage Tank.

The FWS is designed with a cylindrical reinforced concrete wall and a dome-shaped reinforced concrete roof. The FWS is lined with a stainless steel plate to prevent leakage of the stored water. The liner plate is not designed to provide structural integrity to the FWS. The FPE is a reinforced concrete box type structure with shear walls and a roof slab.

The key dimensions of the FWSC are summarized in Table 3.8-8. Figure 3G.4-1. shows the concrete outline drawing of the FWSC.

3G.4.4 Analytical Models

3G.4.4.1 Structural Model

The FWSC is analyzed utilizing the finite element computer program NASTRAN. The finite element model consists of quadrilateral and triangular elements to represent the slabs and walls. The model is shown in Figures 3G.4-2 through 3G.4-6. The model includes the whole portion of the FWSC taking the application of nonaxisymmetrical loads into consideration.

The nodal points are defined by a right hand Cartesian coordinate system X, Y, Z. This system, called the global coordinate system, has its origin located at the center of the FWSC at EL 0 mm. The positive X axis is in the south direction; the Y axis is in the east direction; the Z axis is vertical upward. This coordinate system is shown in Figure 3G.4-2.

3G.4.4.2 Foundation Models

The foundation soil is represented by soil springs. The spring constants for rocking and translations are determined based on the following soil parameters which correspond to the Soft Site conditions described in Appendix 3A:

- *Shear wave velocity: 300 m/s (1000 ft/s)*
- *Unit weight: 0.0196 MN/m^3 (125 lbf/ft^3)*
- *Shear modulus: 180 MN/m^2 (26110 psi)*
- *Poisson's Ratio: 0.478*

Soil springs are attached to the bottom of the foundation mat, and the constraints by side soil are not included in the model. The values of the soil springs used in the analysis are shown in Table 3G.4-1. The springs have perfectly elastic stiffness.

These spring values are multiplied by the foundation mat nodal point tributary areas to compute the spring constants assigned to the base slab nodal points.

3G.4.5 Structural Analysis and Design

3G.4.5.1 Site Design Parameters

The key site design parameters are located in Table 3G.1-2.

3G.4.5.2 Design Loads, Load Combinations, and Material Properties

3G.4.5.2.1 Design Loads

3G.4.5.2.1.1 Dead Load (D) and Live Load (L and L_o)

The weights of structures are evaluated using the following unit weights.

- *reinforced concrete: 23.5 kN/m^3 (150 lbf/ft^3)*
- *steel: 77.0 kN/m^3 (490 lbf/ft^3)*

Weights of major equipment, miscellaneous structures, piping, and commodities are summarized in Tables 3G.4-2 and 3G.4-3.

Live loads on the FWSC floor and roof slabs are described in Subsection 3.8.4.3.5.

3G.4.5.2.1.2 Snow and Rain Load

The snow and rain load is applied to the roof slab and is taken as shown in Table 3G.1-2.

3G.4.5.2.1.3 Lateral Soil Pressure

Lateral soil pressure is not considered since the effect of lateral soil pressure against the solid concrete basemat is negligible.

3G.4.5.2.1.4 Wind Load (W)

Wind load is applied to the roof slab and external walls above grade and is based on basic wind speed given in Table 3G.1-2.

3G.4.5.2.1.5 Tornado Load (W_t)

The tornado load is applied to the roof slab and external walls above grade and its characteristics are given in Table 3G.1-2. The tornado load, W_t, is further defined by the combinations described in Subsection 3G.1.5.2.1.5.

3G.4.5.2.1.6 Thermal Load (T_o)

Thermal load for the FWSC is evaluated for the normal operating condition. Figure 3G.4-7. shows the section location for temperature distributions for various structural elements of the FWSC, and Table 3G.4-4 shows the magnitude of equivalent linear temperature distribution.

Stress-free temperature is 15.5°C (60°F).

3G.4.5.2.1.7 Design Seismic Loads

The design seismic loads are obtained by soil–structure interaction analyses, which are described in Appendix 3A. The seismic loads used for design are as follows:

- *Figures 3G.4-8, 3G.4-9: design seismic shears and moments*
- *Table 3G.4-5: maximum vertical acceleration*

The seismic loads are composed of two perpendicular horizontal and one vertical components. The effects of the three components are combined based on the SRSS method as described in Subsection 3.8.1.3.6.

3G.4.5.2.2 Load Combinations and Acceptance Criteria

Table 3.8-15 gives load combinations for the safety-related reinforced concrete structure. Based on previous experience, critical load combinations are selected for the FWSC design as shown in Table 3G.4-6. The acceptance criteria for the selected combinations are also included in Table 3G.4-6.

3G.4.5.2.3 Material Properties

Properties of the materials used for the FWSC design analyses are the same as those for the RB, and they are described in Subsection 3G.1.5.2.3.

3G.4.5.3 Stability Requirements

The stability requirements for the FWSC foundation are same as those for the RB, and they are described in Subsection 3G.1.5.3.

3G.4.5.4 Structural Design Evaluation

The evaluation of the Seismic Category I structures in the FWSC is performed using the same procedure as the RB, which is described in Subsection 3G.1.5.4.

The locations of the sections that are selected for evaluation are indicated in Figures 3G.4-3 through 3G.4-6. They are selected, in principle, from the center and both ends of wall and slab, where it is reasonably expected that the critical stresses appear based on engineering experience and judgment. Tables 3G.4-7 through 3G.4-11 show the forces and moments at the selected sections from NASTRAN analysis. Element forces and moments listed in the tables are defined with relation to the element coordinate system shown in Figure 3G.4-10.. Tables 3G.4-12 through 3G.4-15 show the combined forces and moments in accordance with the selected load combinations listed in Table 3G.4-6.

Table 3G.4-16 lists the sectional thicknesses and rebar ratios used in the evaluation. The values are retrieved from the outline drawings shown in Figure 3G.4-1..

Tables 3G.4-17 through 3G.4-20 compares the rebar and concrete stresses at these sections for the representative elements with the allowable stresses, which are conservatively taken to be the more limiting of ACI 349-01 and ASME Section III Division 2. Table 3G.4-21 summarizes evaluation results for transverse shear in accordance with ACI 349, Chapter 11.

3G.4.5.4.1 Shear Walls

The maximum rebar stress of 264.5 MPa (38.36 ksi) is found in the vertical rebar of FWS cylindrical wall due to the load combination FWSC-6 as shown in Table 3G.4-19. The maximum horizontal rebar stress is found to be 155.4 MPa (22.54 ksi) in FWS cylindrical wall due to the load combination FWSC-6. The maximum transverse shear force is found to be 0.563 MN/m (3.21 kips/in) against the shear strength of 1.550 MN/m (8.85 kips/in) in the FWS cylindrical wall.

As for the FPE, the maximum rebar stress of 238.7 MPa (34.62 ksi) is found in the horizontal rebar of east wall due to the load combination FWSC-6. The maximum vertical rebar stress is found to be 200.9 MPa (29.14 ksi) in east wall in the same load combination. The maximum transverse shear force is found to be 0.730 MN/m (4.17 kips/in) against the shear strength of 1.313 MN/m (7.50 kips/in).

3G.4.5.4.2 Roof Floor Slabs

As for the FPE roof slab, the maximum rebar stress of 260.7 MPa (37.81 ksi) is found due to the load combination FWSC-6 as shown in Table 3G.4-19. The maximum transverse shear force is

found to be 0.237 MN/m (1.35 kips/in) against the shear strength of 0.364 MN/m (2.08 kips/in) in the roof of FPE.

On the FWS roof slab, the maximum rebar stress of 191.8 MPa (27.82 ksi) is found due to the load combination FWSC-6. The maximum transverse shear force is found to be 0.103 MN/m (0.59 kips/in) against the shear strength of 0.399 MN/m (2.28 kips/in).

3G.4.5.4.3 Foundation Mat

The maximum rebar stress is found to be 294.4 MPa (42.70 ksi) due to the load combination FWSC-6 as shown in Table 3G.4-19. The maximum transverse shear force is found to be 2.674 MN/m (15.27 kips/in) against the shear strength of 4.452 MN/m (25.42 kips/in).

3G.4.5.4.4 Shear Key

The maximum rebar stress of 81.9 MPa (11.88 ksi) is found in the horizontal rebar of shear key due to the load combination FWSC-6 as shown in Table 3G.4-19. The maximum vertical rebar stress is found to be 68.0 MPa (9.86 ksi) in the same load combination. The maximum transverse shear force is found to be 0.376 MN/m (2.15 kips/in) against the shear strength of 1.253 MN/m (7.15 kips/in).

3G.4.5.5 Foundation Stability

The stabilities of the FWSC foundation against overturning, sliding and floatation are evaluated. The energy approach is used in calculating the factor of safety against overturning.

The factors of safety against overturning, sliding and floatation are given in Table 3G.4-22. All of these meet the acceptance criteria given in Table 3.8-14. Shear keys under the basemat shown in Figure 3G.4-1. are used to resist sliding.

Maximum soil bearing stress is found to be 165 kPa (3450 psf) due to dead plus live loads. Maximum bearing stresses for load combinations involving SSE are shown in Table 3G.4-23 for various site conditions.

3G.4.5.5.1 Foundation Settlement

The basemat design is checked against the normal and differential settlement of the FWSC. It is found that the basemat can resist the maximum settlement at mat foundation corner of 17 mm (0.7 in.) and the settlement averaged at four corners of 10 mm (0.4 in.). The relative displacement between two corners along the longest dimension of the building basemat calculated under linearly varying soil stiffness is 12 mm (0.5 in). These values are specified as maximum settlements in Table 2.0-1.

3G.4.5.6 Tornado Missile Evaluation

The FWSC is shown in Figure 3G.4-1.. The minimum thickness required to prevent penetration, concrete spalling and scabbing is evaluated. The methods and procedures are shown in Subsection 3.5.3.1.1.

Table 3G.4-1 Soil Spring Constants for FWSC Analysis Model

Direction of Spring		Loads	Stiffness ($MN/m/m^2$)
Horizontal	X-direction	All	15.303
	Y-direction	All	17.591
Vertical		Horizontal Seismic Loads	63.417
		Other Loads	23.861

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 $MN/m/m^2$= $6.366x10^3$ $lbf/ft/ft^2$

Table 3G.4-2 Equipment Load of FWSC

Description	Weight	Remarks
Diesel Pump Skid	106.8 kN (24,000 lbf)	
RPV Makeup Water Pump Skid	106.8 kN (24,000 lbf)	
Electric Pump Skid	89.0 kN (20,000 lbf)	
Diesel Fuel Oil Storage Tank	44.5 kN (10,000 lbf)	Each Tank
Tank Recirculation Pump	2.2 kN (500 lbf)	Each Pump

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 kN = 224.809 lbf

Table 3G.4-3 Miscellaneous Structures, Piping, and Commodity Load of FWSC

Region	Area Load
Roof of FPE	2.4 kN/m^2 (50 psf)

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 kN/m^2 = 20.885 psf

Table 3G.4-4 Equivalent Linear Temperature Distributions at Various Sections

Section(1)	Side(2)		Equivalent Linear Temperature(3)(°C) Normal Operation	
	1	2	T_d	T_g
W1	FWS	AT	-16.9	42.8
W2	FPE	AT	-22.4	31.3
S1	GR	FWS	10.0	11.0
S2	GR	FPE	10.5	10.1
S3	GR	AT	-11.8	54.6
S4	AT	FWS	-16.4	-41.7
S5	AT	FPE	-22.7	-30.6
S6	GR	GR	15.5	0.0

(1) See Figure 3G.4-7. for the location of sections.

(2) FWS: Firewater Storage Tank,
FPE: Fire Pump Enclosure,
AT: Air,
GR: Ground

(3) T_d: Average Temperature,
T_g: Surface Temperature Difference (positive when temperature at Side 1 is higher)

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1°C = (°F - 32)/1.8

Table 3G.4-5 Maximum Vertical Acceleration

Elevation (m)	Node No.	Stick Model	Max. Vertical Acceleration (g)
19.70	10	FWS	1.69
17.25	9	FWS	1.64
15.53	8	FWS	1.58
13.81	7	FWS	1.58
12.10	6	FWS	1.43
11.00	5	FWS	1.23
9.90	4	FWS	1.13
8.81	3	FWS	1.05
6.73	2	FWS	1.00
4.65	8002	FWSC	0.78
2.15	8001	FWSC	0.78
19.70	11	Oscillator	3.26

Elevation (m)	Node No.	Stick Model	Max. Vertical Acceleration (g)
8.25	405	FPE	1.12
6.45	402	FPE	1.09

See Figure 3A.7-7 for the node numbers.
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 m = 3.28 ft

Table 3G.4-6 Selected Load Combinations for FWSC

Category	**Load Combination**									**Acceptance Criteria**[*1]
	No. [*2]	D	L	H	To	E'	W	W_t	R_o	
Severe	FWSC-3	1.4	1.7	1.7			1.7		1.7	U
Environmental	FWSC-4	1.05	1.3	1.3	1.3		1.3		1.3	U
SSE	FWSC-6	1.0	1.0	1.0	1.0	1.0			1.0	U
Tornado	FWSC-7	1.0	1.0	1.0	1.0			1.0	1.0	U

**1: U = Conservatively taken as envelope of "Allowable Stress as in ASME B&PV Code Section III, Div. 2, Subsection CC-3420 for Factored Load Combination" and "Required section strength based on the strength design method per ACI 349-01".*

**2: Based on Table 3.8-15.*

Table 3G.4-7 *Results of NASTRAN Analysis: Dead Load*

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Basemat EL 4.65	18	0.054	-0.019	-0.036	-0.236	0.112	0.065	-0.073	-0.084
	227	-0.042	0.132	0.089	0.046	0.129	0.077	-0.145	-0.022
	237	0.049	-0.003	-0.042	0.084	0.199	-0.132	-0.190	0.133
	16085	-0.030	0.105	0.052	0.065	0.087	0.053	0.063	0.024
Roof of FPE EL 8.25	51556	-0.036	-0.011	0.004	0.066	0.082	-0.005	0.007	0.011
	51558	-0.040	-0.156	-0.002	-0.040	0.014	-0.011	0.062	-0.003
	51576	0.125	-0.048	0.024	0.000	-0.065	-0.009	-0.004	0.078
	51578	0.029	-0.066	0.023	-0.010	-0.020	-0.025	0.002	0.019
Roof of Tank	26007	-0.160	-0.145	-0.005	0.008	0.008	0.000	0.000	0.000
	26079	0.086	-0.084	0.021	-0.001	-0.021	0.002	-0.003	0.022
	26082	-0.007	0.010	0.091	-0.012	-0.011	0.011	-0.017	0.016
	26085	-0.040	0.045	-0.082	-0.016	-0.007	-0.009	-0.020	-0.012
South Wall of FPE	66004	-0.084	-0.071	0.032	-0.001	-0.006	0.000	0.002	0.032
	66006	-0.078	-0.002	0.174	-0.002	-0.022	-0.003	-0.007	-0.024
	66024	-0.215	-0.107	0.016	-0.014	-0.081	0.003	0.001	0.034
East Wall of FPE	67004	0.084	-0.253	-0.035	-0.006	-0.045	0.001	-0.001	-0.064
	67006	0.116	-0.080	-0.195	-0.006	-0.022	0.002	-0.002	-0.038
	67024	0.179	-0.148	-0.033	0.020	0.102	-0.002	0.000	-0.068
Wall of South Tank	35007	-0.106	-0.264	0.037	-0.006	0.008	-0.002	-0.005	0.016
	35010	-0.064	-0.436	-0.015	0.008	0.023	0.001	0.004	0.018
	36507	-0.018	-0.218	0.007	-0.007	-0.003	0.001	-0.002	-0.006
	36510	0.000	-0.258	0.000	0.005	0.000	-0.001	0.001	-0.003
	38507	0.164	-0.087	0.000	-0.004	-0.016	0.000	0.000	0.027
	38510	0.171	-0.090	0.004	-0.002	-0.016	0.000	0.000	0.029
	45001	-0.081	-0.323	0.010	-0.004	0.006	-0.002	-0.004	0.012
	46501	-0.016	-0.241	0.004	-0.004	-0.001	0.001	-0.001	-0.005
	48501	0.173	-0.091	-0.001	-0.003	-0.016	0.000	0.000	0.029
Shear Key	72008	0.007	0.115	-0.059	0.002	0.001	0.000	0.000	-0.001
	73017	-0.157	0.004	-0.222	0.002	0.003	0.002	0.001	-0.001

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.4-8 Results of NASTRAN Analysis: Thermal Load (Winter)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Basemat EL 4.65	18	8.599	0.057	2.492	-8.171	-0.926	-0.375	0.060	0.553
	227	-2.901	11.308	-0.088	-3.679	-5.852	0.556	0.159	0.124
	237	3.271	4.954	2.362	-6.091	-3.626	-1.039	-0.492	-0.446
	16085	-4.574	-1.873	1.031	-1.132	-0.048	0.345	-0.640	0.006
Roof of FPE EL 8.25	51556	0.100	0.156	0.014	-0.286	-0.237	0.001	-0.006	0.007
	51558	0.190	-0.460	-0.038	-0.194	-0.238	-0.008	-0.031	-0.001
	51576	0.794	0.118	0.100	-0.295	-0.301	0.000	-0.002	0.025
	51578	0.192	-0.230	0.013	-0.256	-0.299	-0.018	-0.031	0.043
Roof of Tank	26007	0.023	-0.036	-0.006	-0.392	-0.393	0.000	0.001	0.001
	26079	0.417	0.111	0.038	-0.446	-0.535	0.011	-0.010	0.079
	26082	0.322	0.147	0.076	-0.485	-0.483	0.042	-0.051	0.051
	26085	0.240	0.181	-0.005	-0.496	-0.461	-0.035	-0.056	-0.035
South Wall of FPE	66004	2.916	-0.130	-0.123	-0.414	-0.717	0.005	-0.005	-0.184
	66006	1.811	0.944	-0.412	-0.378	-0.693	-0.024	-0.203	-0.618
	66024	-0.091	0.007	-0.037	-0.349	-0.277	0.002	0.016	-0.217
East Wall of FPE	67004	3.209	-0.623	-0.268	0.380	0.424	-0.001	0.002	0.026
	67006	3.333	0.484	-2.062	0.317	0.398	0.006	0.135	0.170
	67024	1.582	-0.137	-0.254	0.372	0.346	0.002	-0.007	0.044
Wall of South Tank	35007	3.012	-0.603	0.194	-1.162	-1.081	-0.009	-0.072	-0.324
	35010	2.650	0.030	-0.198	-1.253	-1.254	0.033	0.015	-0.396
	36507	-0.295	-0.327	0.040	-1.147	-1.126	0.000	-0.011	0.082
	36510	-0.284	-0.025	-0.256	-1.181	-1.126	-0.005	0.015	0.078
	38507	0.103	-0.062	0.007	-1.105	-0.771	0.004	0.000	-0.181
	38510	-0.050	0.003	-0.154	-1.112	-0.771	-0.018	-0.005	-0.205
	45001	3.490	0.717	-0.047	-1.173	-1.294	-0.017	0.003	-0.402
	46501	-0.329	0.464	0.093	-1.200	-1.154	-0.002	-0.004	0.080
	48501	-0.195	0.079	0.049	-1.123	-0.772	0.006	0.002	-0.229
Shear Key	72008	0.030	-0.442	0.322	0.098	0.107	0.033	0.018	-0.058
	73017	-6.179	-0.445	-0.899	0.020	0.028	0.034	0.011	-0.015

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.4-9 Results of NASTRAN Analysis: Seismic Load (Horizontal: North to South Direction)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Basemat EL 4.65	18	0.593	0.091	0.022	-1.324	-0.118	0.229	0.540	0.107
	227	2.664	0.037	-0.677	-3.349	-1.025	-0.205	2.090	-0.375
	237	1.515	-0.244	0.179	-3.887	-0.772	0.404	0.772	-0.676
	16085	1.538	0.080	0.030	-2.242	-0.799	0.004	-0.710	-0.678
Roof of FPE EL 8.25	51556	0.027	0.050	-0.097	-0.001	-0.003	-0.003	0.003	0.000
	51558	0.052	0.429	-0.042	-0.019	-0.011	0.000	0.008	-0.001
	51576	0.025	0.018	-0.353	0.000	0.002	-0.004	-0.002	-0.002
	51578	0.017	0.123	-0.139	-0.008	0.003	-0.003	0.006	-0.010
Roof of Tank	26007	0.083	-0.075	0.006	-0.002	-0.002	0.000	-0.003	0.000
	26079	0.169	-0.104	-0.023	-0.006	-0.015	0.005	-0.001	0.009
	26082	0.075	-0.286	-0.086	0.003	0.000	-0.002	0.012	-0.007
	26085	-0.011	-0.315	0.185	0.016	0.006	0.008	0.023	0.013
South Wall of FPE	66004	0.090	-0.141	0.067	-0.006	-0.018	-0.005	-0.014	0.004
	66006	0.143	0.007	-0.313	-0.009	-0.043	-0.012	-0.003	-0.097
	66024	0.521	-0.048	0.004	-0.011	-0.024	-0.002	-0.004	0.005
East Wall of FPE	67004	0.110	-0.097	0.577	0.001	0.005	-0.003	0.001	0.003
	67006	0.515	-0.082	0.035	0.001	0.021	-0.004	0.007	0.036
	67024	0.060	-0.024	0.460	-0.001	-0.002	-0.001	0.000	0.004
Wall of South Tank	35007	0.619	-0.601	-0.978	-0.002	-0.136	-0.018	0.006	-0.155
	35010	1.208	1.697	-1.154	-0.078	-0.518	0.027	0.002	-0.460
	36507	-0.085	-0.429	-1.056	0.041	0.059	-0.007	-0.023	0.016
	36510	-0.572	0.729	-1.061	0.035	0.088	-0.016	0.020	0.037
	38507	0.167	-0.078	-0.226	0.012	0.005	0.010	0.001	0.040
	38510	-0.487	0.209	-0.372	0.011	0.027	-0.027	-0.008	0.013
	45001	1.153	3.799	0.624	-0.171	-0.688	-0.009	0.006	-0.535
	46501	-0.831	1.548	0.283	-0.048	0.065	0.007	-0.012	0.028
	48501	-0.804	0.361	0.101	-0.007	0.035	0.010	0.003	-0.021
Shear Key	72008	-0.203	-0.025	-0.364	0.101	-0.304	0.094	0.128	0.316
	73017	-3.697	1.584	1.701	-0.006	-0.007	0.003	-0.004	0.002

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.4-10 Results of NASTRAN Analysis: Seismic Load (Horizontal: West to East Direction)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Basemat EL 4.65	18	0.800	0.595	0.472	1.071	-0.398	-0.681	0.524	0.306
	227	-0.010	0.186	1.103	-0.105	-0.555	-1.480	0.412	0.297
	237	-0.135	-0.546	0.240	1.105	1.704	-1.255	-1.153	0.983
	16085	0.067	0.055	-0.142	-0.441	-0.396	-0.583	-0.156	0.043
Roof of FPE EL 8.25	51556	0.082	0.035	-0.085	-0.009	-0.007	-0.008	-0.001	0.010
	51558	0.021	-0.112	-0.268	0.009	0.004	-0.014	-0.010	-0.010
	51576	0.827	-0.008	0.031	-0.033	-0.073	0.002	-0.001	0.027
	51578	0.249	-0.109	-0.015	0.014	-0.023	0.003	-0.033	0.031
Roof of Tank	26007	-0.004	0.004	0.037	0.000	-0.001	-0.001	0.000	-0.003
	26079	0.202	0.065	0.082	0.003	0.002	0.002	-0.003	0.014
	26082	0.126	0.074	0.140	-0.011	-0.003	0.006	-0.012	0.011
	26085	-0.116	0.069	0.091	0.004	0.001	0.001	0.002	0.004
South Wall of FPE	66004	-0.132	0.151	-0.153	-0.006	-0.019	0.006	0.002	-0.015
	66006	-0.367	0.296	0.628	-0.028	-0.088	0.002	-0.003	-0.125
	66024	-0.181	0.015	0.142	0.003	0.011	-0.003	-0.007	-0.015
East Wall of FPE	67004	0.294	-0.447	-0.157	-0.035	-0.180	0.001	-0.004	-0.108
	67006	0.374	-0.117	-0.863	-0.008	-0.099	-0.001	-0.040	-0.122
	67024	1.030	-0.143	-0.112	0.011	0.045	0.005	0.004	-0.104
Wall of South Tank	35007	-0.982	-1.785	0.030	-0.003	0.317	-0.022	-0.025	0.356
	35010	-0.396	-2.459	-0.962	0.121	0.371	-0.016	0.027	0.264
	36507	0.770	-0.853	0.028	-0.079	-0.092	0.005	-0.014	-0.036
	36510	0.591	-1.094	-0.891	0.058	-0.019	-0.006	-0.015	-0.005
	38507	0.576	-0.266	0.082	-0.025	-0.037	0.016	0.005	-0.033
	38510	0.501	-0.250	-0.181	0.009	-0.025	0.011	0.002	0.014
	45001	0.183	0.655	-1.590	-0.032	-0.096	0.021	0.032	-0.066
	46501	-0.142	0.304	-1.419	-0.021	0.001	-0.023	0.018	0.001
	48501	-0.124	0.064	-0.362	-0.005	0.006	-0.018	-0.005	-0.007
Shear Key	72008	0.258	0.178	-0.032	-0.013	0.000	0.021	0.015	0.002
	73017	-0.047	0.013	0.029	-0.025	0.219	-0.344	-0.085	-0.239

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.4-11 Results of NASTRAN Analysis: Seismic Load (Vertical: Upward Direction)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Basemat EL 4.65	18	-0.236	0.036	0.135	0.943	-0.181	-0.154	0.252	0.113
	227	-0.084	-0.365	-0.358	0.152	-0.268	-0.261	0.677	0.092
	237	-0.221	-0.014	0.056	-0.064	-0.453	0.267	0.604	-0.349
	16085	-0.326	-0.406	-0.359	0.289	-0.190	-0.239	0.405	-0.026
Roof of FPE EL 8.25	51556	0.018	-0.053	-0.009	-0.079	-0.119	0.006	-0.006	-0.017
	51558	0.019	0.386	0.009	0.026	-0.031	0.016	-0.069	0.004
	51576	-0.508	0.044	-0.076	0.011	0.102	0.011	0.006	-0.113
	51578	-0.134	0.164	-0.091	0.001	0.030	0.035	0.012	-0.037
Roof of Tank	26007	0.344	0.307	0.010	-0.016	-0.016	0.000	0.001	0.000
	26079	-0.158	0.182	-0.043	0.001	0.039	-0.005	0.005	-0.044
	26082	0.033	-0.016	-0.191	0.023	0.020	-0.021	0.033	-0.031
	26085	0.098	-0.091	0.177	0.031	0.013	0.018	0.039	0.024
South Wall of FPE	66004	0.187	-0.009	-0.070	0.013	0.086	-0.002	-0.004	0.000
	66006	0.147	-0.255	-0.428	0.012	0.098	0.007	0.027	0.129
	66024	0.541	0.119	-0.029	0.014	0.091	-0.005	-0.004	-0.001
East Wall of FPE	67004	-0.357	0.551	0.144	0.012	0.084	-0.002	0.003	0.105
	67006	-0.493	-0.011	0.741	0.014	0.045	-0.002	0.003	0.071
	67024	-0.706	0.241	0.128	-0.030	-0.149	0.001	-0.001	0.109
Wall of South Tank	35007	-0.116	0.226	-0.103	-0.005	-0.126	0.004	0.012	-0.217
	35010	-0.212	0.719	0.009	-0.036	-0.159	-0.004	-0.012	-0.221
	36507	-0.773	0.317	-0.016	0.024	0.046	-0.002	0.004	0.041
	36510	-0.824	0.448	-0.016	-0.006	0.037	0.003	-0.003	0.034
	38507	-0.381	0.166	-0.002	0.007	0.020	-0.001	0.000	-0.063
	38510	-0.410	0.181	-0.022	0.001	0.021	-0.001	-0.001	-0.069
	45001	-0.170	0.472	-0.032	-0.006	-0.102	0.008	0.018	-0.200
	46501	-0.787	0.428	-0.007	0.016	0.038	-0.002	0.004	0.040
	48501	-0.425	0.187	0.006	0.004	0.020	-0.001	0.000	-0.070
Shear Key	72008	-0.225	-0.068	-0.221	-0.011	-0.010	0.002	0.000	0.005
	73017	0.888	-0.073	0.845	-0.008	-0.013	-0.009	-0.005	0.006

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.4-12 Combined Forces and Moments: Selected Load Combination FWSC-3

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Basemat EL 4.65	18	OTHR	0.220	-0.029	-0.115	-0.849	0.185	0.149	-0.185	-0.125
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	227	OTHR	0.166	0.374	0.255	-0.232	0.217	0.212	-0.430	-0.114
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	237	OTHR	0.265	-0.003	-0.040	-0.102	0.394	-0.246	-0.483	0.296
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	16085	OTHR	0.284	0.396	0.281	-0.271	0.152	0.190	-0.290	-0.027
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Roof of FPE EL 8.25	51556	OTHR	-0.039	0.031	0.006	0.101	0.138	-0.008	0.009	0.020
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	51558	OTHR	-0.037	-0.341	-0.008	-0.047	0.030	-0.019	0.092	-0.005
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	51576	OTHR	0.410	-0.058	0.057	-0.007	-0.113	-0.014	-0.007	0.131
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	51578	OTHR	0.107	-0.145	0.071	-0.009	-0.033	-0.042	-0.006	0.037
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Roof of Tank	26007	OTHR	-0.265	-0.204	-0.014	0.011	0.011	0.000	-0.002	0.000
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	26079	OTHR	0.107	-0.123	0.041	-0.001	-0.028	0.004	-0.004	0.032
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	26082	OTHR	-0.037	0.030	0.139	-0.017	-0.014	0.014	-0.022	0.021
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	26085	OTHR	-0.076	0.077	-0.135	-0.023	-0.009	-0.013	-0.026	-0.016
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
South Wall of FPE	66004	OTHR	-0.173	-0.049	0.076	-0.009	-0.061	0.001	0.004	0.028
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	66006	OTHR	-0.134	0.168	0.383	-0.009	-0.081	-0.007	-0.023	-0.103
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	66024	OTHR	-0.478	-0.157	0.030	-0.020	-0.122	0.005	0.003	0.024
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
East Wall of FPE	67004	OTHR	0.289	-0.539	-0.091	-0.012	-0.087	0.002	-0.003	-0.121
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	67006	OTHR	0.430	-0.048	-0.615	-0.014	-0.044	0.003	-0.002	-0.073
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	67024	OTHR	0.574	-0.264	-0.091	0.034	0.173	-0.002	0.001	-0.116
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wall of South Tank	35007	OTHR	0.059	-0.269	0.029	0.001	0.097	-0.005	-0.011	0.169
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	35010	OTHR	0.202	-0.655	-0.110	0.027	0.103	0.003	0.012	0.149
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	36507	OTHR	0.595	-0.270	-0.040	-0.023	-0.038	0.001	-0.005	-0.031
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	36510	OTHR	0.607	-0.373	-0.054	0.008	-0.023	-0.005	0.002	-0.024
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	38507	OTHR	0.281	-0.120	0.003	-0.007	-0.016	0.002	0.000	0.042
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	38510	OTHR	0.291	-0.134	0.025	0.000	-0.012	0.003	0.001	0.050
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	45001	OTHR	0.171	-0.295	0.077	-0.005	0.039	-0.007	-0.015	0.120
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	46501	OTHR	0.557	-0.328	0.025	-0.010	-0.021	0.003	-0.002	-0.030
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	48501	OTHR	0.306	-0.143	-0.007	0.000	-0.009	0.000	0.000	0.054
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Shear Key	72008	OTHR	0.165	0.148	0.126	0.012	0.008	0.002	0.005	-0.004
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	73017	OTHR	-0.854	0.175	-0.613	0.006	0.010	0.007	0.004	-0.005
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

OTHR: Loads other than thermal loads
TEMP: Thermal loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.4-13 Combined Forces and Moments: Selected Load Combination FWSC-4

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Basemat EL 4.65	18	OTHR	0.165	-0.021	-0.086	-0.638	0.139	0.112	-0.138	-0.093
		TEMP	11.178	0.074	3.240	-10.622	-1.204	-0.488	0.078	0.719
	227	OTHR	0.126	0.281	0.190	-0.176	0.162	0.159	-0.321	-0.086
		TEMP	-3.772	14.700	-0.114	-4.782	-7.608	0.723	0.207	0.161
	237	OTHR	0.200	-0.002	-0.030	-0.079	0.295	-0.184	-0.361	0.222
		TEMP	4.252	6.441	3.070	-7.918	-4.714	-1.350	-0.640	-0.580
	16085	OTHR	0.214	0.297	0.210	-0.204	0.113	0.143	-0.217	-0.021
		TEMP	-5.946	-2.435	1.340	-1.471	-0.062	0.448	-0.833	0.007
Roof of FPE EL 8.25	51556	OTHR	-0.029	0.023	0.005	0.076	0.104	-0.006	0.007	0.015
		TEMP	0.130	0.203	0.018	-0.371	-0.308	0.001	-0.008	0.009
	51558	OTHR	-0.028	-0.255	-0.006	-0.035	0.023	-0.014	0.069	-0.004
		TEMP	0.247	-0.598	-0.050	-0.253	-0.309	-0.010	-0.040	-0.001
	51576	OTHR	0.307	-0.043	0.042	-0.005	-0.085	-0.011	-0.005	0.098
		TEMP	1.032	0.154	0.130	-0.384	-0.391	0.000	-0.003	0.032
	51578	OTHR	0.080	-0.109	0.053	-0.007	-0.025	-0.032	-0.004	0.028
		TEMP	0.250	-0.299	0.016	-0.333	-0.389	-0.023	-0.040	0.056
Roof of Tank	26007	OTHR	-0.199	-0.153	-0.011	0.008	0.008	0.000	-0.002	0.000
		TEMP	0.030	-0.047	-0.008	-0.510	-0.511	0.000	0.002	0.001
	26079	OTHR	0.080	-0.093	0.031	0.000	-0.021	0.003	-0.003	0.024
		TEMP	0.543	0.144	0.050	-0.580	-0.696	0.015	-0.013	0.102
	26082	OTHR	-0.028	0.023	0.105	-0.013	-0.010	0.011	-0.017	0.016
		TEMP	0.418	0.191	0.099	-0.631	-0.628	0.055	-0.067	0.066
	26085	OTHR	-0.057	0.058	-0.101	-0.017	-0.007	-0.010	-0.020	-0.012
		TEMP	0.311	0.235	-0.007	-0.644	-0.599	-0.046	-0.073	-0.045
South Wall of FPE	66004	OTHR	-0.130	-0.037	0.057	-0.007	-0.046	0.001	0.003	0.021
		TEMP	3.790	-0.169	-0.160	-0.538	-0.932	0.006	-0.006	-0.239
	66006	OTHR	-0.100	0.126	0.286	-0.006	-0.061	-0.005	-0.018	-0.078
		TEMP	2.355	1.227	-0.536	-0.492	-0.900	-0.032	-0.264	-0.803
	66024	OTHR	-0.358	-0.118	0.023	-0.015	-0.092	0.004	0.002	0.018
		TEMP	-0.119	0.009	-0.049	-0.453	-0.360	0.002	0.020	-0.282
East Wall of FPE	67004	OTHR	0.217	-0.404	-0.068	-0.009	-0.065	0.001	-0.002	-0.091
		TEMP	4.172	-0.810	-0.348	0.494	0.551	-0.002	0.002	0.034
	67006	OTHR	0.323	-0.036	-0.461	-0.010	-0.033	0.002	-0.001	-0.055
		TEMP	4.333	0.630	-2.681	0.412	0.518	0.008	0.176	0.222
	67024	OTHR	0.430	-0.198	-0.068	0.026	0.130	-0.002	0.001	-0.087
		TEMP	2.057	-0.179	-0.330	0.484	0.450	0.003	-0.009	0.057
Wall of South Tank	35007	OTHR	0.045	-0.203	0.020	0.001	0.073	-0.004	-0.008	0.127
		TEMP	3.916	-0.784	0.253	-1.510	-1.405	-0.012	-0.093	-0.422
	35010	OTHR	0.153	-0.491	-0.084	0.020	0.077	0.002	0.009	0.111
		TEMP	3.445	0.040	-0.257	-1.628	-1.630	0.043	0.020	-0.515
	36507	OTHR	0.447	-0.203	-0.031	-0.018	-0.029	0.001	-0.004	-0.023
		TEMP	-0.384	-0.425	0.052	-1.491	-1.464	-0.001	-0.014	0.106
	36510	OTHR	0.455	-0.279	-0.041	0.006	-0.017	-0.003	0.001	-0.018
		TEMP	-0.369	-0.033	-0.333	-1.535	-1.464	-0.006	0.019	0.102
	38507	OTHR	0.212	-0.090	0.002	-0.005	-0.012	0.001	0.000	0.032
		TEMP	0.134	-0.081	0.009	-1.437	-1.002	0.005	0.001	-0.236
	38510	OTHR	0.219	-0.100	0.019	0.000	-0.009	0.002	0.001	0.038
		TEMP	-0.065	0.003	-0.200	-1.446	-1.003	-0.023	-0.007	-0.266
	45001	OTHR	0.130	-0.220	0.059	-0.004	0.029	-0.005	-0.011	0.089
		TEMP	4.537	0.932	-0.061	-1.525	-1.682	-0.022	0.004	-0.522
	46501	OTHR	0.417	-0.245	0.019	-0.007	-0.016	0.002	-0.002	-0.023
		TEMP	-0.427	0.603	0.120	-1.560	-1.500	-0.003	-0.005	0.104
	48501	OTHR	0.230	-0.107	-0.005	0.000	-0.007	0.000	0.000	0.041
		TEMP	-0.253	0.103	0.064	-1.459	-1.004	0.008	0.002	-0.298
Shear Key	72008	OTHR	0.123	0.111	0.094	0.009	0.006	0.001	0.004	-0.003
		TEMP	0.038	-0.574	0.418	0.127	0.139	0.043	0.024	-0.076
	73017	OTHR	-0.643	0.132	-0.458	0.005	0.007	0.005	0.003	-0.004
		TEMP	-8.033	-0.578	-1.169	0.026	0.037	0.044	0.014	-0.019

OTHR: Loads other than thermal loads
TEMP: Thermal loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.4-14 Combined Forces and Moments: Selected Load Combination FWSC-6

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Basemat EL 4.65	18	OTHR	0.136	-0.025	-0.082	-0.547	0.146	0.101	-0.151	-0.099
		TEMP	8.599	0.057	2.492	-8.171	-0.926	-0.375	0.060	0.553
		SEIS	1.026	0.603	0.495	1.947	0.453	0.735	0.794	0.343
	227	OTHR	0.015	0.250	0.212	-0.033	0.201	0.158	-0.382	-0.064
		TEMP	-2.901	11.308	-0.088	-3.679	-5.852	0.556	0.159	0.124
		SEIS	2.665	0.412	1.364	3.354	1.197	1.518	2.235	0.488
	237	OTHR	0.125	0.007	-0.044	0.072	0.311	-0.187	-0.371	0.229
		TEMP	3.271	4.954	2.362	-6.091	-3.626	-1.039	-0.492	-0.446
		SEIS	1.544	0.600	0.321	4.042	1.925	1.345	1.513	1.244
	16085	OTHR	0.156	0.258	0.200	-0.119	0.146	0.136	-0.186	0.007
		TEMP	-4.574	-1.873	1.031	-1.132	-0.048	0.345	-0.640	0.006
		SEIS	1.574	0.418	0.397	2.303	0.912	0.630	0.833	0.681
Roof of FPE EL 8.25	51556	OTHR	-0.033	0.013	0.006	0.080	0.108	-0.006	0.008	0.015
		TEMP	0.100	0.156	0.014	-0.286	-0.237	0.001	-0.006	0.007
		SEIS	0.088	0.081	0.130	0.079	0.120	0.010	0.007	0.020
	51558	OTHR	-0.036	-0.265	-0.005	-0.039	0.023	-0.015	0.073	-0.004
		TEMP	0.190	-0.460	-0.038	-0.194	-0.238	-0.008	-0.031	-0.001
		SEIS	0.060	0.588	0.272	0.033	0.033	0.022	0.071	0.011
	51576	OTHR	0.292	-0.052	0.047	-0.004	-0.088	-0.011	-0.005	0.102
		TEMP	0.794	0.118	0.100	-0.295	-0.301	0.000	-0.002	0.025
		SEIS	0.971	0.048	0.363	0.035	0.125	0.012	0.006	0.116
	51578	OTHR	0.074	-0.112	0.053	-0.008	-0.026	-0.032	-0.003	0.028
		TEMP	0.192	-0.230	0.013	-0.256	-0.299	-0.018	-0.031	0.043
		SEIS	0.283	0.233	0.167	0.016	0.038	0.036	0.036	0.049
Roof of Tank	26007	OTHR	-0.217	-0.194	-0.006	0.010	0.010	0.000	0.000	0.000
		TEMP	0.023	-0.036	-0.006	-0.392	-0.393	0.000	0.001	0.001
		SEIS	0.354	0.316	0.038	0.016	0.016	0.001	0.003	0.003
	26079	OTHR	0.103	-0.115	0.028	-0.001	-0.025	0.003	-0.003	0.028
		TEMP	0.417	0.111	0.038	-0.446	-0.535	0.011	-0.010	0.079
		SEIS	0.307	0.220	0.095	0.007	0.042	0.007	0.006	0.047
	26082	OTHR	-0.019	0.010	0.121	-0.015	-0.013	0.013	-0.021	0.020
		TEMP	0.322	0.147	0.076	-0.485	-0.483	0.042	-0.051	0.051
		SEIS	0.151	0.296	0.252	0.026	0.020	0.022	0.037	0.034
	26085	OTHR	-0.061	0.058	-0.111	-0.020	-0.008	-0.012	-0.025	-0.015
		TEMP	0.240	0.181	-0.005	-0.496	-0.461	-0.035	-0.056	-0.035
		SEIS	0.152	0.335	0.272	0.035	0.014	0.020	0.046	0.028

Table 3G.4-14 Combined Forces and Moments: Selected Load Combination FWSC-6 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
South Wall of FPE	66004	OTHR	-0.132	-0.039	0.053	-0.006	-0.040	0.001	0.003	0.023
		TEMP	2.916	-0.130	-0.123	-0.414	-0.717	0.005	-0.005	-0.184
		SEIS	0.246	0.207	0.204	0.015	0.090	0.008	0.014	0.015
	66006	OTHR	-0.109	0.109	0.291	-0.006	-0.055	-0.005	-0.016	-0.069
		TEMP	1.811	0.944	-0.412	-0.378	-0.693	-0.024	-0.203	-0.618
		SEIS	0.420	0.392	0.825	0.032	0.139	0.014	0.027	0.204
	66024	OTHR	-0.367	-0.122	0.023	-0.016	-0.095	0.004	0.002	0.025
		TEMP	-0.091	0.007	-0.037	-0.349	-0.277	0.002	0.016	-0.217
		SEIS	0.772	0.129	0.167	0.018	0.095	0.006	0.009	0.016
East Wall of FPE	67004	OTHR	0.205	-0.394	-0.083	-0.009	-0.065	0.001	-0.002	-0.088
		TEMP	3.209	-0.623	-0.268	0.380	0.424	-0.001	0.002	0.026
		SEIS	0.475	0.716	0.617	0.037	0.199	0.004	0.005	0.150
	67006	OTHR	0.283	-0.042	-0.435	-0.010	-0.033	0.002	-0.002	-0.054
		TEMP	3.333	0.484	-2.062	0.317	0.398	0.006	0.135	0.170
		SEIS	0.805	0.146	1.139	0.016	0.110	0.005	0.040	0.146
	67024	OTHR	0.410	-0.200	-0.075	0.026	0.133	-0.002	0.001	-0.092
		TEMP	1.582	-0.137	-0.254	0.372	0.346	0.002	-0.007	0.044
		SEIS	1.250	0.281	0.492	0.032	0.156	0.005	0.005	0.151
Wall of South Tank	35007	OTHR	0.019	-0.186	0.072	0.000	0.070	-0.003	-0.008	0.121
		TEMP	3.012	-0.603	0.194	-1.162	-1.081	-0.009	-0.072	-0.324
		SEIS	1.167	1.897	0.991	0.006	0.368	0.029	0.028	0.445
	35010	OTHR	0.088	-0.517	-0.014	0.022	0.093	0.003	0.008	0.123
		TEMP	2.650	0.030	-0.198	-1.253	-1.254	0.033	0.015	-0.396
		SEIS	1.289	3.073	1.507	0.149	0.657	0.032	0.030	0.575
	36507	OTHR	0.401	-0.211	0.011	-0.016	-0.026	0.002	-0.003	-0.023
		TEMP	-0.295	-0.327	0.040	-1.147	-1.126	0.000	-0.011	0.082
		SEIS	1.094	1.006	1.059	0.092	0.119	0.009	0.027	0.057
	36510	OTHR	0.436	-0.296	0.006	0.005	-0.020	-0.002	0.002	-0.019
		TEMP	-0.284	-0.025	-0.256	-1.181	-1.126	-0.005	0.015	0.078
		SEIS	1.165	1.389	1.387	0.068	0.098	0.017	0.026	0.051
	38507	OTHR	0.237	-0.106	0.001	-0.005	-0.014	0.001	0.000	0.039
		TEMP	0.103	-0.062	0.007	-1.105	-0.771	0.004	0.000	-0.181
		SEIS	0.711	0.323	0.242	0.029	0.042	0.019	0.005	0.082
	38510	OTHR	0.254	-0.115	0.012	-0.001	-0.015	0.001	0.000	0.043
		TEMP	-0.050	0.003	-0.154	-1.112	-0.771	-0.018	-0.005	-0.205
		SEIS	0.810	0.372	0.415	0.015	0.043	0.029	0.009	0.071
	45001	OTHR	0.057	-0.328	0.025	0.002	0.058	-0.005	-0.011	0.111
		TEMP	3.490	0.717	-0.047	-1.173	-1.294	-0.017	0.003	-0.402
		SEIS	1.180	3.884	1.713	0.174	0.702	0.024	0.037	0.575
	46501	OTHR	0.409	-0.273	0.006	-0.010	-0.021	0.002	-0.003	-0.023
		TEMP	-0.329	0.464	0.093	-1.200	-1.154	-0.002	-0.004	0.080
		SEIS	1.154	1.634	1.448	0.054	0.075	0.024	0.022	0.048
	48501	OTHR	0.262	-0.117	-0.003	-0.003	-0.014	0.000	0.000	0.043
		TEMP	-0.195	0.079	0.049	-1.123	-0.772	0.006	0.002	-0.229
		SEIS	0.918	0.412	0.377	0.009	0.041	0.020	0.005	0.073
Shear Key	72008	OTHR	0.130	0.104	0.106	0.006	0.005	-0.001	0.000	-0.003
		TEMP	0.030	-0.442	0.322	0.098	0.107	0.033	0.018	-0.058
		SEIS	0.398	0.192	0.427	0.102	0.304	0.096	0.129	0.316
	73017	OTHR	-0.472	0.064	-0.497	0.005	0.007	0.005	0.003	-0.003
		TEMP	-6.179	-0.445	-0.899	0.020	0.028	0.034	0.011	-0.015
		SEIS	3.802	1.586	1.899	0.032	0.219	0.344	0.085	0.239

OTHR: Loads other than thermal and seismic loads
TEMP: Thermal loads
SEIS: Seismic loads SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = $6.852x10^4$ lbf/ft
1 MNm/m = $2.248x10^5$ lbf-ft/ft

Table 3G.4-15 Combined Forces and Moments: Selected Load Combination FWSC-7

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
Basemat EL 4.65	18	OTHR	0.182	-0.015	-0.085	-0.690	0.111	0.118	-0.114	-0.073
		TEMP	8.599	0.057	2.492	-8.171	-0.926	-0.375	0.060	0.553
	227	OTHR	0.259	0.286	0.149	-0.352	0.101	0.147	-0.228	-0.107
		TEMP	-2.901	11.308	-0.088	-3.679	-5.852	0.556	0.159	0.124
	237	OTHR	0.269	-0.015	-0.012	-0.258	0.245	-0.158	-0.316	0.189
		TEMP	3.271	4.954	2.362	-6.091	-3.626	-1.039	-0.492	-0.446
	16085	OTHR	0.267	0.311	0.209	-0.294	0.070	0.142	-0.250	-0.054
		TEMP	-4.574	-1.873	1.031	-1.132	-0.048	0.345	-0.640	0.006
Roof of FPE EL 8.25	51556	OTHR	-0.015	0.042	0.002	0.046	0.070	-0.004	0.004	0.010
		TEMP	0.100	0.156	0.014	-0.286	-0.237	0.001	-0.006	0.007
	51558	OTHR	-0.004	-0.215	-0.008	-0.014	0.018	-0.010	0.040	-0.002
		TEMP	0.190	-0.460	-0.038	-0.194	-0.238	-0.008	-0.031	-0.001
	51576	OTHR	0.306	-0.017	0.032	-0.007	-0.059	-0.006	-0.003	0.066
		TEMP	0.794	0.118	0.100	-0.295	-0.301	0.000	-0.002	0.025
	51578	OTHR	0.086	-0.089	0.046	0.000	-0.017	-0.021	-0.008	0.022
		TEMP	0.192	-0.230	0.013	-0.256	-0.299	-0.018	-0.031	0.043
Roof of Tank	26007	OTHR	-0.124	-0.051	-0.015	0.003	0.004	0.000	-0.004	0.000
		TEMP	0.023	-0.036	-0.006	-0.392	-0.393	0.000	0.001	0.001
	26079	OTHR	0.023	-0.033	0.030	0.000	-0.008	0.003	-0.001	0.010
		TEMP	0.417	0.111	0.038	-0.446	-0.535	0.011	-0.010	0.079
	26082	OTHR	-0.034	0.036	0.053	-0.006	-0.003	0.004	-0.005	0.005
		TEMP	0.322	0.147	0.076	-0.485	-0.483	0.042	-0.051	0.051
	26085	OTHR	-0.037	0.044	-0.059	-0.008	-0.003	-0.004	-0.006	-0.004
		TEMP	0.240	0.181	-0.005	-0.496	-0.461	-0.035	-0.056	-0.035

Table 3G.4-15 Combined Forces and Moments: Selected Load Combination FWSC-7 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
South Wall of FPE	66004	OTHR	-0.114	-0.002	0.058	-0.008	-0.054	0.001	0.002	0.005
		TEMP	2.916	-0.130	-0.123	-0.414	-0.717	0.005	-0.005	-0.184
	66006	OTHR	-0.082	0.139	0.253	-0.008	-0.064	-0.005	-0.017	-0.084
		TEMP	1.811	0.944	-0.412	-0.378	-0.693	-0.024	-0.203	-0.618
	66024	OTHR	-0.309	-0.074	0.021	-0.008	-0.055	0.003	0.002	-0.006
		TEMP	-0.091	0.007	-0.037	-0.349	-0.277	0.002	0.016	-0.217
East Wall of FPE	67004	OTHR	0.215	-0.353	-0.045	-0.008	-0.055	0.001	-0.002	-0.073
		TEMP	3.209	-0.623	-0.268	0.380	0.424	-0.001	0.002	0.026
	67006	OTHR	0.341	-0.019	-0.454	-0.009	-0.028	0.002	-0.001	-0.047
		TEMP	3.333	0.484	-2.062	0.317	0.398	0.006	0.135	0.170
	67024	OTHR	0.426	-0.150	-0.053	0.018	0.090	-0.001	0.001	-0.059
		TEMP	1.582	-0.137	-0.254	0.372	0.346	0.002	-0.007	0.044
Wall of South Tank	35007	OTHR	0.060	-0.180	-0.040	0.001	0.071	-0.005	-0.007	0.123
		TEMP	3.012	-0.603	0.194	-1.162	-1.081	-0.009	-0.072	-0.324
	35010	OTHR	0.209	-0.397	-0.158	0.016	0.052	0.001	0.010	0.086
		TEMP	2.650	0.030	-0.198	-1.253	-1.254	0.033	0.015	-0.396
	36507	OTHR	0.451	-0.152	-0.075	-0.019	-0.031	0.001	-0.005	-0.020
		TEMP	-0.295	-0.327	0.040	-1.147	-1.126	0.000	-0.011	0.082
	36510	OTHR	0.428	-0.216	-0.091	0.008	-0.013	-0.005	0.000	-0.014
		TEMP	-0.284	-0.025	-0.256	-1.181	-1.126	-0.005	0.015	0.078
	38507	OTHR	0.115	-0.043	0.005	-0.005	-0.004	0.003	0.000	0.012
		TEMP	0.103	-0.062	0.007	-1.105	-0.771	0.004	0.000	-0.181
	38510	OTHR	0.112	-0.056	0.026	0.003	0.003	0.004	0.001	0.021
		TEMP	-0.050	0.003	-0.154	-1.112	-0.771	-0.018	-0.005	-0.205
	45001	OTHR	0.195	-0.053	0.094	-0.011	-0.009	-0.004	-0.011	0.054
		TEMP	3.490	0.717	-0.047	-1.173	-1.294	-0.017	0.003	-0.402
	46501	OTHR	0.379	-0.173	0.032	-0.003	-0.007	0.003	-0.001	-0.019
		TEMP	-0.329	0.464	0.093	-1.200	-1.154	-0.002	-0.004	0.080
	48501	OTHR	0.126	-0.068	-0.007	0.004	0.006	-0.001	0.000	0.026
		TEMP	-0.195	0.079	0.049	-1.123	-0.772	0.006	0.002	-0.229
Shear Key	72008	OTHR	0.112	0.106	0.084	0.012	0.007	0.004	0.007	-0.003
		TEMP	0.030	-0.442	0.322	0.098	0.107	0.033	0.018	-0.058
	73017	OTHR	-0.800	0.216	-0.375	0.004	0.007	0.005	0.003	-0.003
		TEMP	-6.179	-0.445	-0.899	0.020	0.028	0.034	0.011	-0.015

OTHR: Loads other than thermal loads
TEMP: Thermal loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.4-16 Sectional Thicknesses and Rebar Ratios Used in the Evaluation

Location	Element ID	Thickness (m)	Primary Reinforcement					Shear Tie	
			Position	Direction 1[*1]		Direction 2[*1]			
				Arrangement	Ratio (%)	Arrangement	Ratio (%)	Arrangement	Ratio (%)
Basemat EL 4.65	18	2.50	Top	3-#11@200	0.604	3-#11@200	0.604	#7@400x400	0.242
			Bottom	3-#11@200	0.604	3-#11@200	0.604		
	227 237 16085	2.50	Top	3-#11@200 + 1-#11@400	0.705	3-#11@200 + 1-#11@400	0.705	#7@400x200	0.484
			Bottom	3-#11@200	0.604	3-#11@200	0.604		
Roof of FPE EL 8.25	51556 51558 51576 51578	0.60	Top	1-#11@200	0.839	1-#11@200	0.839	-	-
			Bottom	1-#11@200	0.839	1-#11@200	0.839		
Roof of Tank	26007 26079 26082 26085	0.60	Top	1-#9@200	0.538	1-#9@200	0.538	-	-
			Bottom	1-#9@200	0.538	1-#9@200	0.538		

Table 3G.4-16 Sectional Thicknesses and Rebar Ratios Used in the Evaluation (Continued)

Location	Element ID	Thickness (m)	Primary Reinforcement					Shear Tie	
			Position	Directtion 1[*1]		Directtion 2[*1]			
				Arrangement	Ratio (%)	Arrangement	Ratio (%)	Arrangement	Ratio (%)
South Wall of FPE	66004	0.65	Inside	1-#11@200	0.774	1-#11@200	0.774	-	-
			Outside	2-#11@200	1.548	2-#11@200	1.548		
	66006	0.65	Inside	1-#11@200	0.774	1-#11@133	1.164	#6@200x200	0.710
			Outside	2-#11@200	1.548	1-#11@133 + 1-#11@200	1.938		
	66024	0.65	Inside	1-#11@200	0.774	1-#11@200	0.774	-	-
			Outside	1-#11@200 + 1-#11@400	1.161	1-#11@200 + 1-#11@400	1.161		
East Wall of FPE	67004	0.65	Inside	1-#11@200	0.774	1-#11@133	1.164	-	-
			Outside	2-#11@200	1.548	2-#11@200	1.548		
	67006	0.65	Inside	1-#11@200	0.774	1-#11@133	1.164	#6@200x200	0.710
			Outside	2-#11@200	1.548	1-#11@133 + 1-#11@200	1.938		
	67024	0.65	Inside	1-#11@200	0.774	1-#11@133	1.164	-	-
			Outside	1-#11@200 + 1-#11@400	1.161	1-#11@200 + 1-#11@400	1.161		
Wall of South Tank	35007 35010 45001	1.00	Inside	1-#11@150 + 1-#11@300	1.006	2-#11@150[*2]	1.342	#6@150[*2]x300	0.631
			Outside	2-#11@150 + 1-#11@300	1.677	2-#11@150[*2] + 1-#11@300[*3]	1.677		
	36507 36510 46501	1.00	Inside	1-#11@150	0.671	1-#11@150[*2]	0.671	-	-
			Outside	2-#11@150	1.342	2-#11@150[*2]	1.342		
	38507 38510 48501	1.00	Inside	1-#11@150	0.671	1-#11@150[*2]	0.671	-	-
			Outside	1-#11@150	0.671	1-#11@150[*2]	0.671		
Shear key	72008	2.00	Inside	1-#11@200 + 1-#11@400	0.377	1-#11@200 + 1-#11@400	0.377	-	-
			Outside	1-#11@200 + 1-#11@400	0.377	1-#11@200 + 1-#11@400	0.377		
	73017	2.00	Inside	3-#11@200	0.755	2-#11@200 + 1-#11@400	0.629	#6@400x400	0.177
			Outside	3-#11@200	0.755	2-#11@200 + 1-#11@400	0.629		

Note *1: Wall — Direction 1:Horizontal, Direction 2:Vertical
Basemat, Slab ,Roof — Direction 1:N-S, Direction 2:E-W

Note *2: Rebar described as @150 is arranged by @1°

Note *3: Rebar described as @300 is arranged by @2°

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 m = 3.28 ft

Table 3G.4-17 Rebar and Concrete Stresses: Selected Load Combination FWSC-3

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				X-direction*		Y-direction*		
				+Z side*	-Z side*	+Z side*	-Z side*	
Basemat EL 4.65	18	-1.6	-20.7	40.2	-5.6	5.9	6.0	372.2
	227	-0.8		13.2	14.6	4.6	34.1	
	237	-1.1		21.5	8.1	-10.0	30.0	
	16085	-0.7		19.5	15.6	9.1	33.0	
Roof of FPE EL 8.25	51556	-5.0	-25.9	-4.9	39.6	2.3	69.8	372.2
	51558	-1.5		18.3	-3.8	-4.5	-1.4	
	51576	-5.2		56.6	23.1	62.9	-5.1	
	51578	-2.8		34.1	6.2	23.3	-1.4	
Roof of Tank	26007	-0.6	-25.9	-3.2	-1.9	-2.3	-1.2	372.2
	26079	-0.8		18.4	17.9	4.9	-1.9	
	26082	-1.0		18.9	17.1	26.1	21.9	
	26085	-0.9		19.5	9.5	28.4	28.3	
South Wall of FPE	66004	-1.9	-25.9	1.3	-0.9	15.3	-1.7	372.2
	66006	-2.8		23.2	7.9	45.1	5.0	
	66024	-3.5		-3.8	-4.3	29.4	-4.0	
East Wall of FPE	67004	-2.5	-25.9	32.5	14.1	4.1	-6.5	372.2
	67006	-2.0		89.6	52.5	83.0	16.8	
	67024	-6.1		25.2	62.5	-9.0	45.2	
Wall of South Tank	35007	-0.9	-25.9	1.7	3.3	-3.4	2.5	372.2
	35010	-1.1		4.3	16.1	-5.2	-1.0	
	36507	-0.4		24.9	39.7	2.6	-4.7	
	36510	-0.5		21.4	48.8	-1.5	-1.4	
	38507	-0.2		20.1	21.8	-0.6	-0.9	
	38510	-0.2		19.4	24.7	-0.7	-0.8	
	45001	-0.5		6.2	8.6	-1.6	-0.3	
	46501	-0.4		21.6	40.0	-1.7	-1.8	
	48501	-0.2		20.4	25.2	-0.5	-1.1	
Shear Key	72008	-0.1	-20.7	18.1	20.2	17.5	19.1	372.2
	73017	-0.7		5.8	5.6	20.8	21.4	

Note: Negative value means compression.

* for denominations of table columns, see the definition of local coordinate in Figure 3G.4-10

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.4-18 Rebar and Concrete Stresses: Selected Load Combination FWSC-4

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated				Allowable
		Calculated	Allowable	X-direction*		Y-direction*		
				+Z side*	-Z side*	+Z side*	-Z side*	
Basemat EL 4.65	18	-3.9	-23.5	179.4	0.6	62.2	6.8	372.2
	227	-5.1		17.0	-29.7	84.2	27.7	
	237	-4.9		129.0	-7.5	87.7	15.1	
	16085	-3.9		-8.4	-24.1	-5.0	-2.1	
Roof of FPE EL 8.25	51556	-2.7	-29.3	45.4	-5.3	26.3	6.5	372.2
	51558	-4.4		47.4	-2.0	5.4	-15.9	
	51576	-9.0		121.0	19.9	124.3	0.0	
	51578	-7.3		69.1	3.9	59.0	-7.3	
Roof of Tank	26007	-3.3	-29.3	32.3	-8.6	28.7	-2.8	372.2
	26079	-5.3		92.7	6.5	78.8	1.7	
	26082	-6.2		141.1	0.1	127.4	14.7	
	26085	-4.7		105.0	-2.9	97.8	15.0	
South Wall of FPE	66004	-9.9	-29.3	55.3	23.3	71.4	-13.9	372.2
	66006	-9.5		82.7	26.7	120.4	13.9	
	66024	-5.1		16.5	-11.0	48.0	-2.0	
East Wall of FPE	67004	-5.5	-29.3	42.4	72.7	-24.6	8.5	372.2
	67006	-8.9		51.7	148.5	11.9	135.5	
	67024	-9.4		35.0	111.7	-9.4	76.3	
Wall of South Tank	35007	-7.1	-29.3	82.5	19.3	38.2	-10.2	372.2
	35010	-6.7		84.5	17.8	44.2	-5.9	
	36507	-5.8		73.6	-5.0	44.4	-9.8	
	36510	-6.4		74.9	-4.5	48.4	-7.2	
	38507	-3.7		87.6	2.2	35.6	-1.2	
	38510	-4.0		86.1	0.8	34.9	-0.7	
	45001	-5.4		85.2	25.1	48.0	0.8	
	46501	-5.9		73.5	-6.0	50.9	-3.3	
	48501	-4.1		86.1	-0.5	35.0	0.1	
SHEARKEY	72008	-0.5	-23.5	24.5	32.2	7.7	14.9	372.2
	73017	-4.1		-31.0	-30.6	3.2	3.8	

Note: Negative value means compression.

* See the definition of local coordinate in Figure 3G.4-10.

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.4-19 Rebar and Concrete Stresses: Selected Load Combination FWSC-6

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				X-direction*		Y-direction*		
				+Z side*	-Z side*	+Z side*	-Z side*	
Basemat EL 4.65	18	-5.7	-23.5	229.9	3.9	43.4	33.9	372.2
	227	-12.4		30.2	124.9	111.0	117.3	
	237	-13.7		294.4	97.7	195.0	98.8	
	16085	-5.8		-12.6	-35.5	-11.0	9.3	
Roof of FPE EL 8.25	51556	-10.2	-29.3	33.5	16.8	33.5	108.2	372.2
	51558	-4.9		63.9	5.2	51.2	-19.6	
	51576	-15.1		260.7	78.9	246.7	6.2	
	51578	-8.8		123.1	15.9	67.8	-11.6	
Roof of Tank	26007	-2.4	-29.3	64.6	-10.9	57.4	9.7	372.2
	26079	-6.1		140.6	29.6	72.5	11.5	
	26082	-4.4		179.2	21.9	191.8	42.9	
	26085	-3.3		171.9	13.6	180.0	63.5	
South Wall of FPE	66004	-10.0	-29.3	75.9	31.6	72.8	-13.7	372.2
	66006	-12.8		145.4	66.3	192.4	14.6	
	66024	-7.4		70.6	-16.1	67.4	7.1	
East Wall of FPE	67004	-12.8	-29.3	60.1	121.3	-35.5	43.2	372.2
	67006	-7.4		157.1	222.4	9.1	200.9	
	67024	-17.4		103.2	238.7	-17.5	159.2	
Wall of South Tank	35007	-11.4	-29.3	121.6	58.6	74.1	35.0	372.2
	35010	-11.3		141.1	51.9	61.5	194.1	
	36507	-6.9		139.3	31.1	92.4	22.8	
	36510	-4.7		149.4	41.5	115.3	70.9	
	38507	-2.8		137.9	27.9	50.7	9.6	
	38510	-3.5		149.9	42.5	64.8	15.4	
	45001	-11.9		138.0	102.7	83.3	264.5	
	46501	-4.5		147.8	39.0	131.3	122.2	
	48501	-3.0		155.4	39.6	64.1	16.5	
SHEARKEY	72008	-1.2	-23.5	66.1	81.9	22.2	41.1	372.2
	73017	-5.8		-36.4	-36.2	68.0	39.5	

Note: Negative value means compression.

* See the definition of local coordinate in Figure 3G.4-10.

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.4-20 Rebar and Concrete Stresses: Selected Load Combination FWSC-7

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				X-direction*		Y-direction*		
				+Z side*	-Z side*	+Z side*	-Z side*	
Basemat EL 4.65	18	-3.2	-23.5	144.8	-0.3	46.0	5.7	372.2
	227	-4.2		20.6	-23.0	67.6	22.6	
	237	-4.3		114.4	-6.3	79.4	11.2	
	16085	-3.1		-5.6	-18.9	-3.7	-1.4	
Roof of FPE EL 8.25	51556	-2.7	-29.3	7.0	-6.4	-1.9	25.9	372.2
	51558	-3.3		32.2	-0.2	3.4	-12.8	
	51576	-5.8		93.7	18.9	79.8	-0.1	
	51578	-5.3		50.8	3.9	41.9	-5.7	
Roof of Tank	26007	-2.9	-29.3	32.7	-5.9	34.0	0.8	372.2
	26079	-3.8		67.8	4.6	64.3	3.4	
	26082	-4.8		105.3	-1.6	95.9	12.0	
	26085	-4.6		97.0	-4.1	84.9	12.9	
South Wall of FPE	66004	-10.3	-29.3	44.6	26.6	57.3	-14.5	372.2
	66006	-7.8		67.6	16.8	101.5	9.3	
	66024	-3.5		10.7	-9.1	33.2	-1.0	
East Wall of FPE	67004	-4.3	-29.3	37.3	58.1	-19.0	4.3	372.2
	67006	-6.9		44.3	124.3	10.8	109.8	
	67024	-7.4		30.8	94.2	-8.2	58.5	
Wall of South Tank	35007	-4.7	-29.3	61.2	14.0	19.6	-9.0	372.2
	35010	-5.5		71.2	16.8	37.6	-4.3	
	36507	-5.1		63.3	-1.3	38.7	-6.8	
	36510	-5.9		69.4	-1.3	55.4	-3.9	
	38507	-2.9		64.0	0.6	28.3	-0.4	
	38510	-3.1		62.1	-0.6	26.2	0.2	
	45001	-4.8		72.7	21.1	52.5	4.4	
	46501	-4.5		59.1	-3.5	40.0	-1.9	
	48501	-3.2		61.9	-1.5	25.7	0.5	
SHEARKEY	72008	-0.4	-23.5	20.4	27.6	6.9	13.4	372.2
	73017	-3.3		-23.9	-24.1	11.8	12.8	

Note: Negative value means compression.

* See the definition of local coordinate in Figure 3G.4-10.

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.4-21 Calculation Results for Transverse Shear

Location	Element ID	Load ID	d (m)	ρ_w (%)	ρ_v (%)	Shear Forces (MN/m)				Vu/ϕVn
						Vu	Vc	Vs	ϕVn	
Basemat EL 4.65	18	FWSC-6	2.243	0.673	0.242	1.036	1.362	2.247	3.067	0.338
	227	FWSC-6	2.055	0.858	0.484	2.674	1.120	4.118	4.452	0.601
	237	FWSC-6	2.045	0.862	0.484	2.432	1.217	4.098	4.517	0.538
	16085	FWSC-6	2.044	0.862	0.242	1.228	1.609	2.048	3.108	0.395
Roof of FPE EL 8.25	51556	FWSC-6	0.465	1.082	0.000	0.039	0.406	0.000	0.345	0.113
	51558	FWSC-6	0.499	1.008	0.000	0.132	0.453	0.000	0.385	0.343
	51576	FWSC-6	0.450	1.118	0.000	0.237	0.428	0.000	0.364	0.651
	51578	FWSC-6	0.462	1.090	0.000	0.078	0.442	0.000	0.375	0.208
Roof of Tank	26007	FWSC-6	0.473	0.682	0.000	0.005	0.427	0.000	0.363	0.013
	26079	FWSC-6	0.451	0.716	0.000	0.094	0.454	0.000	0.386	0.243
	26082	FWSC-6	0.476	0.678	0.000	0.102	0.457	0.000	0.389	0.263
	26085	FWSC-6	0.486	0.664	0.000	0.103	0.469	0.000	0.399	0.258
South Wall of FPE	66004	FWSC-4	0.422	2.387	0.000	0.215	0.459	0.000	0.390	0.551
	66006	FWSC-6	0.436	2.873	0.710	0.730	0.263	1.282	1.313	0.556
	66024	FWSC-4	0.443	1.701	0.000	0.192	0.491	0.000	0.418	0.460
East Wall of FPE	67004	FWSC-6	0.485	1.037	0.000	0.226	0.826	0.000	0.702	0.322
	67006	FWSC-6	0.436	2.862	0.710	0.206	0.257	1.282	1.308	0.158
	67024	FWSC-6	0.443	1.702	0.000	0.243	0.494	0.000	0.420	0.579
Wall of South Tank	35007	FWSC-6	0.735	2.285	0.631	0.553	0.282	1.920	1.871	0.295
	35010	FWSC-6	0.698	1.919	0.631	0.452	0.155	1.823	1.682	0.269
	36507	FWSC-6	0.779	1.721	0.000	0.049	0.499	0.000	0.424	0.116
	36510	FWSC-4	0.772	1.735	0.000	0.084	0.753	0.000	0.640	0.132
	38507	FWSC-6	0.835	0.804	0.000	0.122	1.075	0.000	0.914	0.133
	38510	FWSC-4	0.835	0.804	0.000	0.228	0.896	0.000	0.762	0.299
	45001	FWSC-6	0.698	1.918	0.631	0.563	0.000	1.823	1.550	0.363
	46501	FWSC-6	0.780	1.718	0.000	0.039	0.270	0.000	0.229	0.170
	48501	FWSC-7	0.835	0.804	0.000	0.089	0.810	0.000	0.688	0.130
Shear Key	72008	FWSC-6	1.798	0.419	0.000	0.376	1.474	0.000	1.253	0.300
	73017	FWSC-6	1.737	0.741	0.177	0.259	0.966	1.273	1.903	0.136

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MN/m=6.852x10^4 lbf/ft

Table 3G.4-22 Factors of Safety for Foundation Stability

Load Combination	Overturning		Sliding		Floatation	
	Required	Actual	Required	Actual	Required	Actual
D + H + E’	1.1	129.1	1.1	1.10	--	--
D + F’	--	--	--	--	1.1	7.4

Where,
D = Dead Load
H = Lateral soil pressure
E’ = Safe Shutdown Earthquake
F’ = Buoyant force of design basis flood

Table 3G.4-23 Maximum Dynamic Soil Bearing Pressure Involving SSE + Static

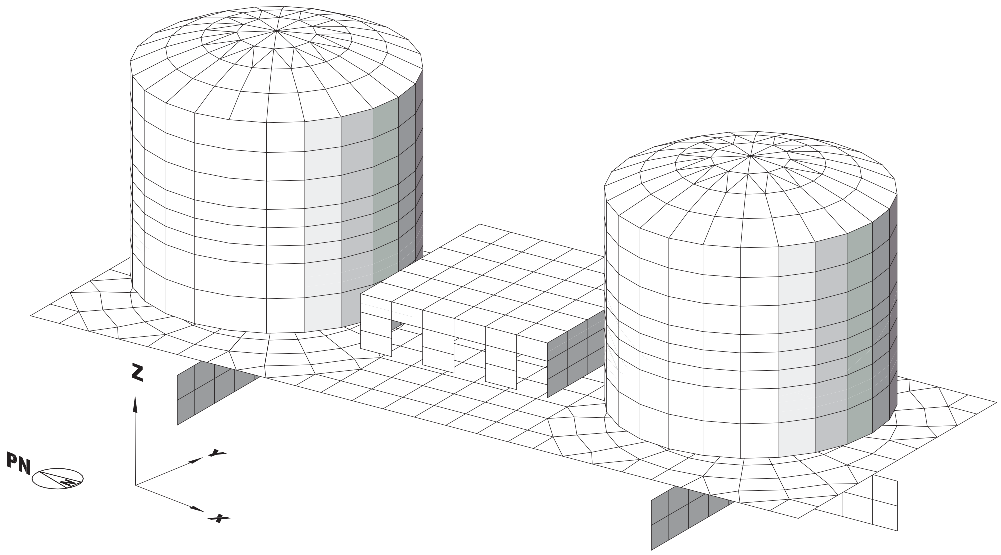
	Site Condition*		
	Soft (V_s = 300 m/sec)	Medium (V_s = 800 m/sec)	Hard ($V_s \geq$ 1700 m/sec)
Bearing Stress (MPa)	0.46	0.69	1.2

**: See Table 3A.3-1 for site properties. For site specific application, use the larger value or a linearly interpolated value of the applicable range of shear wave velocities at the foundation level.*
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MPa = 145.038 psi
1 m/sec = 3.28 ft/sec

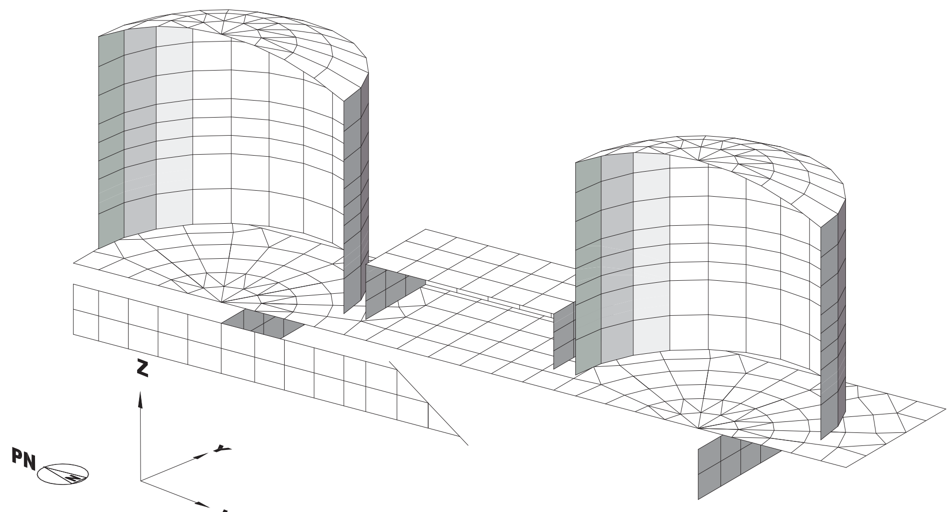
Note: All dimensions are in mm unless otherwise noted.

Figure 3G.4-1. FWSC Concrete Outline and Typical Rebar Arrangement

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}



Whole View



Cut View

Figure 3G.4-2. Finite Element Model of FWSC (Isometric View)

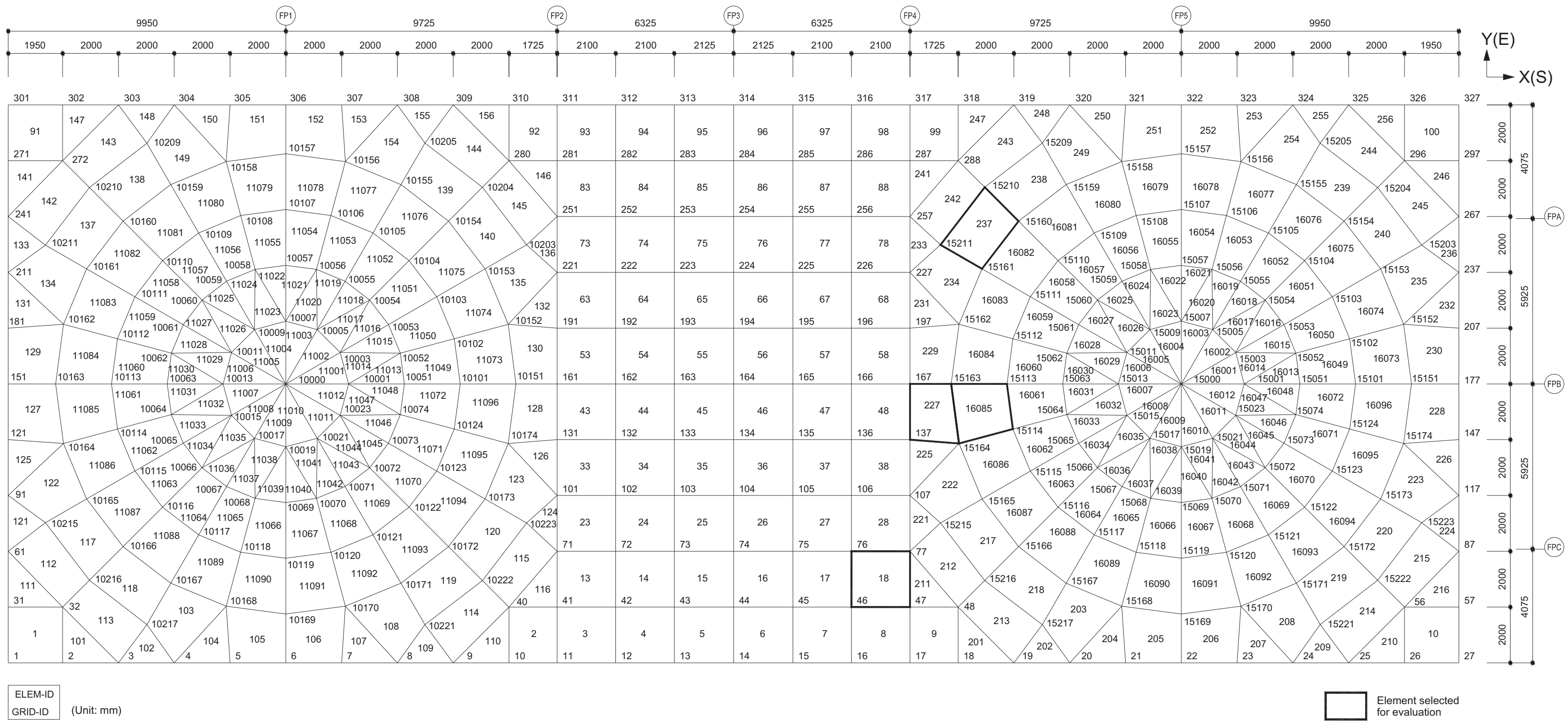


Figure 3G.4-3a. Finite Element Model of FWSC (Foundation Mat)

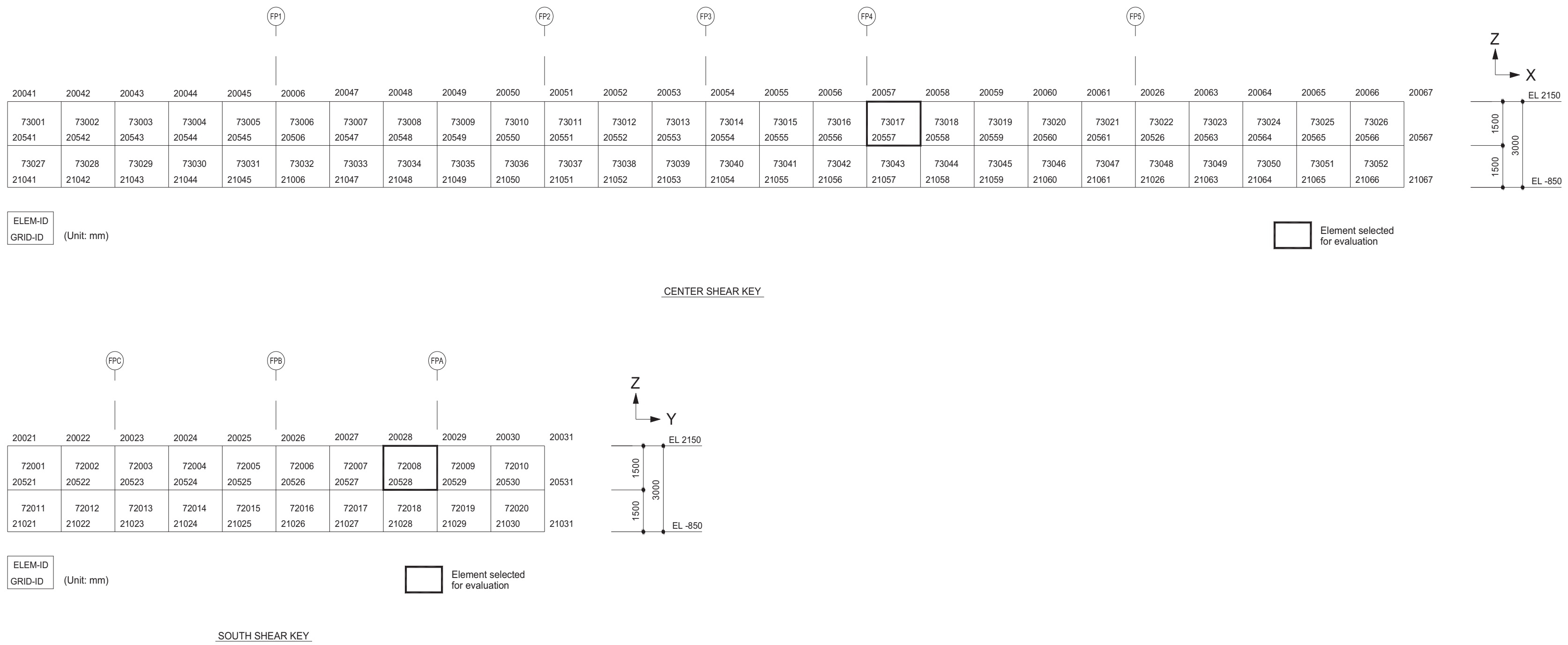


Figure 3G.4-3b. Finite Element Model of FWSC (Center Shear Key and South Shear Key of Basemat)

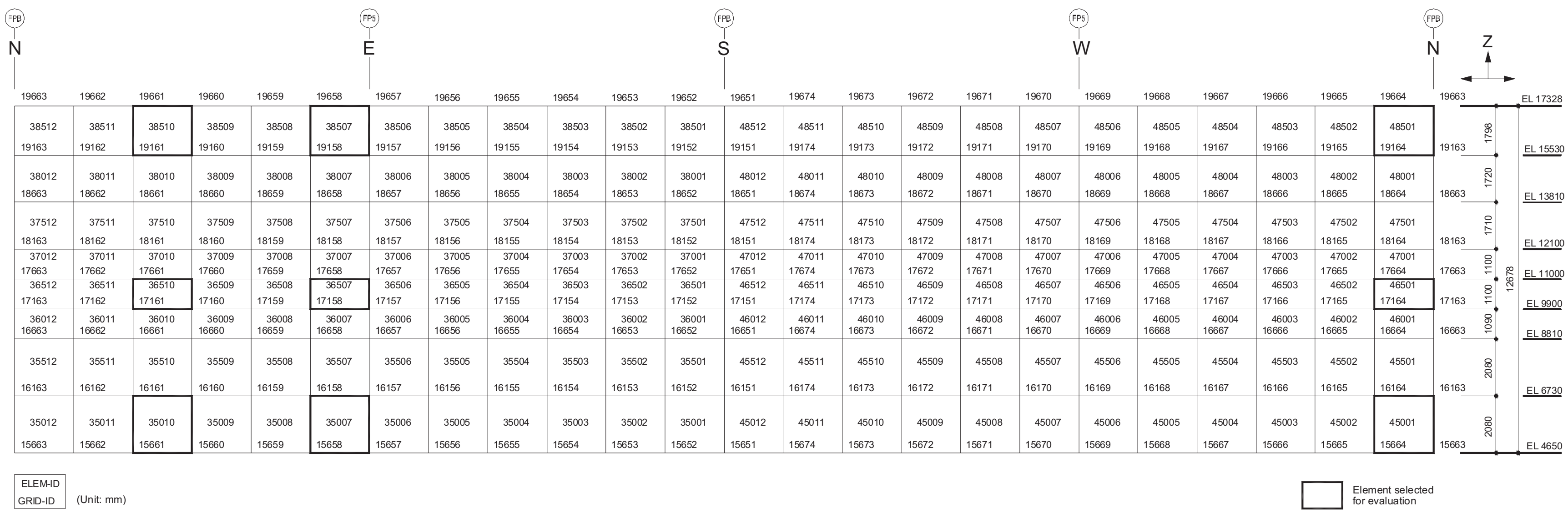
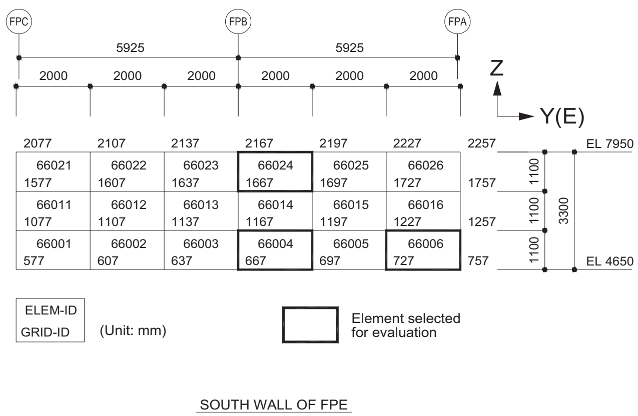


Figure 3G.4-4. Finite Element Model of FWSC (South FWS Wall)



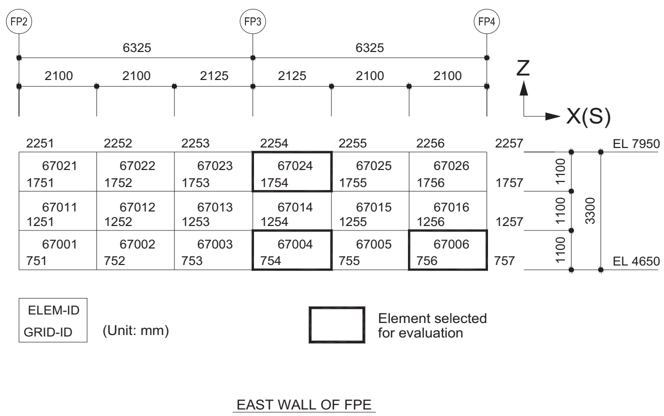


Figure 3G.4-5. Finite Element Model of FWSC (FPE Wall: East and South)

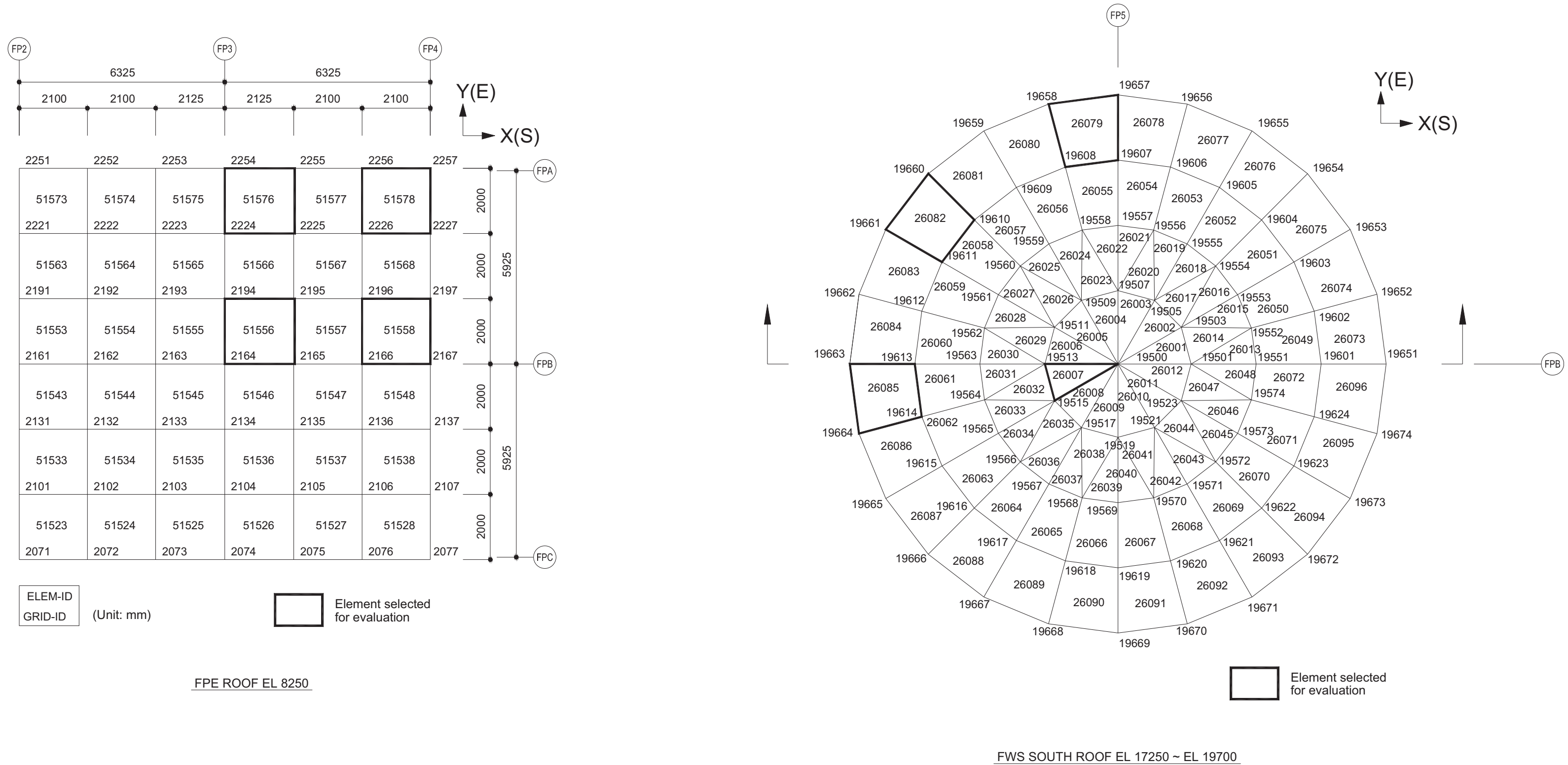


Figure 3G.4-6. Finite Element Model of FWSC (FPE Roof Slab, South FWS Roof Slab)

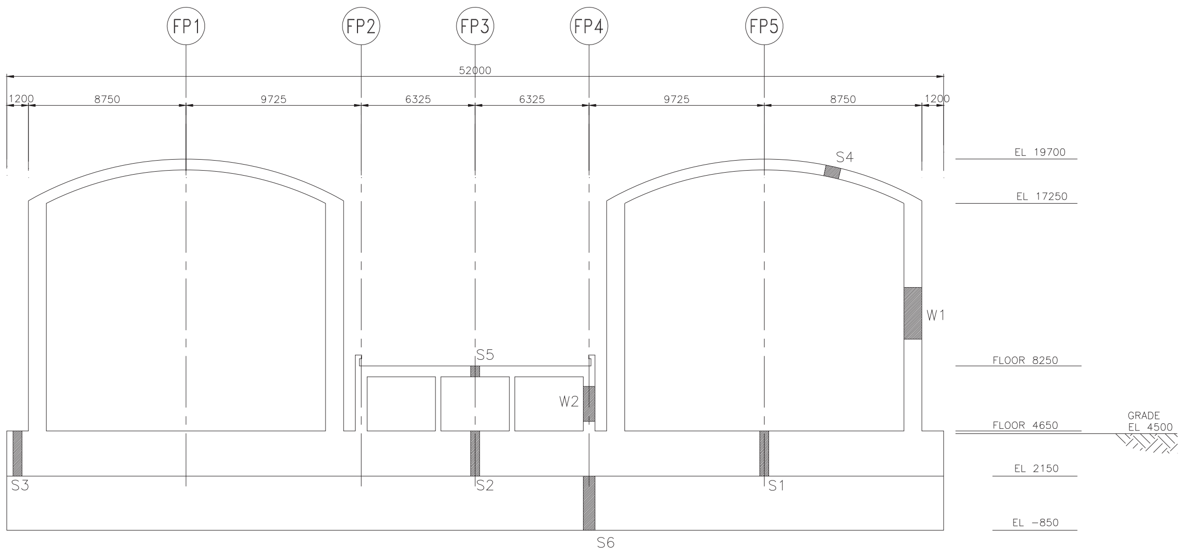


Figure 3G.4-7. Sections Where Thermal Loads Are Defined

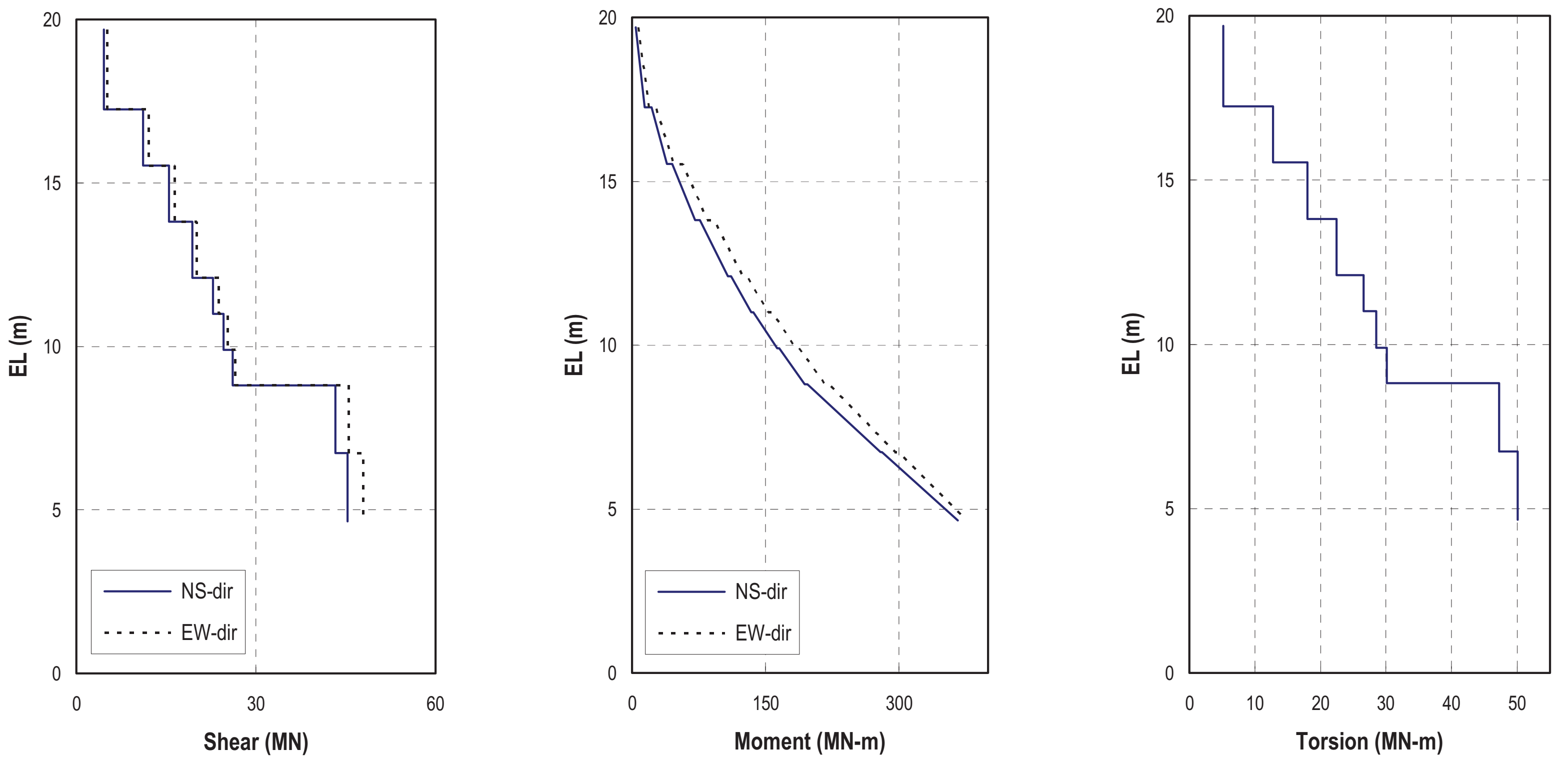


Figure 3G.4-8. Design Seismic Shears and Moments for FWSC (FWS)

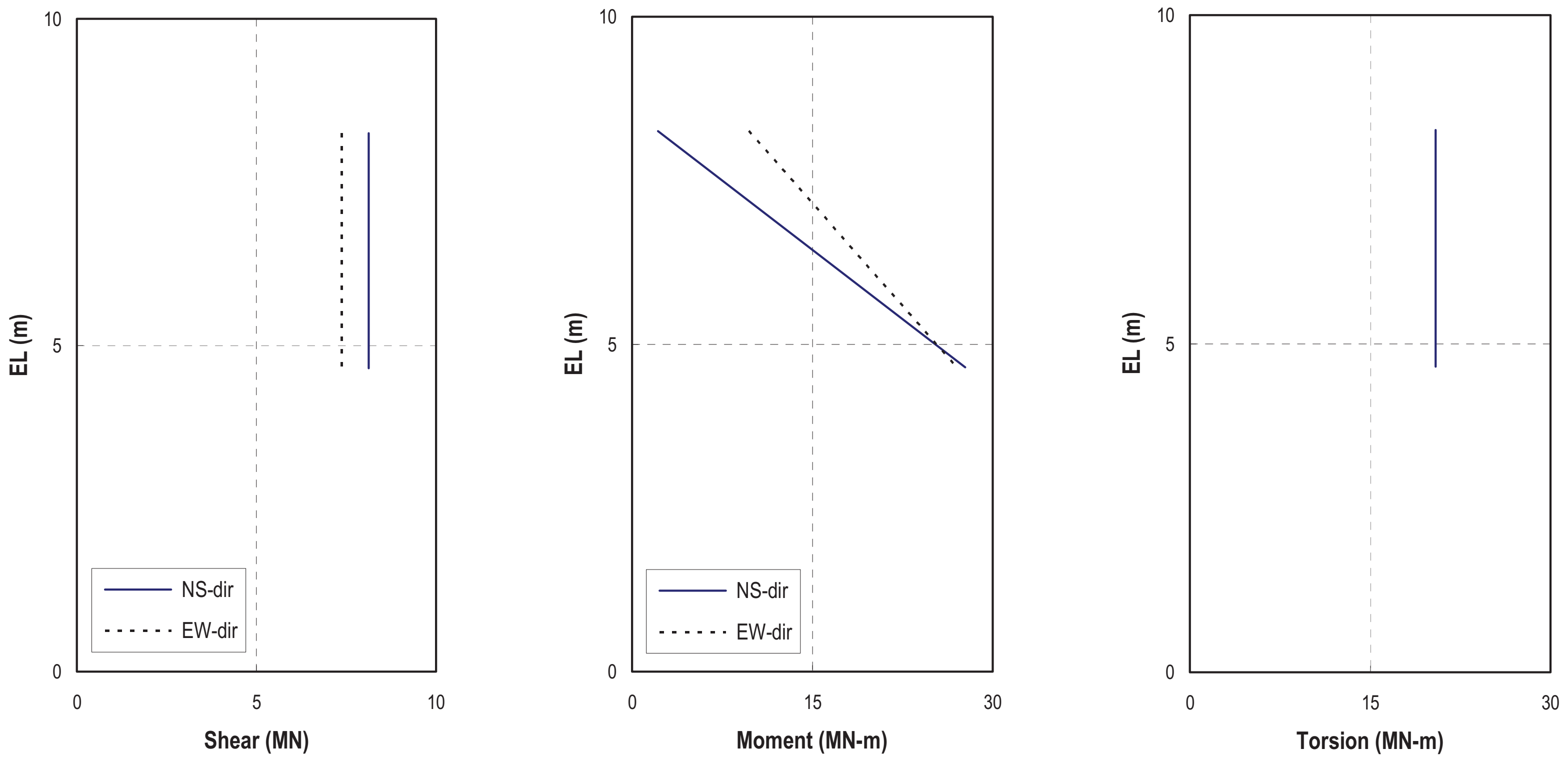
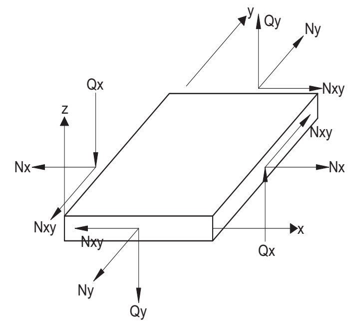
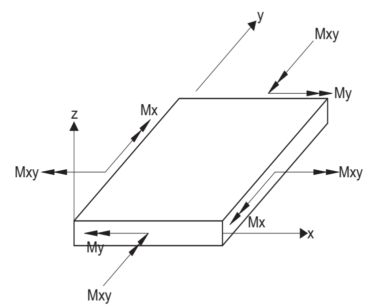


Figure 3G.4-9. Design Seismic Shears and Moments for FWSC (FPE)



Membrane and Shear Forces



Moments

Definition of Element Coordinate System

Structure	*x*	*y*	*z*
Wall in N-S direction	*horizontal*	*vertical*	*toward West*
Wall in E-W direction	*horizontal*	*vertical*	*toward North*
Tank Wall	*horizontal*	*vertical*	*outward*
Foundation Mat & Roof	*toward South*	*toward East*	*Upward*
Shear key in N-S direction	*horizontal*	*vertical*	*toward West*
Shear key in E-W direction	*horizontal*	*vertical*	*toward North*

Figure 3G.4-10. **Force and Moment in Shell Element**

Figure 3G.4-11. (Deleted)

3G.5 STRUCTURAL EVALUATION FOR TRACG CALCULATED LOCA TEMPERATURES

A quantitative evaluation is performed to demonstrate that the thermal transient profiles calculated by TRACG do not invalidate the structural design analysis using the thermal loads presented in Subsection 3G.1.5.2.1.6. The following six break cases in the event of a LOCA are examined:

MSLA:Main Steamline Break inside Containment – nominal

MSLCB:Main Steamline Break inside Containment – containment bounding

FWLA:Feedwater Line Break – nominal

FWLCB:Feedwater Line Break – containment bounding

GDL:GDCS Injection Line – nominal

BDL:Bottom Drain Line – nominal

The TRACG calculated bulk temperature curves (including consideration of uncertainties) of these break cases are bounded by the design temperature curves considered in the structural analysis at all locations except for the drywell (DW), wetwell (WW) airspace and RB upper pools. Evaluation details of the DW, WW, and RB upper pools where the design temperature is not bounding are presented below.

3G.5.1 Drywell

The TRACG temperature curves in the DW are compared with the design temperature curve (labeled ENV) in Figures 3G.5-1 through 3G.5-3 for short-term, medium-term and long-term break cases, respectively. It is observed that the MSLA and MSLCB cases result in the highest temperature in the short term (t < 0.1 hr); the FWLA and FWLCB cases result in the highest temperature in the medium term (0.3 < t < 0.5 hr); and the BDL case results in the highest temperature in the long term (t > 0.5 hr). The GDL case is not bounding over any time interval for the DW.

The MSLA case is the most critical because it has the highest temperature at 193°C (379°F) as compared to the 171°C (340°F) peak design temperature. However, this exceedance occurs very early in the transient and is very short in duration. It should be noted that the TRACG results are bulk fluid temperatures. The actual temperatures in the structures are lower than the fluid temperatures due to heat transfer effects at the surface. The beneficial effects of reduced surface heat transfer are ignored in the structural design analysis in which the design temperature curve was directly applied to the structure assuming an infinite value for the heat transfer coefficient.

To show that the actual structural temperature is lower than the fluid temperature, a transient 1-D heat transfer analysis is performed for the DW liner (6.4 mm (0.25 in) thick) with the inside liner face subjected to the bulk fluid temperature and the outside liner face (which is at the liner-concrete interface) perfectly insulated for the MSLA transient up to 0.1 hr. A conservative heat transfer coefficient derived from TRACG results is applied at the inside liner face. The results of this heat

transfer analysis show that the maximum temperature uniformly across the liner thickness and at the concrete surface is 167°C (333°F), which is less than the 171°C (340°F) peak temperature used in the structural design. The 167°C (333°F) temperature at the concrete surface is also within the 177°C (350°F) limit stipulated in ASME Code Section III, Division 2, Subarticle CC-3440 for an accident or any other short-term period.

Besides the containment liner, there are other steel structures subjected to the DW temperature. They consist of containment metal components not backed by concrete (such as the DW head) and containment internal steel structures (such as the diaphragm floor (D/F), vent wall (VW), GDCS pool wall and reactor shield wall). Since these steel structures are thicker than the liner plate and one face of the liner plate is conservatively assumed to be fully insulated in the heat transfer analysis described above, the calculated 167°C (333°F) maximum temperature is also applicable to all steel structures for which the design temperature is higher at 171°C (340°F). It should be noted that the design stress analyses performed for the D/F and VW ignores the infill concrete; the steel plates on the DW side are designed to 171°C (340°F) peak design temperature and the steel plates on the WW airspace side are designed to 130°C (266°F) peak design temperature. The WW temperature is discussed separately below.

As opposed to steel structures, concrete structures react to temperature loading very slowly. The more important consideration is how much heat is penetrating into the concrete as the accident progresses. The integrated TRACG curves versus the integrated design temperature curve over the 72-hr duration are shown in Figures 3G.5-4 through 3G.5-6 for short-term, medium-term and long-term break cases, respectively. The accumulated heat input at 72 hours, which is the most critical timing for concrete response when the thermal gradient across the thickness is largest, is less than that of the design temperature curve for all breaks. At the very early stage of the transient up to about 0.6 hr, however, some breaks result in higher accumulated heat input but they are inconsequential to structural design since the duration is too short for heat penetrating into the concrete.

3G.5.2 Wetwell Airspace

The TRACG temperature curves in the airspace of the WW are compared with the design temperature curve (labeled ENV) in Figures 3G.5-7 through 3G.5-9 for short-term, medium-term and long-term break cases, respectively. The peak temperatures calculated by TRACG are less than the 130°C (266°F) peak design temperature up to 0.1 hr for all break cases except for FWLA and FWLCB. The slightly higher FWLA and FWLCB temperatures (134°C (273°F) maximum) are fluid temperatures, and the actual temperatures in the structures are expected to be lower for short-duration heat buildup in view of the heat transfer analysis described above for the DW. At the late stage of the transient approaching 72 hours, the TRACG temperatures reach a maximum value of about 137°C (279°F) at 72 hours associated with MSLCB. It is about 13% higher than the 121°C (250°F) design temperature. The impact on the structural design is evaluated assuming that the

existing total stresses of the abnormal and abnormal/extreme environmental load combinations, which include the accident thermal load, are increased by 13%. This approach is very conservative since stresses other than thermal are not affected by the 13% increase in the WW airspace temperature. The design margins of the affected structures, D/F, VW, containment liner and Reinforced Concrete Containment Vessel (RCCV), are presented below.

The structural elements of the D/F on the WW side are the bottom plate and the web and flange plates of the supporting radial beams. Their existing maximum stresses are summarized in Table 3G.1-37. The bottom plate stresses reported in this table have a minimum stress margin (defined to be the ratio of the allowable to calculated stresses) equal to 1.35 associated with tensile stress under the normal load condition. The stress margin for the abnormal and abnormal/extreme environmental conditions is higher. This provides ample design margin against 13% higher temperature load. As noted in Table 3G.1-37 for the radial web plate (lower web) and bottom flange, the thermal stress associated with extreme and abnormal load conditions meets deformation limits of AISC N690 Subsection Q1.5.7.2 and the total stress excluding thermal stress satisfies the allowable stress limit in Table Q1.5.7.1 of AISC N690. With a 13% increase in the total stresses for these plates, the resulting deformation is still within 27% of the allowable ductility. Hence, the D/F structure has adequate margins to accommodate a 13% temperature increase in the WW airspace.

The stress summary of the VW is provided in Table 3G.1-39. The smallest stress margin is 1.4. The outside cylinder is on the WW side and its stress margin is 1.8. The stress margin is sufficient to accommodate a 13% temperature increase in the WW airspace.

The maximum strains of the containment liners are in Table 3G.1-35. The smallest strain margin is 1.22 for the cylinder, which includes the portions in the WW airspace. The strain margin is sufficient to accommodate 13% temperature increase in the WW airspace.

The thermal response of the RCCV, being a concrete structure, is a function of heat input accumulated over time. As shown in Figures 3G.5-10 through 3G.5-12, the integrated TRACG temperature curves are bounded by the integrated design temperature curve for all breaks after 0.0003 hr. Prior to 0.0003 hr the TRACG accumulated heat input is higher but has no impact on structural design since the duration is too short for significant heat to penetrate into the concrete. It should be further noted that the ascending trend of TRACG temperatures does not extend beyond 72 hours in accordance with Figure 6.2-14e2. The change in the temperature trend and reduction in temperature in Figure 6.2-14e2 is due to operation of the PCCS vent fans, which reduce the non-condensable gas concentration in the PCCS heat exchangers, increasing heat removal.

Furthermore, for a very conservative check, the concrete and rebar stresses of the RCCV provided in Tables 3G.1-29 through 3G.1-33 for abnormal and abnormal/extreme environmental conditions are examined for design margins. At the WW airspace the smallest stress margin is 1.14 for the outer layer rebars near the WW top. Therefore, the RCCV has sufficient margin even if the

combined stresses were increased by 13%, which is the same amount as the 13% temperature increase in the WW airspace.

3G.5.3 RB Upper Pools

The RB upper pools consist of equipment storage pool, reactor well, buffer pool, IC/PCCS pools, inner expansion pool and outer expansion pool. Four (4) temperature cases are considered for minimum and maximum pool temperatures at 72 hours following a DBA, taking into account minimum/maximum initial temperatures, operator actions, equipment performance, and uncertainties. The maximum and minimum temperature conditions are designated to be Case 1 and Case 2, respectively, in this structural evaluation. A third case with a combination of maximum and minimum temperatures is also considered in this evaluation and designated as Case 3. The intent of Case 3 is to maximize the temperature differences across common walls between pools, such as the wall between the inner and outer expansion pools. Furthermore, to account for the possibility that the pools could be at a very low temperature above freezing when a LOCA occurred, a lower bound temperature at 0ºC (32ºF) is also assumed for all pools and this case is designated as Case 4. These 4 analysis cases are summarized below.

Case 1: Maximum as temperatures in all pools are at their respective maximum values.

Case 2: Minimum as temperatures in all pools are at their respective minimum values.

Case 3: Mixed temperatures in the individual pools are at either maximum or minimum values.

Case 4: Lower bound temperature in all pools at 0ºC (32ºF).

The temperature distributions in various pool regions for these cases are shown in Figure 3G.5-13.. In all cases the temperature in the rooms outside the pool boundary is at 10ºC (50ºF) in winter and the winter air temperature outside the building is –40ºC (-40ºF). The drywell (DW) temperature at the bottom surface of the RCCV top slab is 150ºC (302ºF), which is the accident temperature at 72 hours after a LOCA in all cases.

Steady-state heat transfer calculations are performed for slab/wall sections shown in Figures 3G.5-14 and 3G.5-15. The results of equivalent linear temperatures are summarized in Tables 3G.5-1.

Stress analyses are performed using the global NASTRAN model described in Subsection 3G.1.4.1 with updates for current pool gate design and design changes identified through iterations in this evaluation. These design changes, required in order to meet design acceptance criteria, are:

a. *Top slab: The concrete strength is increased from 34.5 MPa (5000 psi) to 41.4 MPa (6000 psi) and reinforcement is rearranged.*
b. *RB floor slab outside of the RCCV at EL 27000 mm (88.58 ft): The thickness is increased from 1000 mm (3.28 ft) to 1500 mm (4.92 ft) and reinforcement is rearranged.*

c. Pool girder: Reinforcement is rearranged.

d. IC/PCCS pool walls in the North-South direction between the IC/PCCS pools and the inner expansion pool: The thickness is increased from 600 mm (1.97 ft) to 1000 mm (3.28 ft) and reinforcement is rearranged.

Additional reinforcement in local regions is also added to the RB slab at EL 34000 mm (111.55 ft), RB exterior walls at EL 27000 mm (88.58 ft), IC/PCCS pool walls in the East-West direction and walls between inner and outer expansion pools.

The upper pool portions of the global NASTRAN finite element model are shown in Figure 3G.5-16.. In addition to the accident thermal (T_a) load, the updated NASTRAN model is also analyzed for dead load (D), accident pressure (P_a) and seismic (E') loads. The original NASTRAN model is used for other loads such as live load (L), pipe reaction (R_a), SRV and chugging loads that are not influenced by the upper pools.

The loads are combined for the abnormal and abnormal/extreme environmental categories in accordance with Table 3G.5-2. The calculated section forces and moments at selected elements in Figures 3G.5-17 through 3G.5-20 for sections identified in Figure 3G.1-28. are shown in Tables 3G.5-3 through 3G.5-12 for individual loads. The combined section forces and moments are presented in Tables 3G.5-13 through 3G.5-20 for various load combinations. The element coordinate system for section forces and moments follows Figure 3G.1-29..

Stress evaluation is performed using the section properties in Table 3G.5-21. The calculated rebar and concrete stresses are summarized in Tables 3G.5-22 through 3G.5-29 for individual load combination cases. The enveloping transverse shear results of load combination cases are presented in Tables 3G.5-30 and 3G.5-31. As shown the design meets all allowable limits.

The maximum compressive liner strain in the containment top slab is found to be 0.0023. It is 21% larger than the maximum compressive liner strain of 0.0019 at the top slab for the abnormal and abnormal/extreme environmental categories in Table 3G.1-35 and is still well within the allowable compressive strain of 0.005. Therefore, the top slab containment liner design is adequate.

3G.5.4 Conclusions

On the basis of the evaluations described above, it can be concluded that the TRACG calculated LOCA temperatures do not invalidate the DW and WW structural design analysis. The RB upper pool structure with the afore-mentioned design changes implemented is adequate to withstand a wide range of pool temperatures in conjunction with LOCA.

Furthermore, the design changes to the RB upper pool structure described in Subsection 3G.5.3 increase the design strength of the RCCV top slab. Therefore, the Level C capacity of the top slab presented in Section 19B and the pressure fragility of the top slab presented in Section 19C for the previous design are conservative.

Table 3G.5-1 RB Upper Pools – Equivalent Linear Temperature Distributions at Various Sections

Section[*1]	Side[*2]		Equivalent Linear Temperature [*3](ºC)							
			Case 1		Case 2		Case 3		Case 4	
	1	2	Td	Tg	Td	Tg	Td	Tg	Td	Tg
SL1	RM	RM	10.00	0.0	10.00	0.0	10.00	0.0	10.00	0.0
SL2	IP	RM	69.46	81.1	39.73	40.5	39.73	40.5	4.05	-8.1
SL3	RM	XI	66.73	-86.5	4.33	8.7	66.73	-86.5	4.33	8.7
SL4	RM	BP	28.51	-31.0	4.56	9.1	4.56	9.1	4.56	9.1
SL5	RM	AT	-18.80	39.3	-18.80	39.3	-18.80	39.3	-18.80	39.3
SL6	XO	AT	3.10	79.8	-19.23	38.5	-19.23	38.5	-19.23	38.5
SL9	RM	XO	28.72	-28.6	4.33	8.7	4.33	8.7	4.33	8.7
SL10	RM	XS	66.73	-86.5	4.33	8.7	4.33	8.7	4.33	8.7
SL11	XS	RM	69.46	81.1	4.05	-8.1	4.05	-8.1	4.05	-8.1
SL12	PP	RM	69.46	81.1	63.51	73.0	63.51	73.0	4.05	-8.1
SL13	XI	RM	69.46	81.1	4.05	-8.1	69.46	81.1	4.05	-8.1
MT5	MT	DS	83.50	-53.0	78.50	-43.0	83.50	-53.0	28.50	57.0
MT6	MT	XS	83.50	-53.0	28.50	57.0	28.50	57.0	28.50	57.0
MT8	MT	AT	9.30	95.4	9.30	95.4	9.30	95.4	9.30	95.4
MT9	MT	RM	35.58	42.8	35.58	42.8	35.58	42.8	35.58	42.8
TS1	DW	DS	128.23	36.5	122.78	45.6	128.23	36.5	68.35	136.7
TS2	DW	IP	128.23	36.5	101.01	82.0	101.01	82.0	68.35	136.7
TS3	DW	XI	128.23	36.5	68.35	136.7	128.23	36.5	68.35	136.7
TS4	DW	RW	128.23	36.5	122.78	45.6	128.23	36.5	68.35	136.7
TS5	DW	RM	80.00	117.2	80.00	117.2	80.00	117.2	80.00	117.2
TS6	DW	PP	128.23	36.5	122.78	45.6	122.78	45.6	68.35	136.7
TS7	DW	BP	92.30	96.6	68.35	136.7	68.35	136.7	68.35	136.7
PG1	PP	RW	110.00	0.0	100.00	0.0	105.00	-10.0	0.00	0.0
PG2	XI	BP	77.00	66.0	0.00	0.0	55.00	110.0	0.00	0.0
PG3	RM	DS	66.36	-87.3	60.73	-78.5	66.36	-87.3	4.36	8.7
PG4	IP	DS	110.00	0.0	80.00	-40.0	85.00	-50.0	0.00	0.0
PG5	PP	DS	110.00	0.0	100.00	0.0	105.00	-10.0	0.00	0.0
PG6	IP	BP	77.00	66.0	30.00	60.0	30.00	60.0	0.00	0.0
PG7	RM	BP	29.16	-29.7	4.36	8.7	4.36	8.7	4.36	8.7
PG8	XS	DS	110.00	0.0	50.00	-100.0	55.00	-110.0	0.00	0.0
PG9	PP	BP	77.00	66.0	50.00	100.0	50.00	100.0	0.00	0.0

Table 3G.5-1 RB Upper Pools – Equivalent Linear Temperature Distributions at Various Sections (Continued)

Section[*1]	Side[*2]		Equivalent Linear Temperature [*3] (ºC)							
			Case 1		Case 2		Case 3		Case 4	
	1	2	Td	Tg	Td	Tg	Td	Tg	Td	Tg
GW1	AT	RM	-17.73	-42.3	-17.73	-42.3	-17.73	-42.3	-17.73	-42.3
GW3	AT	XO	3.10	-79.8	-19.23	-38.5	-19.23	-38.5	-19.23	-38.5
GW5	AT	BP	2.68	-82.6	-19.68	-39.4	-19.68	-39.4	-19.68	-39.4
GW6	DS	AT	35.85	148.3	30.79	138.4	35.85	148.3	-19.77	39.5
GW7	XS	AT	36.95	146.1	-19.48	39.0	-19.48	39.0	-19.48	39.0
GW8	RM	XO	29.62	-26.8	4.05	8.1	4.05	8.1	4.05	8.1
GW9	AT	RM	-18.80	-39.3	-18.80	-39.3	-18.80	-39.3	-18.80	-39.3
GW10	RM	RM	10.00	0.0	10.00	0.0	10.00	0.0	10.00	0.0
GW11	AT	BP	3.09	-81.8	-19.48	-39.0	-19.48	-39.0	-19.48	-39.0
PW1	RW	DS	110.00	0.0	100.00	0.0	110.00	0.0	0.00	0.0
PW2	PP	PP	110.00	0.0	100.00	0.0	100.00	0.0	0.00	0.0
PW4	XI	PP	110.00	0.0	50.00	-100.0	105.00	10.0	0.00	0.0
PW6	XI	XS	110.00	0.0	0.00	0.0	55.00	110.0	0.00	0.0
PW7	XO	XI	76.50	-67.0	0.00	0.0	55.00	-110.0	0.00	0.0
PW8	XI	RM	69.46	81.1	4.05	-8.1	69.46	81.1	4.05	-8.1
PW9	RM	XS	65.22	-89.6	4.48	9.0	4.48	9.0	4.48	9.0
PW10	RM	RM	10.00	0.0	10.00	0.0	10.00	0.0	10.00	0.0
PW11	RM	RM	10.00	0.0	10.00	0.0	10.00	0.0	10.00	0.0
PW12	IP	XI	110.00	0.0	30.00	60.0	85.00	-50.0	0.00	0.0
PW13	IP	RM	69.46	81.1	39.73	40.5	39.73	40.5	4.05	-8.1
PW14	XI	IP	110.00	0.0	30.00	-60.0	85.00	50.0	0.00	0.0
PW15	XI	IP	110.00	0.0	30.00	-60.0	85.00	50.0	0.00	0.0
PW16	PP	IP	110.00	0.0	80.00	40.0	80.00	40.0	0.00	0.0
PW17	XO	RM	29.62	26.8	4.05	-8.1	4.05	-8.1	4.05	-8.1
PW18	RM	XS	69.46	-81.1	4.05	8.1	4.05	8.1	4.05	8.1
PW19	BP	RW	77.00	-66.0	50.00	-100.0	55.00	-110.0	0.00	0.0

*1: Refer to Figures 3G.5-14 and 3G.5-15
*2: Side
DW: Drywell; WW: Wetwell; SP: Suppression Pool
GP: GDCS Pool; IP: IC Pool; PP: PCCS Pool
XI: Inner Expansion Pool; XO: Outer Expansion Pool; XS: Side Expansion Pool
RM: Room; DS: Equipment Storage Pool; BP: Buffer Pool
RW: Reactor Well; FP: Spent Fuel Pool; MT: MS Tunnel
GR: Ground; AT: Outside Air
*3: Td: Average Temperature
Tg: Surface Temperature Difference (positive when temperature at Side 1 is higher)
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1°C = (°F - 32)/1.8

Table 3G.5-2 RB Upper Pools - Load Combination Cases

Category	No.	Load Combinations										
		Ta				D	L	Pa	E'	Ra	SRV	CHUG
		Case1	Case2	Case3	Case4							
LOCA (1.5Pa) 72hr	6001	1.0				1.0	1.0	1.5		1.0	1.25	1.5
	6002		1.0			1.0	1.0	1.5		1.0	1.25	1.5
	6003			1.0		1.0	1.0	1.5		1.0	1.25	1.5
	6004				1.0	1.0	1.0	1.5		1.0	1.25	1.5
LOCA + SSE 72hr	7001	1.0				1.0	1.0	1.0	1.0	1.0	1.0	1.0
	7002		1.0			1.0	1.0	1.0	1.0	1.0	1.0	1.0
	7003			1.0		1.0	1.0	1.0	1.0	1.0	1.0	1.0
	7004				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 3G.5-3 RB Upper Pools - Results of NASTRAN Analysis, Dead Load

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	1.036	0.302	0.400	-0.507	-0.113	-0.344	0.076	0.431
@ Drywell Head	98135	2.629	0.236	-0.219	-0.683	0.262	0.142	-0.059	0.367
Opening	98104	0.101	0.824	-0.093	-0.262	-1.581	0.308	-0.005	0.235
16 Topslab	98149	1.638	-0.329	0.508	-0.766	-0.196	0.046	-0.001	-0.299
@ Center	98170	1.363	-0.014	0.037	-0.708	-0.786	0.077	0.002	0.056
	98109	0.160	0.566	0.005	-0.675	-0.939	0.178	0.114	0.097
17 Topslab	98174	0.788	-0.132	0.161	-0.738	-0.577	-0.281	-0.173	0.044
@ RCCV	98197	0.463	-0.011	-0.204	-0.267	1.160	0.167	0.066	0.707
	98103	-0.138	0.430	0.027	1.884	0.303	0.201	0.924	0.115
27 Slab	98472	0.386	0.059	0.126	0.294	0.487	-0.422	0.345	-0.402
EL27.0m	98514	0.146	0.113	0.032	0.043	0.188	0.035	-0.019	-0.143
@ RCCV	98424	-0.118	0.440	0.004	0.736	0.195	-0.053	-0.980	-0.066
28 Pool Girder	123054	0.420	-2.372	-0.765	0.050	0.044	0.046	-0.012	-0.020
@ Storage Pool	123154	1.306	-0.479	-0.607	0.072	0.028	0.088	0.008	0.011
29 Pool Girder	123062	0.397	0.548	0.257	-0.042	-0.210	0.022	0.017	-0.109
@ Well	123162	-1.349	0.198	0.131	-0.071	-0.046	0.012	0.081	0.026
30 Pool Girder	123067	0.402	-2.129	1.430	0.011	-0.044	-0.066	-0.097	-0.052
@ Buffer Pool	123167	0.464	-0.540	1.244	0.033	0.026	0.012	-0.024	0.006
32 IC/PCCS	125051	-0.097	-1.275	-0.895	0.001	-0.057	-0.002	0.002	-0.042
Pool Wall	125151	-0.106	-0.520	-0.735	-0.002	-0.007	-0.005	0.008	-0.002
in NS Direction	125055	0.046	-0.168	-0.099	-0.017	-0.104	0.003	-0.035	-0.069
	125155	-0.520	-0.112	-0.082	0.006	0.028	0.005	0.032	-0.037

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.5-4 RB Upper Pools - Results of NASTRAN Analysis, Drywell Unit Pressure (1 MPa)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	-3.150	1.277	1.710	4.429	2.161	2.392	0.700	-3.963
@ Drywell Head	98135	-10.174	-1.998	-0.613	4.070	-1.545	0.122	0.692	-4.596
Opening	98104	-1.122	3.501	-1.772	3.419	13.462	-1.944	-1.146	-2.684
16 Topslab	98149	-5.521	4.268	-2.737	3.180	0.397	0.935	0.042	2.043
@ Center	98170	-4.759	2.307	-1.249	3.571	3.185	-0.300	-0.112	-0.752
	98109	0.143	2.115	-0.591	4.697	8.341	-1.314	-0.597	-1.348
17 Topslab	98174	-0.945	2.890	-0.854	2.822	2.603	2.043	0.821	-0.526
@ RCCV	98197	-0.851	3.297	-0.103	0.473	-7.759	-0.739	-0.371	-4.950
	98103	1.926	3.191	-0.430	-7.889	0.558	-1.512	-5.074	-0.925
27 Slab	98472	0.163	0.996	-0.907	-0.605	-0.974	1.234	-0.362	0.445
EL27.0m	98514	0.037	0.075	-0.055	-0.199	-1.790	-0.112	0.035	0.525
@ RCCV	98424	-0.484	2.018	-0.119	-3.039	-0.601	-0.179	1.527	0.088
28 Pool Girder	123054	-0.702	7.558	5.501	0.029	-0.028	-0.463	-0.088	-0.117
@ Storage Pool	123154	-2.824	1.013	4.826	-0.013	0.047	-0.605	-0.224	0.053
29 Pool Girder	123062	-0.641	-4.572	-3.810	0.138	1.124	-0.031	0.036	0.525
@ Well	123162	8.026	-1.931	-2.543	0.323	0.246	-0.048	-0.321	-0.086
30 Pool Girder	123067	-0.860	8.105	-7.114	-0.065	0.021	0.320	0.259	-0.060
@ Buffer Pool	123167	-2.176	1.703	-6.458	-0.046	-0.082	0.022	0.061	0.053
32 IC/PCCS	125051	0.631	4.482	4.339	-0.082	0.227	0.008	-0.073	0.187
Pool Wall	125151	0.945	1.262	3.557	-0.093	0.031	0.016	-0.146	0.023
in NS Direction	125055	0.099	-0.466	-0.041	0.109	0.530	-0.005	0.174	0.329
	125155	2.945	-0.386	-0.013	-0.014	-0.143	-0.026	-0.195	0.216

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-5 RB Upper Pools - Results of NASTRAN Analysis, Wetwell Unit Pressure (1 MPa)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	0.422	0.617	0.348	-0.005	-0.004	-0.004	-0.011	-0.008
@ Drywell Head	98135	0.783	0.177	-0.205	-0.040	-0.006	0.006	-0.001	-0.001
Opening	98104	0.185	1.159	-0.205	-0.001	-0.034	0.000	-0.001	0.004
16 Topslab	98149	0.497	0.728	0.027	-0.049	-0.063	0.027	0.011	-0.050
@ Center	98170	0.686	0.305	0.028	-0.064	-0.090	-0.017	-0.011	-0.013
	98109	0.400	0.774	-0.006	-0.055	-0.053	-0.006	-0.022	0.006
17 Topslab	98174	0.533	0.830	0.112	-0.230	-0.292	0.127	0.058	-0.074
@ RCCV	98197	0.400	0.299	-0.002	-0.158	-0.131	-0.045	-0.024	-0.002
	98103	0.352	0.616	0.040	-0.258	-0.074	-0.001	-0.031	-0.004
27 Slab	98472	-0.079	0.083	0.373	0.226	0.288	-0.176	0.137	-0.118
EL27.0m	98514	0.179	0.119	0.007	0.049	0.379	0.009	-0.004	-0.230
@ RCCV	98424	0.095	0.378	0.015	0.208	0.039	0.009	-0.171	-0.011
28 Pool Girder	123054	0.151	0.051	-0.045	-0.001	-0.012	0.001	0.017	-0.016
@ Storage Pool	123154	0.033	0.022	-0.047	0.005	0.007	-0.001	0.006	0.001
29 Pool Girder	123062	0.245	0.035	0.047	-0.010	-0.011	-0.001	0.017	-0.009
@ Well	123162	0.168	0.026	0.059	-0.001	0.003	-0.004	0.005	-0.002
30 Pool Girder	123067	0.107	-0.487	-0.009	-0.027	-0.046	-0.017	-0.022	-0.044
@ Buffer Pool	123167	0.251	-0.136	-0.046	0.006	0.008	0.000	-0.012	-0.002
32 IC/PCCS	125051	0.045	-0.153	0.010	-0.009	-0.021	0.001	-0.007	-0.012
Pool Wall	125151	0.022	-0.056	-0.008	-0.006	-0.004	0.000	-0.005	-0.002
in NS Direction	125055	0.158	0.039	0.046	-0.001	-0.006	0.001	0.000	-0.003
	125155	0.067	0.031	0.057	0.001	0.002	0.000	0.002	-0.003

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-6 *RB Upper Pools - Results of NASTRAN Analysis, Thermal Load (Case 1)*

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	-15.960	-22.072	-9.476	4.431	2.330	3.669	-1.086	-1.337
@ Drywell Head	98135	-30.538	-10.944	7.791	5.005	-0.130	-1.253	0.261	-0.282
Opening	98104	-10.782	-29.517	7.027	0.326	5.448	-1.241	0.153	-0.246
16 Topslab	98149	-26.935	-16.562	1.835	4.430	5.459	1.273	-0.543	-0.210
@ Center	98170	-24.575	-14.574	0.622	4.385	6.101	-0.019	0.102	0.612
	98109	-21.084	-20.420	2.654	3.532	4.859	0.021	0.689	-0.121
17 Topslab	98174	-24.341	-16.231	-0.525	5.956	7.862	-0.379	-0.487	1.344
@ RCCV	98197	-28.708	-14.153	-1.482	4.297	5.736	0.291	0.369	-1.230
	98103	-23.625	-19.677	0.017	8.929	6.517	0.137	1.162	0.098
27 Slab	98472	-6.688	-5.372	14.755	-3.970	-2.975	-0.477	1.234	-1.689
EL27.0m	98514	12.327	-5.717	-3.144	-1.352	-0.396	-0.165	0.097	-0.409
@ RCCV	98424	-19.507	-7.609	-2.516	-9.062	-5.593	-0.059	-6.087	0.027
28 Pool Girder	123054	-1.938	-2.515	1.566	5.417	5.584	0.162	-0.786	1.285
@ Storage Pool	123154	2.827	2.088	-1.845	4.580	2.974	-0.774	-0.233	0.669
29 Pool Girder	123062	-5.127	-4.093	-0.708	-0.074	0.431	0.003	-0.026	0.353
@ Well	123162	-3.908	-3.486	-2.637	-0.570	-0.433	0.167	-0.034	0.235
30 Pool Girder	123067	-3.820	-9.165	-4.161	-2.718	-3.315	-0.123	-0.102	0.614
@ Buffer Pool	123167	-2.808	-4.392	-4.025	-3.283	-3.669	-0.676	0.202	-0.166
32 IC/PCCS	125051	-1.704	-1.534	-0.758	0.082	0.171	0.014	-0.047	0.053
Pool Wall	125151	-1.701	-1.207	1.885	0.196	0.283	0.076	-0.028	-0.077
in NS Direction	125055	-5.013	0.266	0.012	0.033	0.309	0.010	0.048	0.102
	125155	-5.698	-0.537	-0.141	-0.037	-0.038	-0.015	-0.287	0.230

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.5-7 RB Upper Pools - Results of NASTRAN Analysis, Thermal Load (Case 2)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	-19.902	-26.667	-11.787	5.629	2.584	4.364	-2.001	-2.323
@ Drywell Head	98135	-39.294	-13.488	9.764	5.599	-0.234	-1.593	0.184	-0.375
Opening	98104	-13.270	-35.829	8.792	0.352	6.123	-1.341	0.149	-0.199
16 Topslab	98149	-33.733	-21.119	4.825	5.213	5.993	1.060	-1.406	0.102
@ Center	98170	-34.893	-14.930	1.452	5.732	10.037	-0.064	-0.308	2.366
	98109	-25.371	-25.382	2.731	3.872	5.508	0.166	0.756	-0.215
17 Topslab	98174	-26.600	-14.222	8.993	10.857	12.992	1.314	-1.498	1.903
@ RCCV	98197	-13.284	-10.483	-1.148	17.845	17.217	0.071	0.069	-0.159
	98103	-27.839	-21.759	0.163	10.698	7.647	0.099	1.647	0.121
27 Slab	98472	0.560	2.997	21.415	2.417	3.120	-1.205	1.317	-1.610
EL27.0m	98514	12.596	-5.530	-2.667	1.250	5.280	0.063	-0.064	-2.425
@ RCCV	98424	-25.159	-6.289	-2.594	-9.143	-5.309	-0.140	-8.276	-0.118
28 Pool Girder	123054	-2.533	-12.587	0.553	5.558	5.234	0.165	0.381	0.217
@ Storage Pool	123154	-1.617	-4.773	2.290	5.684	3.025	-0.503	0.458	0.837
29 Pool Girder	123062	-7.087	-7.406	0.091	-0.429	0.232	-0.240	0.122	0.390
@ Well	123162	-6.089	-5.905	-3.162	-1.202	-0.494	0.073	0.108	0.172
30 Pool Girder	123067	5.357	-5.116	-3.767	0.633	-0.017	-0.360	-0.406	-0.305
@ Buffer Pool	123167	0.172	-1.539	-1.800	0.764	0.265	-0.025	-0.182	-0.019
32 IC/PCCS	125051	2.182	1.406	0.841	1.141	1.454	0.062	-0.706	0.145
Pool Wall	125151	0.820	0.470	1.675	1.267	1.459	0.112	-0.609	-0.022
in NS Direction	125055	0.876	2.406	-0.406	2.535	2.933	0.001	0.149	0.312
	125155	-1.094	1.213	0.165	2.361	2.132	-0.036	-0.297	0.357

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-8 RB Upper Pools - Results of NASTRAN Analysis, Thermal Load (Case 3)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	-15.482	-25.691	-9.974	5.489	2.234	4.322	-2.021	-2.368
@ Drywell Head	98135	-32.537	-12.430	9.556	4.505	-0.194	-1.508	0.066	-0.258
Opening	98104	-12.512	-34.938	8.362	0.044	4.959	-1.046	0.084	-0.255
16 Topslab	98149	-28.675	-18.892	4.137	6.478	7.026	1.078	-2.189	-0.583
@ Center	98170	-25.010	-15.923	1.978	5.084	6.564	-0.038	0.234	0.414
	98109	-23.621	-24.363	2.681	3.361	4.562	0.150	0.762	-0.169
17 Topslab	98174	-22.078	-8.288	0.121	9.502	11.524	-0.392	-0.423	0.969
@ RCCV	98197	-32.845	-14.689	-0.677	3.897	4.991	0.352	0.353	-1.504
	98103	-26.644	-21.930	0.304	9.531	6.548	0.056	1.410	0.111
27 Slab	98472	-10.555	-5.730	14.877	-3.631	-2.841	-0.701	1.393	-1.882
EL27.0m	98514	19.208	-5.647	-2.587	1.045	2.953	-0.194	0.107	-1.118
@ RCCV	98424	-24.231	-6.952	-2.278	-10.190	-6.460	-0.167	-7.964	-0.108
28 Pool Girder	123054	-0.796	-10.849	0.720	6.148	6.064	0.167	0.364	0.243
@ Storage Pool	123154	2.563	-3.589	1.883	6.336	3.560	-0.289	0.575	0.983
29 Pool Girder	123062	-3.492	-7.610	-0.329	0.235	0.976	-0.143	0.144	0.349
@ Well	123162	-2.959	-6.337	-3.847	-0.450	0.157	0.052	0.056	0.215
30 Pool Girder	123067	-1.268	-8.891	-3.861	-5.866	-6.788	0.001	-0.270	0.070
@ Buffer Pool	123167	-0.187	-3.829	-3.108	-6.192	-5.622	-0.821	0.411	-0.590
32 IC/PCCS	125051	-1.590	-0.135	-1.056	-0.896	-0.957	0.021	-0.132	0.072
Pool Wall	125151	-1.514	-0.093	1.642	-0.781	-0.803	0.065	-0.132	-0.123
in NS Direction	125055	-5.687	0.084	-0.180	-0.145	0.088	0.019	0.049	0.095
	125155	-6.471	-0.673	-0.245	-0.209	-0.233	-0.039	-0.277	0.218

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.5-9 *RB Upper Pools - Results of NASTRAN Analysis, Thermal Load (Case 4)*

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	-19.685	-9.620	-6.700	13.625	13.102	10.762	-0.910	-0.945
@ Drywell Head	98135	-32.643	-9.465	3.312	21.679	2.367	-4.692	1.311	-1.131
Opening	98104	-8.235	-7.644	3.764	4.770	25.728	-6.165	0.516	-0.138
16 Topslab	98149	-21.295	-8.598	-2.582	17.374	16.424	1.478	-0.731	0.060
@ Center	98170	-22.487	-9.601	-1.177	18.047	16.314	-0.099	0.184	0.965
	98109	-14.161	-10.561	1.426	14.914	19.897	-0.725	0.771	-0.034
17 Topslab	98174	-18.223	-10.690	1.049	17.510	16.987	0.904	-0.266	0.393
@ RCCV	98197	-21.470	-6.681	-1.270	17.924	18.933	-0.016	-0.052	-0.217
	98103	-13.879	-12.975	-0.003	21.263	20.723	0.115	1.239	0.090
27 Slab	98472	-0.712	2.508	15.854	2.844	3.563	-1.727	1.485	-1.701
EL27.0m	98514	8.714	-4.774	-2.722	1.284	5.685	0.103	-0.091	-2.673
@ RCCV	98424	-12.877	1.351	-2.967	7.731	9.604	-0.006	-6.463	-0.087
28 Pool Girder	123054	9.857	-7.176	3.794	0.061	-0.484	-0.222	0.790	-0.570
@ Storage Pool	123154	7.646	-1.589	2.072	0.291	0.127	-0.235	0.262	0.022
29 Pool Girder	123062	11.194	0.038	-2.026	-0.395	0.719	0.207	1.138	-0.117
@ Well	123162	7.371	0.069	-1.416	-0.059	0.546	-0.247	0.304	-0.082
30 Pool Girder	123067	7.387	-5.704	-5.204	0.309	-0.082	-0.083	-0.415	-0.377
@ Buffer Pool	123167	4.800	-1.367	-2.400	0.306	0.335	0.026	-0.128	0.066
32 IC/PCCS	125051	3.473	-2.171	0.893	-0.574	-0.630	0.049	-0.282	-0.058
Pool Wall	125151	1.753	-1.442	-0.967	-0.439	-0.226	-0.016	-0.265	-0.069
in NS Direction	125055	6.938	0.773	-0.207	0.007	-0.199	-0.001	0.298	0.181
	125155	3.393	0.481	0.012	0.006	-0.149	-0.010	0.012	-0.083

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-10 RB Upper Pools - Results of NASTRAN Analysis, Seismic Load (Horizontal: North to South Direction)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	0.235	-0.044	0.071	-0.051	-0.138	-0.104	-0.073	0.004
@ Drywell Head	98135	1.035	0.092	-0.142	-0.221	-0.021	0.005	-0.023	0.007
Opening	98104	-0.084	-1.784	0.108	-0.058	-0.368	0.021	-0.040	0.026
16 Topslab	98149	0.423	0.405	0.169	-0.189	0.019	-0.108	-0.077	-0.011
@ Center	98170	0.217	-0.354	0.174	-0.147	-0.177	-0.024	-0.013	-0.028
	98109	0.113	-1.458	-0.076	-0.301	-0.443	-0.020	-0.062	0.071
17 Topslab	98174	-0.019	1.048	0.104	-0.037	-0.115	-0.228	-0.023	-0.035
@ RCCV	98197	0.022	-0.577	0.515	-0.005	-0.114	-0.083	0.025	0.103
	98103	-0.135	-1.647	0.037	-1.188	-0.641	0.020	-0.259	0.017
27 Slab	98472	1.116	-0.286	-0.210	-0.458	-0.547	0.217	-0.164	0.224
EL27.0m	98514	-0.393	-0.172	-0.105	-0.145	-0.496	0.031	0.039	0.344
@ RCCV	98424	0.985	-1.102	0.090	0.114	-0.140	0.096	1.033	0.048
28 Pool Girder	123054	-0.105	1.449	-0.517	-0.067	-0.009	0.032	-0.016	0.019
@ Storage Pool	123154	-1.168	0.463	-0.380	-0.096	-0.032	0.026	-0.027	0.002
29 Pool Girder	123062	-0.189	-0.076	0.304	-0.137	-0.022	-0.035	0.063	0.032
@ Well	123162	-0.879	-0.127	0.165	-0.262	-0.069	-0.019	0.118	0.007
30 Pool Girder	123067	-0.733	1.734	0.963	0.067	0.024	0.023	0.027	0.021
@ Buffer Pool	123167	-1.131	0.330	1.275	0.023	0.033	0.007	0.000	0.002
32 IC/PCCS	125051	0.011	0.304	0.367	0.004	0.011	-0.004	0.022	-0.004
Pool Wall	125151	-0.196	0.229	0.311	0.015	0.010	0.000	0.028	-0.006
in NS Direction	125055	-0.070	-0.045	0.465	-0.026	-0.017	0.001	0.007	-0.006
	125155	-0.383	0.002	0.392	-0.019	0.007	0.003	0.022	-0.011

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-11 RB Upper Pools - Results of NASTRAN Analysis, Seismic Load (Horizontal: East to West Direction)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	-1.240	-1.096	-0.904	-0.127	-0.652	-0.222	-0.033	-0.121
@ Drywell Head	98135	0.102	0.348	-0.578	-0.204	-0.277	0.143	0.064	-0.135
Opening	98104	0.415	0.577	-0.602	0.025	-0.414	-0.041	0.065	-0.356
16 Topslab	98149	-0.977	-0.370	-0.560	-0.093	-0.291	-0.052	0.052	0.072
@ Center	98170	-0.967	0.084	-0.901	-0.016	0.009	-0.005	0.016	0.005
	98109	0.062	0.021	-0.799	-0.052	-0.261	-0.120	-0.001	-0.135
17 Topslab	98174	-1.434	-0.290	-0.736	-0.295	-0.232	0.064	0.139	-0.097
@ RCCV	98197	-1.364	-0.007	-0.783	0.000	0.041	-0.042	-0.037	0.039
	98103	-0.214	0.174	-1.220	-0.038	-0.059	-0.233	0.040	-0.053
27 Slab	98472	0.133	-1.152	-0.544	-0.004	-0.006	-0.007	-0.086	0.100
EL27.0m	98514	-0.592	0.235	-0.459	0.123	0.955	-0.014	-0.020	-0.659
@ RCCV	98424	0.199	-0.160	-5.679	0.062	0.046	-0.190	0.048	0.096
28 Pool Girder	123054	0.284	0.140	0.134	0.314	0.154	-0.070	0.030	0.193
@ Storage Pool	123154	-0.397	0.342	0.687	0.200	-0.061	-0.086	0.047	-0.009
29 Pool Girder	123062	-0.420	0.966	0.140	0.076	0.056	-0.028	-0.060	0.078
@ Well	123162	-0.616	0.896	0.142	0.062	-0.051	0.020	-0.069	0.007
30 Pool Girder	123067	0.051	-0.015	0.251	0.158	0.162	0.053	0.017	0.247
@ Buffer Pool	123167	-0.442	0.383	-0.359	0.053	-0.109	0.064	-0.055	-0.013
32 IC/PCCS	125051	-0.143	0.258	-0.277	-0.002	-0.011	-0.002	-0.002	0.021
Pool Wall	125151	-0.100	0.150	-0.088	0.003	-0.002	-0.012	-0.003	-0.013
in NS Direction	125055	-0.353	0.072	0.102	-0.002	-0.017	-0.004	-0.018	0.041
	125155	-0.384	0.018	0.084	-0.001	-0.019	0.004	-0.019	-0.027

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-12 RB Upper Pools - Results of NASTRAN Analysis, Seismic Load (Vertical: Upward Direction)

Location	Element ID	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	-0.954	-0.304	-0.371	0.470	0.090	0.320	-0.072	-0.420
@ Drywell Head	98135	-2.389	-0.191	0.169	0.631	-0.264	-0.130	0.057	-0.358
Opening	98104	-0.068	-0.730	0.049	0.246	1.523	-0.290	0.004	-0.224
16 Topslab	98149	-1.492	0.268	-0.491	0.717	0.174	-0.057	-0.004	0.283
@ Center	98170	-1.261	0.050	-0.077	0.664	0.675	-0.068	0.000	-0.069
	98109	-0.112	-0.491	-0.048	0.643	0.909	-0.168	-0.107	-0.097
17 Topslab	98174	-0.688	0.055	-0.172	0.698	0.511	0.243	0.160	-0.053
@ RCCV	98197	-0.363	0.058	0.151	0.302	-1.018	-0.150	-0.065	-0.623
	98103	0.168	-0.329	-0.065	-1.794	-0.292	-0.194	-0.889	-0.111
27 Slab	98472	-0.327	0.037	-0.190	-0.348	-0.573	0.440	-0.351	0.414
EL27.0m	98514	-0.087	-0.065	-0.052	-0.056	-0.248	-0.034	0.018	0.140
@ RCCV	98424	0.215	-0.340	-0.004	-0.744	-0.207	0.050	0.989	0.063
28 Pool Girder	123054	-0.395	2.229	0.690	-0.046	-0.036	-0.043	0.007	0.018
@ Storage Pool	123154	-1.306	0.402	0.534	-0.060	-0.031	-0.083	-0.011	-0.009
29 Pool Girder	123062	-0.387	-0.532	-0.268	0.043	0.210	-0.024	-0.019	0.109
@ Well	123162	1.190	-0.198	-0.132	0.069	0.048	-0.015	-0.083	-0.026
30 Pool Girder	123067	-0.408	2.312	-1.252	-0.014	0.043	0.066	0.096	0.045
@ Buffer Pool	123167	-0.618	0.554	-1.041	-0.035	-0.022	-0.009	0.025	-0.005
32 IC/PCCS	125051	0.093	1.224	0.837	-0.001	0.056	0.003	-0.001	0.041
Pool Wall	125151	0.093	0.503	0.683	0.006	0.010	0.005	-0.006	0.002
in NS Direction	125055	-0.046	0.124	0.070	0.016	0.098	-0.003	0.033	0.064
	125155	0.472	0.103	0.057	-0.006	-0.025	-0.006	-0.033	0.036

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-13 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 6001

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab @ Drywell Head Opening	98120	OTHR	-0.116	1.220	1.421	1.549	0.876	0.764	0.398	-1.412
		TEMP	-15.960	-22.072	-9.476	4.431	2.330	3.669	-1.086	-1.337
		HYDR	0.239	0.081	0.101	0.050	0.074	0.036	0.009	0.019
	98135	OTHR	-1.528	-0.597	-0.608	1.179	-0.461	0.203	0.263	-1.771
		TEMP	-30.538	-10.944	7.791	5.005	-0.130	-1.253	0.261	-0.282
		HYDR	0.374	0.055	0.078	0.068	0.021	0.017	0.005	0.009
	98104	OTHR	-0.337	2.874	-1.003	1.321	4.626	-0.589	-0.539	-1.018
		TEMP	-10.782	-29.517	7.027	0.326	5.448	-1.241	0.153	-0.246
		HYDR	0.069	0.289	0.113	0.021	0.123	0.026	0.005	0.047
16 Topslab @ Center	98149	OTHR	-0.546	2.189	-0.729	0.733	0.035	0.500	0.014	0.527
		TEMP	-26.935	-16.562	1.835	4.430	5.459	1.273	-0.543	-0.210
		HYDR	0.350	0.186	0.040	0.047	0.037	0.026	0.016	0.020
	98170	OTHR	-0.368	1.466	-0.516	0.916	0.680	-0.069	-0.031	-0.221
		TEMP	-24.575	-14.574	0.622	4.385	6.101	-0.019	0.102	0.612
		HYDR	0.252	0.185	0.120	0.035	0.051	0.012	0.005	0.005
	98109	OTHR	0.445	1.908	-0.252	1.490	2.892	-0.434	-0.170	-0.525
		TEMP	-21.084	-20.420	2.654	3.532	4.859	0.021	0.689	-0.121
		HYDR	0.042	0.153	0.192	0.028	0.083	0.027	0.005	0.013
17 Topslab @ RCCV	98174	OTHR	0.746	1.816	-0.160	0.551	0.562	0.702	0.224	-0.159
		TEMP	-24.341	-16.231	-0.525	5.956	7.862	-0.379	-0.487	1.344
		HYDR	0.298	0.192	0.069	0.113	0.126	0.079	0.041	0.038
	98197	OTHR	0.452	1.949	-0.214	-0.141	-2.616	-0.196	-0.109	-1.508
		TEMP	-28.708	-14.153	-1.482	4.297	5.736	0.291	0.369	-1.230
		HYDR	0.414	0.266	0.108	0.072	0.133	0.034	0.017	0.035
	98103	OTHR	0.937	2.239	-0.127	-1.911	0.510	-0.503	-1.454	-0.318
		TEMP	-23.625	-19.677	0.017	8.929	6.517	0.137	1.162	0.098
		HYDR	0.056	0.174	0.229	0.090	0.079	0.016	0.023	0.001
27 Slab EL27.0m @ RCCV	98472	OTHR	0.598	0.749	-0.160	0.093	0.116	0.074	0.310	-0.312
		TEMP	-6.688	-5.372	14.755	-3.970	-2.975	-0.477	1.234	-1.689
		HYDR	0.100	0.049	0.144	0.060	0.079	0.039	0.048	0.050
	98514	OTHR	0.388	0.537	0.023	-0.035	-0.502	-0.013	-0.005	-0.005
		TEMP	12.327	-5.717	-3.144	-1.352	-0.396	-0.165	0.097	-0.409
		HYDR	0.171	0.075	0.171	0.027	0.126	0.002	0.002	0.099
	98424	OTHR	-0.280	1.593	-0.036	-0.576	-0.082	-0.132	-0.308	-0.030
		TEMP	-19.507	-7.609	-2.516	-9.062	-5.593	-0.059	-6.087	0.027
		HYDR	0.038	0.122	0.094	0.045	0.058	0.019	0.155	0.004

Table 3G.5-13 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 6001 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
28 Pool Girder @ Storage Pool	123054	OTHR	0.181	1.271	1.721	0.070	0.026	-0.166	-0.053	-0.068
		TEMP	-1.938	-2.515	1.566	5.417	5.584	0.162	-0.786	1.285
		HYDR	0.115	0.149	0.128	0.009	0.008	0.005	0.012	0.012
	123154	OTHR	0.064	0.064	1.522	0.074	0.040	-0.189	-0.096	0.030
		TEMP	2.827	2.088	-1.845	4.580	2.974	-0.774	-0.233	0.669
		HYDR	0.211	0.029	0.122	0.014	0.009	0.016	0.006	0.001
29 Pool Girder @ Well	123062	OTHR	0.341	-1.396	-1.460	0.027	0.300	-0.001	0.043	0.174
		TEMP	-5.127	-4.093	-0.708	-0.074	0.431	0.003	-0.026	0.353
		HYDR	0.127	0.014	0.099	0.009	0.011	0.004	0.005	0.003
	123162	OTHR	2.594	-0.537	-1.030	0.081	0.023	0.000	-0.058	-0.029
		TEMP	-3.908	-3.486	-2.637	-0.570	-0.433	0.167	-0.034	0.235
		HYDR	0.315	0.013	0.093	0.017	0.011	0.003	0.011	0.003
30 Pool Girder @ Buffer Pool	123067	OTHR	0.174	1.598	-1.845	-0.044	-0.074	0.042	-0.040	-0.043
		TEMP	-3.820	-9.165	-4.161	-2.718	-3.315	-0.123	-0.102	0.614
		HYDR	0.121	0.753	0.285	0.022	0.021	0.008	0.017	0.021
	123167	OTHR	-0.295	0.333	-1.783	-0.009	-0.064	0.036	-0.080	0.002
		TEMP	-2.808	-4.392	-4.025	-3.283	-3.669	-0.676	0.202	-0.166
		HYDR	0.336	0.218	0.312	0.013	0.006	0.006	0.008	0.003
32 IC/PCCS Pool Wall in NS Direction	125051	OTHR	0.275	1.012	1.148	-0.051	0.034	0.003	-0.041	0.049
		TEMP	-1.704	-1.534	-0.758	0.082	0.171	0.014	-0.047	0.053
		HYDR	0.011	0.065	0.043	0.002	0.001	0.000	0.002	0.001
	125151	OTHR	0.410	0.298	0.920	-0.064	-0.011	0.002	-0.068	0.005
		TEMP	-1.701	-1.207	1.885	0.196	0.283	0.076	-0.028	-0.077
		HYDR	0.026	0.037	0.048	0.003	0.001	0.000	0.003	0.000
	125055	OTHR	0.260	-0.040	-0.079	0.032	0.139	0.001	0.054	0.096
		TEMP	-5.013	0.266	0.012	0.033	0.309	0.010	0.048	0.102
		HYDR	0.033	0.031	0.066	0.001	0.001	0.000	0.001	0.000
	125155	OTHR	0.974	0.033	-0.057	-0.002	-0.050	-0.006	-0.046	0.055
		TEMP	-5.698	-0.537	-0.141	-0.037	-0.038	-0.015	-0.287	0.230
		HYDR	0.052	0.012	0.070	0.001	0.000	0.000	0.001	0.001

OTHR: Loads other than thermal and hydrodynamic loads
TEMP: Thermal loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.5-14 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 6002

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	OTHR	-0.116	1.220	1.421	1.549	0.876	0.764	0.398	-1.412
@ Drywell Head		TEMP	-19.902	-26.667	-11.787	5.629	2.584	4.364	-2.001	-2.323
Opening		HYDR	0.239	0.081	0.101	0.050	0.074	0.036	0.009	0.019
	98135	OTHR	-1.528	-0.597	-0.608	1.179	-0.461	0.203	0.263	-1.771
		TEMP	-39.294	-13.488	9.764	5.599	-0.234	-1.593	0.184	-0.375
		HYDR	0.374	0.055	0.078	0.068	0.021	0.017	0.005	0.009
	98104	OTHR	-0.337	2.874	-1.003	1.321	4.626	-0.589	-0.539	-1.018
		TEMP	-13.270	-35.829	8.792	0.352	6.123	-1.341	0.149	-0.199
		HYDR	0.069	0.289	0.113	0.021	0.123	0.026	0.005	0.047
16 Topslab	98149	OTHR	-0.546	2.189	-0.729	0.733	0.035	0.500	0.014	0.527
@ Center		TEMP	-33.733	-21.119	4.825	5.213	5.993	1.060	-1.406	0.102
		HYDR	0.350	0.186	0.040	0.047	0.037	0.026	0.016	0.020
	98170	OTHR	-0.368	1.466	-0.516	0.916	0.680	-0.069	-0.031	-0.221
		TEMP	-34.893	-14.930	1.452	5.732	10.037	-0.064	-0.308	2.366
		HYDR	0.252	0.185	0.120	0.035	0.051	0.012	0.005	0.005
	98109	OTHR	0.445	1.908	-0.252	1.490	2.892	-0.434	-0.170	-0.525
		TEMP	-25.371	-25.382	2.731	3.872	5.508	0.166	0.756	-0.215
		HYDR	0.042	0.153	0.192	0.028	0.083	0.027	0.005	0.013
17 Topslab	98174	OTHR	0.746	1.816	-0.160	0.551	0.562	0.702	0.224	-0.159
@ RCCV		TEMP	-26.600	-14.222	8.993	10.857	12.992	1.314	-1.498	1.903
		HYDR	0.298	0.192	0.069	0.113	0.126	0.079	0.041	0.038
	98197	OTHR	0.452	1.949	-0.214	-0.141	-2.616	-0.196	-0.109	-1.508
		TEMP	-13.284	-10.483	-1.148	17.845	17.217	0.071	0.069	-0.159
		HYDR	0.414	0.266	0.108	0.072	0.133	0.034	0.017	0.035
	98103	OTHR	0.937	2.239	-0.127	-1.911	0.510	-0.503	-1.454	-0.318
		TEMP	-27.839	-21.759	0.163	10.698	7.647	0.099	1.647	0.121
		HYDR	0.056	0.174	0.229	0.090	0.079	0.016	0.023	0.001
27 Slab	98472	OTHR	0.598	0.749	-0.160	0.093	0.116	0.074	0.310	-0.312
EL27.0m		TEMP	0.560	2.997	21.415	2.417	3.120	-1.205	1.317	-1.610
@ RCCV		HYDR	0.100	0.049	0.144	0.060	0.079	0.039	0.048	0.050
	98514	OTHR	0.388	0.537	0.023	-0.035	-0.502	-0.013	-0.005	-0.005
		TEMP	12.596	-5.530	-2.667	1.250	5.280	0.063	-0.064	-2.425
		HYDR	0.171	0.075	0.171	0.027	0.126	0.002	0.002	0.099
	98424	OTHR	-0.280	1.593	-0.036	-0.576	-0.082	-0.132	-0.308	-0.030
		TEMP	-25.159	-6.289	-2.594	-9.143	-5.309	-0.140	-8.276	-0.118
		HYDR	0.038	0.122	0.094	0.045	0.058	0.019	0.155	0.004

Table 3G.5-14 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 6002 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
28 Pool Girder @ Storage Pool	123054	OTHR	0.181	1.271	1.721	0.070	0.026	-0.166	-0.053	-0.068
		TEMP	-2.533	-12.587	0.553	5.558	5.234	0.165	0.381	0.217
		HYDR	0.115	0.149	0.128	0.009	0.008	0.005	0.012	0.012
	123154	OTHR	0.064	0.064	1.522	0.074	0.040	-0.189	-0.096	0.030
		TEMP	-1.617	-4.773	2.290	5.684	3.025	-0.503	0.458	0.837
		HYDR	0.211	0.029	0.122	0.014	0.009	0.016	0.006	0.001
29 Pool Girder @ Well	123062	OTHR	0.341	-1.396	-1.460	0.027	0.300	-0.001	0.043	0.174
		TEMP	-7.087	-7.406	0.091	-0.429	0.232	-0.240	0.122	0.390
		HYDR	0.127	0.014	0.099	0.009	0.011	0.004	0.005	0.003
	123162	OTHR	2.594	-0.537	-1.030	0.081	0.023	0.000	-0.058	-0.029
		TEMP	-6.089	-5.905	-3.162	-1.202	-0.494	0.073	0.108	0.172
		HYDR	0.315	0.013	0.093	0.017	0.011	0.003	0.011	0.003
30 Pool Girder @ Buffer Pool	123067	OTHR	0.174	1.598	-1.845	-0.044	-0.074	0.042	-0.040	-0.043
		TEMP	5.357	-5.116	-3.767	0.633	-0.017	-0.360	-0.406	-0.305
		HYDR	0.121	0.753	0.285	0.022	0.021	0.008	0.017	0.021
	123167	OTHR	-0.295	0.333	-1.783	-0.009	-0.064	0.036	-0.080	0.002
		TEMP	0.172	-1.539	-1.800	0.764	0.265	-0.025	-0.182	-0.019
		HYDR	0.336	0.218	0.312	0.013	0.006	0.006	0.008	0.003
32 IC/PCCS Pool Wall in NS Direction	125051	OTHR	0.275	1.012	1.148	-0.051	0.034	0.003	-0.041	0.049
		TEMP	2.182	1.406	0.841	1.141	1.454	0.062	-0.706	0.145
		HYDR	0.011	0.065	0.043	0.002	0.001	0.000	0.002	0.001
	125151	OTHR	0.410	0.298	0.920	-0.064	-0.011	0.002	-0.068	0.005
		TEMP	0.820	0.470	1.675	1.267	1.459	0.112	-0.609	-0.022
		HYDR	0.026	0.037	0.048	0.003	0.001	0.000	0.003	0.000
	125055	OTHR	0.260	-0.040	-0.079	0.032	0.139	0.001	0.054	0.096
		TEMP	0.876	2.406	-0.406	2.535	2.933	0.001	0.149	0.312
		HYDR	0.033	0.031	0.066	0.001	0.001	0.000	0.001	0.000
	125155	OTHR	0.974	0.033	-0.057	-0.002	-0.050	-0.006	-0.046	0.055
		TEMP	-1.094	1.213	0.165	2.361	2.132	-0.036	-0.297	0.357
		HYDR	0.052	0.012	0.070	0.001	0.000	0.000	0.001	0.001

OTHR: Loads other than thermal and hydrodynamic loads
TEMP: Thermal loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-15 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 6003

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab @ Drywell Head Opening	98120	OTHR	-0.116	1.220	1.421	1.549	0.876	0.764	0.398	-1.412
		TEMP	-15.482	-25.691	-9.974	5.489	2.234	4.322	-2.021	-2.368
		HYDR	0.239	0.081	0.101	0.050	0.074	0.036	0.009	0.019
	98135	OTHR	-1.528	-0.597	-0.608	1.179	-0.461	0.203	0.263	-1.771
		TEMP	-32.537	-12.430	9.556	4.505	-0.194	-1.508	0.066	-0.258
		HYDR	0.374	0.055	0.078	0.068	0.021	0.017	0.005	0.009
	98104	OTHR	-0.337	2.874	-1.003	1.321	4.626	-0.589	-0.539	-1.018
		TEMP	-12.512	-34.938	8.362	0.044	4.959	-1.046	0.084	-0.255
		HYDR	0.069	0.289	0.113	0.021	0.123	0.026	0.005	0.047
16 Topslab @ Center	98149	OTHR	-0.546	2.189	-0.729	0.733	0.035	0.500	0.014	0.527
		TEMP	-28.675	-18.892	4.137	6.478	7.026	1.078	-2.189	-0.583
		HYDR	0.350	0.186	0.040	0.047	0.037	0.026	0.016	0.020
	98170	OTHR	-0.368	1.466	-0.516	0.916	0.680	-0.069	-0.031	-0.221
		TEMP	-25.010	-15.923	1.978	5.084	6.564	-0.038	0.234	0.414
		HYDR	0.252	0.185	0.120	0.035	0.051	0.012	0.005	0.005
	98109	OTHR	0.445	1.908	-0.252	1.490	2.892	-0.434	-0.170	-0.525
		TEMP	-23.621	-24.363	2.681	3.361	4.562	0.150	0.762	-0.169
		HYDR	0.042	0.153	0.192	0.028	0.083	0.027	0.005	0.013
17 Topslab @ RCCV	98174	OTHR	0.746	1.816	-0.160	0.551	0.562	0.702	0.224	-0.159
		TEMP	-22.078	-8.288	0.121	9.502	11.524	-0.392	-0.423	0.969
		HYDR	0.298	0.192	0.069	0.113	0.126	0.079	0.041	0.038
	98197	OTHR	0.452	1.949	-0.214	-0.141	-2.616	-0.196	-0.109	-1.508
		TEMP	-32.845	-14.689	-0.677	3.897	4.991	0.352	0.353	-1.504
		HYDR	0.414	0.266	0.108	0.072	0.133	0.034	0.017	0.035
	98103	OTHR	0.937	2.239	-0.127	-1.911	0.510	-0.503	-1.454	-0.318
		TEMP	-26.644	-21.930	0.304	9.531	6.548	0.056	1.410	0.111
		HYDR	0.056	0.174	0.229	0.090	0.079	0.016	0.023	0.001
27 Slab EL27.0m @ RCCV	98472	OTHR	0.598	0.749	-0.160	0.093	0.116	0.074	0.310	-0.312
		TEMP	-10.555	-5.730	14.877	-3.631	-2.841	-0.701	1.393	-1.882
		HYDR	0.100	0.049	0.144	0.060	0.079	0.039	0.048	0.050
	98514	OTHR	0.388	0.537	0.023	-0.035	-0.502	-0.013	-0.005	-0.005
		TEMP	19.208	-5.647	-2.587	1.045	2.953	-0.194	0.107	-1.118
		HYDR	0.171	0.075	0.171	0.027	0.126	0.002	0.002	0.099
	98424	OTHR	-0.280	1.593	-0.036	-0.576	-0.082	-0.132	-0.308	-0.030
		TEMP	-24.231	-6.952	-2.278	-10.190	-6.460	-0.167	-7.964	-0.108
		HYDR	0.038	0.122	0.094	0.045	0.058	0.019	0.155	0.004

Table 3G.5-15 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 6003 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
28 Pool Girder @ Storage Pool	123054	OTHR	0.181	1.271	1.721	0.070	0.026	-0.166	-0.053	-0.068
		TEMP	-0.796	-10.849	0.720	6.148	6.064	0.167	0.364	0.243
		HYDR	0.115	0.149	0.128	0.009	0.008	0.005	0.012	0.012
	123154	OTHR	0.064	0.064	1.522	0.074	0.040	-0.189	-0.096	0.030
		TEMP	2.563	-3.589	1.883	6.336	3.560	-0.289	0.575	0.983
		HYDR	0.211	0.029	0.122	0.014	0.009	0.016	0.006	0.001
29 Pool Girder @ Well	123062	OTHR	0.341	-1.396	-1.460	0.027	0.300	-0.001	0.043	0.174
		TEMP	-3.492	-7.610	-0.329	0.235	0.976	-0.143	0.144	0.349
		HYDR	0.127	0.014	0.099	0.009	0.011	0.004	0.005	0.003
	123162	OTHR	2.594	-0.537	-1.030	0.081	0.023	0.000	-0.058	-0.029
		TEMP	-2.959	-6.337	-3.847	-0.450	0.157	0.052	0.056	0.215
		HYDR	0.315	0.013	0.093	0.017	0.011	0.003	0.011	0.003
30 Pool Girder @ Buffer Pool	123067	OTHR	0.174	1.598	-1.845	-0.044	-0.074	0.042	-0.040	-0.043
		TEMP	-1.268	-8.891	-3.861	-5.866	-6.788	0.001	-0.270	0.070
		HYDR	0.121	0.753	0.285	0.022	0.021	0.008	0.017	0.021
	123167	OTHR	-0.295	0.333	-1.783	-0.009	-0.064	0.036	-0.080	0.002
		TEMP	-0.187	-3.829	-3.108	-6.192	-5.622	-0.821	0.411	-0.590
		HYDR	0.336	0.218	0.312	0.013	0.006	0.006	0.008	0.003
32 IC/PCCS Pool Wall in NS Direction	125051	OTHR	0.275	1.012	1.148	-0.051	0.034	0.003	-0.041	0.049
		TEMP	-1.590	-0.135	-1.056	-0.896	-0.957	0.021	-0.132	0.072
		HYDR	0.011	0.065	0.043	0.002	0.001	0.000	0.002	0.001
	125151	OTHR	0.410	0.298	0.920	-0.064	-0.011	0.002	-0.068	0.005
		TEMP	-1.514	-0.093	1.642	-0.781	-0.803	0.065	-0.132	-0.123
		HYDR	0.026	0.037	0.048	0.003	0.001	0.000	0.003	0.000
	125055	OTHR	0.260	-0.040	-0.079	0.032	0.139	0.001	0.054	0.096
		TEMP	-5.687	0.084	-0.180	-0.145	0.088	0.019	0.049	0.095
		HYDR	0.033	0.031	0.066	0.001	0.001	0.000	0.001	0.000
	125155	OTHR	0.974	0.033	-0.057	-0.002	-0.050	-0.006	-0.046	0.055
		TEMP	-6.471	-0.673	-0.245	-0.209	-0.233	-0.039	-0.277	0.218
		HYDR	0.052	0.012	0.070	0.001	0.000	0.000	0.001	0.001

OTHR: Loads other than thermal and hydrodynamic loads
TEMP: Thermal loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.5-16 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 6004

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab @ Drywell Head Opening	98120	OTHR	-0.116	1.220	1.421	1.549	0.876	0.764	0.398	-1.412
		TEMP	-19.685	-9.620	-6.700	13.625	13.102	10.762	-0.910	-0.945
		HYDR	0.239	0.081	0.101	0.050	0.074	0.036	0.009	0.019
	98135	OTHR	-1.528	-0.597	-0.608	1.179	-0.461	0.203	0.263	-1.771
		TEMP	-32.643	-9.465	3.312	21.679	2.367	-4.692	1.311	-1.131
		HYDR	0.374	0.055	0.078	0.068	0.021	0.017	0.005	0.009
	98104	OTHR	-0.337	2.874	-1.003	1.321	4.626	-0.589	-0.539	-1.018
		TEMP	-8.235	-7.644	3.764	4.770	25.728	-6.165	0.516	-0.138
		HYDR	0.069	0.289	0.113	0.021	0.123	0.026	0.005	0.047
16 Topslab @ Center	98149	OTHR	-0.546	2.189	-0.729	0.733	0.035	0.500	0.014	0.527
		TEMP	-21.295	-8.598	-2.582	17.374	16.424	1.478	-0.731	0.060
		HYDR	0.350	0.186	0.040	0.047	0.037	0.026	0.016	0.020
	98170	OTHR	-0.368	1.466	-0.516	0.916	0.680	-0.069	-0.031	-0.221
		TEMP	-22.487	-9.601	-1.177	18.047	16.314	-0.099	0.184	0.965
		HYDR	0.252	0.185	0.120	0.035	0.051	0.012	0.005	0.005
	98109	OTHR	0.445	1.908	-0.252	1.490	2.892	-0.434	-0.170	-0.525
		TEMP	-14.161	-10.561	1.426	14.914	19.897	-0.725	0.771	-0.034
		HYDR	0.042	0.153	0.192	0.028	0.083	0.027	0.005	0.013
17 Topslab @ RCCV	98174	OTHR	0.746	1.816	-0.160	0.551	0.562	0.702	0.224	-0.159
		TEMP	-18.223	-10.690	1.049	17.510	16.987	0.904	-0.266	0.393
		HYDR	0.298	0.192	0.069	0.113	0.126	0.079	0.041	0.038
	98197	OTHR	0.452	1.949	-0.214	-0.141	-2.616	-0.196	-0.109	-1.508
		TEMP	-21.470	-6.681	-1.270	17.924	18.933	-0.016	-0.052	-0.217
		HYDR	0.414	0.266	0.108	0.072	0.133	0.034	0.017	0.035
	98103	OTHR	0.937	2.239	-0.127	-1.911	0.510	-0.503	-1.454	-0.318
		TEMP	-13.879	-12.975	-0.003	21.263	20.723	0.115	1.239	0.090
		HYDR	0.056	0.174	0.229	0.090	0.079	0.016	0.023	0.001
27 Slab EL27.0m @ RCCV	98472	OTHR	0.598	0.749	-0.160	0.093	0.116	0.074	0.310	-0.312
		TEMP	-0.712	2.508	15.854	2.844	3.563	-1.727	1.485	-1.701
		HYDR	0.100	0.049	0.144	0.060	0.079	0.039	0.048	0.050
	98514	OTHR	0.388	0.537	0.023	-0.035	-0.502	-0.013	-0.005	-0.005
		TEMP	8.714	-4.774	-2.722	1.284	5.685	0.103	-0.091	-2.673
		HYDR	0.171	0.075	0.171	0.027	0.126	0.002	0.002	0.099
	98424	OTHR	-0.280	1.593	-0.036	-0.576	-0.082	-0.132	-0.308	-0.030
		TEMP	-12.877	1.351	-2.967	7.731	9.604	-0.006	-6.463	-0.087
		HYDR	0.038	0.122	0.094	0.045	0.058	0.019	0.155	0.004

Table 3G.5-16 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 6004 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
28 Pool Girder @ Storage Pool	123054	OTHR	0.181	1.271	1.721	0.070	0.026	-0.166	-0.053	-0.068
		TEMP	9.857	-7.176	3.794	0.061	-0.484	-0.222	0.790	-0.570
		HYDR	0.115	0.149	0.128	0.009	0.008	0.005	0.012	0.012
	123154	OTHR	0.064	0.064	1.522	0.074	0.040	-0.189	-0.096	0.030
		TEMP	7.646	-1.589	2.072	0.291	0.127	-0.235	0.262	0.022
		HYDR	0.211	0.029	0.122	0.014	0.009	0.016	0.006	0.001
29 Pool Girder @ Well	123062	OTHR	0.341	-1.396	-1.460	0.027	0.300	-0.001	0.043	0.174
		TEMP	11.194	0.038	-2.026	-0.395	0.719	0.207	1.138	-0.117
		HYDR	0.127	0.014	0.099	0.009	0.011	0.004	0.005	0.003
	123162	OTHR	2.594	-0.537	-1.030	0.081	0.023	0.000	-0.058	-0.029
		TEMP	7.371	0.069	-1.416	-0.059	0.546	-0.247	0.304	-0.082
		HYDR	0.315	0.013	0.093	0.017	0.011	0.003	0.011	0.003
30 Pool Girder @ Buffer Pool	123067	OTHR	0.174	1.598	-1.845	-0.044	-0.074	0.042	-0.040	-0.043
		TEMP	7.387	-5.704	-5.204	0.309	-0.082	-0.083	-0.415	-0.377
		HYDR	0.121	0.753	0.285	0.022	0.021	0.008	0.017	0.021
	123167	OTHR	-0.295	0.333	-1.783	-0.009	-0.064	0.036	-0.080	0.002
		TEMP	4.800	-1.367	-2.400	0.306	0.335	0.026	-0.128	0.066
		HYDR	0.336	0.218	0.312	0.013	0.006	0.006	0.008	0.003
32 IC/PCCS Pool Wall in NS Direction	125051	OTHR	0.275	1.012	1.148	-0.051	0.034	0.003	-0.041	0.049
		TEMP	3.473	-2.171	0.893	-0.574	-0.630	0.049	-0.282	-0.058
		HYDR	0.011	0.065	0.043	0.002	0.001	0.000	0.002	0.001
	125151	OTHR	0.410	0.298	0.920	-0.064	-0.011	0.002	-0.068	0.005
		TEMP	1.753	-1.442	-0.967	-0.439	-0.226	-0.016	-0.265	-0.069
		HYDR	0.026	0.037	0.048	0.003	0.001	0.000	0.003	0.000
	125055	OTHR	0.260	-0.040	-0.079	0.032	0.139	0.001	0.054	0.096
		TEMP	6.938	0.773	-0.207	0.007	-0.199	-0.001	0.298	0.181
		HYDR	0.033	0.031	0.066	0.001	0.001	0.000	0.001	0.000
	125155	OTHR	0.974	0.033	-0.057	-0.002	-0.050	-0.006	-0.046	0.055
		TEMP	3.393	0.481	0.012	0.006	-0.149	-0.010	0.012	-0.083
		HYDR	0.052	0.012	0.070	0.001	0.000	0.000	0.001	0.001

OTHR: Loads other than thermal and hydrodynamic loads
TEMP: Thermal loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-17 *RB Upper Pools - Combined Forces and Moments, Selected Load Combination 7001*

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab @ Drywell Head Opening	98120	OTHR	0.283	0.926	1.091	0.861	0.544	0.392	0.290	-0.798
		TEMP	-15.960	-22.072	-9.476	4.431	2.330	3.669	-1.086	-1.337
		SEIS	1.584	1.139	0.981	0.492	0.682	0.404	0.110	0.437
		HYDR	0.167	0.057	0.071	0.036	0.052	0.026	0.006	0.014
	98135	OTHR	-0.136	-0.322	-0.474	0.554	-0.221	0.183	0.155	-1.059
		TEMP	-30.538	-10.944	7.791	5.005	-0.130	-1.253	0.261	-0.282
		SEIS	2.606	0.408	0.619	0.703	0.385	0.195	0.091	0.383
		HYDR	0.259	0.037	0.053	0.049	0.015	0.012	0.004	0.006
	98104	OTHR	-0.195	2.182	-0.694	0.792	2.553	-0.289	-0.361	-0.602
		TEMP	-10.782	-29.517	7.027	0.326	5.448	-1.241	0.153	-0.246
		SEIS	0.429	2.013	0.613	0.255	1.629	0.294	0.079	0.422
		HYDR	0.047	0.201	0.077	0.015	0.089	0.019	0.004	0.032
16 Topslab @ Center	98149	OTHR	0.191	1.354	-0.308	0.230	-0.048	0.349	0.009	0.251
		TEMP	-26.935	-16.562	1.835	4.430	5.459	1.273	-0.543	-0.210
		SEIS	1.835	0.611	0.764	0.750	0.348	0.134	0.094	0.293
		HYDR	0.245	0.130	0.028	0.034	0.026	0.019	0.012	0.014
	98170	OTHR	0.218	0.971	-0.319	0.369	0.178	-0.020	-0.020	-0.131
		TEMP	-24.575	-14.574	0.622	4.385	6.101	-0.019	0.102	0.612
		SEIS	1.606	0.369	0.920	0.682	0.702	0.074	0.021	0.076
		HYDR	0.176	0.127	0.084	0.025	0.036	0.009	0.003	0.004
	98109	OTHR	0.348	1.457	-0.158	0.767	1.612	-0.231	-0.076	-0.318
		TEMP	-21.084	-20.420	2.654	3.532	4.859	0.021	0.689	-0.121
		SEIS	0.171	1.539	0.805	0.714	1.056	0.208	0.123	0.183
		HYDR	0.030	0.106	0.129	0.021	0.060	0.018	0.004	0.009
17 Topslab @ RCCV	98174	OTHR	0.766	1.170	-0.048	0.120	0.176	0.371	0.089	-0.091
		TEMP	-24.341	-16.231	-0.525	5.956	7.862	-0.379	-0.487	1.344
		SEIS	1.598	1.092	0.763	0.763	0.581	0.341	0.216	0.118
		HYDR	0.208	0.134	0.049	0.078	0.086	0.057	0.028	0.026
	98197	OTHR	0.467	1.292	-0.199	-0.183	-1.351	-0.075	-0.049	-0.764
		TEMP	-28.708	-14.153	-1.482	4.297	5.736	0.291	0.369	-1.230
		SEIS	1.413	0.587	0.950	0.302	1.025	0.177	0.080	0.633
		HYDR	0.290	0.186	0.078	0.051	0.091	0.024	0.011	0.026
	98103	OTHR	0.576	1.630	-0.068	-0.649	0.436	-0.269	-0.662	-0.174
		TEMP	-23.625	-19.677	0.017	8.929	6.517	0.137	1.162	0.098
		SEIS	0.304	1.689	1.238	2.160	0.733	0.304	0.930	0.125
		HYDR	0.039	0.121	0.155	0.068	0.059	0.011	0.018	0.001
27 Slab EL27.0m @ RCCV	98472	OTHR	0.541	0.521	-0.068	0.159	0.239	-0.092	0.321	-0.342
		TEMP	-6.688	-5.372	14.755	-3.970	-2.975	-0.477	1.234	-1.689
		SEIS	1.176	1.193	0.615	0.578	0.794	0.492	0.399	0.483
		HYDR	0.075	0.036	0.103	0.045	0.059	0.029	0.035	0.038
	98514	OTHR	0.312	0.396	0.031	-0.011	-0.282	0.003	-0.010	-0.043
		TEMP	12.327	-5.717	-3.144	-1.352	-0.396	-0.165	0.097	-0.409
		SEIS	0.726	0.299	0.479	0.203	1.130	0.049	0.047	0.777
		HYDR	0.121	0.054	0.118	0.020	0.094	0.001	0.001	0.074
	98424	OTHR	-0.224	1.211	-0.021	-0.140	0.005	-0.107	-0.521	-0.042
		TEMP	-19.507	-7.609	-2.516	-9.062	-5.593	-0.059	-6.087	0.027
		SEIS	1.028	1.165	5.763	0.759	0.269	0.223	1.468	0.128
		HYDR	0.028	0.084	0.064	0.033	0.044	0.013	0.117	0.003

Table 3G.5-17 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 7001 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
28 Pool Girder @ Storage Pool	123054	OTHR	0.254	0.062	0.883	0.063	0.032	-0.096	-0.040	-0.052
		TEMP	-1.938	-2.515	1.566	5.417	5.584	0.162	-0.786	1.285
		SEIS	0.509	2.690	0.878	0.333	0.162	0.091	0.035	0.197
		HYDR	0.085	0.112	0.096	0.007	0.006	0.004	0.008	0.009
	123154	OTHR	0.469	-0.118	0.803	0.073	0.035	-0.096	-0.061	0.024
		TEMP	2.827	2.088	-1.845	4.580	2.974	-0.774	-0.233	0.669
		SEIS	1.814	0.723	0.957	0.238	0.075	0.124	0.056	0.013
		HYDR	0.157	0.021	0.091	0.010	0.007	0.011	0.004	0.001
29 Pool Girder @ Well	123062	OTHR	0.359	-0.748	-0.884	0.004	0.130	0.007	0.034	0.079
		TEMP	-5.127	-4.093	-0.708	-0.074	0.431	0.003	-0.026	0.353
		SEIS	0.623	1.105	0.433	0.163	0.219	0.052	0.090	0.138
		HYDR	0.088	0.010	0.070	0.006	0.008	0.003	0.003	0.002
	123162	OTHR	1.266	-0.294	-0.641	0.030	-0.001	0.004	-0.012	-0.011
		TEMP	-3.908	-3.486	-2.637	-0.570	-0.433	0.167	-0.034	0.235
		SEIS	1.619	0.928	0.272	0.279	0.099	0.033	0.160	0.027
		HYDR	0.233	0.010	0.066	0.012	0.008	0.002	0.008	0.002
30 Pool Girder @ Buffer Pool	123067	OTHR	0.253	0.356	-0.750	-0.024	-0.063	0.006	-0.059	-0.044
		TEMP	-3.820	-9.165	-4.161	-2.718	-3.315	-0.123	-0.102	0.614
		SEIS	0.854	2.907	1.607	0.181	0.179	0.091	0.102	0.257
		HYDR	0.090	0.556	0.209	0.015	0.014	0.006	0.012	0.015
	123167	OTHR	-0.044	0.041	-0.769	0.005	-0.035	0.028	-0.062	0.004
		TEMP	-2.808	-4.392	-4.025	-3.283	-3.669	-0.676	0.202	-0.166
		SEIS	1.387	0.756	1.690	0.073	0.117	0.066	0.061	0.015
		HYDR	0.249	0.161	0.229	0.010	0.004	0.004	0.006	0.002
32 IC/PCCS Pool Wall in NS Direction	125051	OTHR	0.151	0.243	0.465	-0.034	0.004	0.001	-0.026	0.018
		TEMP	-1.704	-1.534	-0.758	0.082	0.171	0.014	-0.047	0.053
		SEIS	0.174	1.291	0.962	0.006	0.058	0.006	0.023	0.046
		HYDR	0.008	0.048	0.031	0.001	0.001	0.000	0.002	0.001
	125151	OTHR	0.235	0.020	0.367	-0.043	-0.010	0.000	-0.042	0.002
		TEMP	-1.701	-1.207	1.885	0.196	0.283	0.076	-0.028	-0.077
		SEIS	0.240	0.575	0.764	0.017	0.015	0.013	0.029	0.014
		HYDR	0.020	0.027	0.035	0.002	0.001	0.000	0.002	0.000
	125055	OTHR	0.188	-0.090	-0.086	0.016	0.058	0.002	0.024	0.041
		TEMP	-5.013	0.266	0.012	0.033	0.309	0.010	0.048	0.102
		SEIS	0.372	0.153	0.491	0.031	0.101	0.006	0.038	0.076
		HYDR	0.023	0.022	0.047	0.000	0.000	0.000	0.000	0.000
	125155	OTHR	0.472	-0.022	-0.065	0.001	-0.024	-0.002	-0.020	0.024
		TEMP	-5.698	-0.537	-0.141	-0.037	-0.038	-0.015	-0.287	0.230
		SEIS	0.722	0.105	0.419	0.020	0.033	0.008	0.044	0.047
		HYDR	0.039	0.008	0.050	0.000	0.000	0.000	0.001	0.000

OTHR: Loads other than thermal and hydrodynamic loads
TEMP: Thermal loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852x10^4 lbf/ft
1 MNm/m = 2.248x10^5 lbf-ft/ft

Table 3G.5-18 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 7002

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab @ Drywell Head Opening	98120	OTHR	0.283	0.926	1.091	0.861	0.544	0.392	0.290	-0.798
		TEMP	-19.902	-26.667	-11.787	5.629	2.584	4.364	-2.001	-2.323
		SEIS	1.584	1.139	0.981	0.492	0.682	0.404	0.110	0.437
		HYDR	0.167	0.057	0.071	0.036	0.052	0.026	0.006	0.014
	98135	OTHR	-0.136	-0.322	-0.474	0.554	-0.221	0.183	0.155	-1.059
		TEMP	-39.294	-13.488	9.764	5.599	-0.234	-1.593	0.184	-0.375
		SEIS	2.606	0.408	0.619	0.703	0.385	0.195	0.091	0.383
		HYDR	0.259	0.037	0.053	0.049	0.015	0.012	0.004	0.006
	98104	OTHR	-0.195	2.182	-0.694	0.792	2.553	-0.289	-0.361	-0.602
		TEMP	-13.270	-35.829	8.792	0.352	6.123	-1.341	0.149	-0.199
		SEIS	0.429	2.013	0.613	0.255	1.629	0.294	0.079	0.422
		HYDR	0.047	0.201	0.077	0.015	0.089	0.019	0.004	0.032
16 Topslab @ Center	98149	OTHR	0.191	1.354	-0.308	0.230	-0.048	0.349	0.009	0.251
		TEMP	-33.733	-21.119	4.825	5.213	5.993	1.060	-1.406	0.102
		SEIS	1.835	0.611	0.764	0.750	0.348	0.134	0.094	0.293
		HYDR	0.245	0.130	0.028	0.034	0.026	0.019	0.012	0.014
	98170	OTHR	0.218	0.971	-0.319	0.369	0.178	-0.020	-0.020	-0.131
		TEMP	-34.893	-14.930	1.452	5.732	10.037	-0.064	-0.308	2.366
		SEIS	1.606	0.369	0.920	0.682	0.702	0.074	0.021	0.076
		HYDR	0.176	0.127	0.084	0.025	0.036	0.009	0.003	0.004
	98109	OTHR	0.348	1.457	-0.158	0.767	1.612	-0.231	-0.076	-0.318
		TEMP	-25.371	-25.382	2.731	3.872	5.508	0.166	0.756	-0.215
		SEIS	0.171	1.539	0.805	0.714	1.056	0.208	0.123	0.183
		HYDR	0.030	0.106	0.129	0.021	0.060	0.018	0.004	0.009
17 Topslab @ RCCV	98174	OTHR	0.766	1.170	-0.048	0.120	0.176	0.371	0.089	-0.091
		TEMP	-26.600	-14.222	8.993	10.857	12.992	1.314	-1.498	1.903
		SEIS	1.598	1.092	0.763	0.763	0.581	0.341	0.216	0.118
		HYDR	0.208	0.134	0.049	0.078	0.086	0.057	0.028	0.026
	98197	OTHR	0.467	1.292	-0.199	-0.183	-1.351	-0.075	-0.049	-0.764
		TEMP	-13.284	-10.483	-1.148	17.845	17.217	0.071	0.069	-0.159
		SEIS	1.413	0.587	0.950	0.302	1.025	0.177	0.080	0.633
		HYDR	0.290	0.186	0.078	0.051	0.091	0.024	0.011	0.026
	98103	OTHR	0.576	1.630	-0.068	-0.649	0.436	-0.269	-0.662	-0.174
		TEMP	-27.839	-21.759	0.163	10.698	7.647	0.099	1.647	0.121
		SEIS	0.304	1.689	1.238	2.160	0.733	0.304	0.930	0.125
		HYDR	0.039	0.121	0.155	0.068	0.059	0.011	0.018	0.001
27 Slab EL27.0m @ RCCV	98472	OTHR	0.541	0.521	-0.068	0.159	0.239	-0.092	0.321	-0.342
		TEMP	0.560	2.997	21.415	2.417	3.120	-1.205	1.317	-1.610
		SEIS	1.176	1.193	0.615	0.578	0.794	0.492	0.399	0.483
		HYDR	0.075	0.036	0.103	0.045	0.059	0.029	0.035	0.038
	98514	OTHR	0.312	0.396	0.031	-0.011	-0.282	0.003	-0.010	-0.043
		TEMP	12.596	-5.530	-2.667	1.250	5.280	0.063	-0.064	-2.425
		SEIS	0.726	0.299	0.479	0.203	1.130	0.049	0.047	0.777
		HYDR	0.121	0.054	0.118	0.020	0.094	0.001	0.001	0.074
	98424	OTHR	-0.224	1.211	-0.021	-0.140	0.005	-0.107	-0.521	-0.042
		TEMP	-25.159	-6.289	-2.594	-9.143	-5.309	-0.140	-8.276	-0.118
		SEIS	1.028	1.165	5.763	0.759	0.269	0.223	1.468	0.128
		HYDR	0.028	0.084	0.064	0.033	0.044	0.013	0.117	0.003

Table 3G.5-18 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 7002 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
28 Pool Girder @ Storage Pool	123054	OTHR	0.254	0.062	0.883	0.063	0.032	-0.096	-0.040	-0.052
		TEMP	-2.533	-12.587	0.553	5.558	5.234	0.165	0.381	0.217
		SEIS	0.509	2.690	0.878	0.333	0.162	0.091	0.035	0.197
		HYDR	0.085	0.112	0.096	0.007	0.006	0.004	0.008	0.009
	123154	OTHR	0.469	-0.118	0.803	0.073	0.035	-0.096	-0.061	0.024
		TEMP	-1.617	-4.773	2.290	5.684	3.025	-0.503	0.458	0.837
		SEIS	1.814	0.723	0.957	0.238	0.075	0.124	0.056	0.013
		HYDR	0.157	0.021	0.091	0.010	0.007	0.011	0.004	0.001
29 Pool Girder @ Well	123062	OTHR	0.359	-0.748	-0.884	0.004	0.130	0.007	0.034	0.079
		TEMP	-7.087	-7.406	0.091	-0.429	0.232	-0.240	0.122	0.390
		SEIS	0.623	1.105	0.433	0.163	0.219	0.052	0.090	0.138
		HYDR	0.088	0.010	0.070	0.006	0.008	0.003	0.003	0.002
	123162	OTHR	1.266	-0.294	-0.641	0.030	-0.001	0.004	-0.012	-0.011
		TEMP	-6.089	-5.905	-3.162	-1.202	-0.494	0.073	0.108	0.172
		SEIS	1.619	0.928	0.272	0.279	0.099	0.033	0.160	0.027
		HYDR	0.233	0.010	0.066	0.012	0.008	0.002	0.008	0.002
30 Pool Girder @ Buffer Pool	123067	OTHR	0.253	0.356	-0.750	-0.024	-0.063	0.006	-0.059	-0.044
		TEMP	5.357	-5.116	-3.767	0.633	-0.017	-0.360	-0.406	-0.305
		SEIS	0.854	2.907	1.607	0.181	0.179	0.091	0.102	0.257
		HYDR	0.090	0.556	0.209	0.015	0.014	0.006	0.012	0.015
	123167	OTHR	-0.044	0.041	-0.769	0.005	-0.035	0.028	-0.062	0.004
		TEMP	0.172	-1.539	-1.800	0.764	0.265	-0.025	-0.182	-0.019
		SEIS	1.387	0.756	1.690	0.073	0.117	0.066	0.061	0.015
		HYDR	0.249	0.161	0.229	0.010	0.004	0.004	0.006	0.002
32 IC/PCCS Pool Wall in NS Direction	125051	OTHR	0.151	0.243	0.465	-0.034	0.004	0.001	-0.026	0.018
		TEMP	2.182	1.406	0.841	1.141	1.454	0.062	-0.706	0.145
		SEIS	0.174	1.291	0.962	0.006	0.058	0.006	0.023	0.046
		HYDR	0.008	0.048	0.031	0.001	0.001	0.000	0.002	0.001
	125151	OTHR	0.235	0.020	0.367	-0.043	-0.010	0.000	-0.042	0.002
		TEMP	0.820	0.470	1.675	1.267	1.459	0.112	-0.609	-0.022
		SEIS	0.240	0.575	0.764	0.017	0.015	0.013	0.029	0.014
		HYDR	0.020	0.027	0.035	0.002	0.001	0.000	0.002	0.000
	125055	OTHR	0.188	-0.090	-0.086	0.016	0.058	0.002	0.024	0.041
		TEMP	0.876	2.406	-0.406	2.535	2.933	0.001	0.149	0.312
		SEIS	0.372	0.153	0.491	0.031	0.101	0.006	0.038	0.076
		HYDR	0.023	0.022	0.047	0.000	0.000	0.000	0.000	0.000
	125155	OTHR	0.472	-0.022	-0.065	0.001	-0.024	-0.002	-0.020	0.024
		TEMP	-1.094	1.213	0.165	2.361	2.132	-0.036	-0.297	0.357
		SEIS	0.722	0.105	0.419	0.020	0.033	0.008	0.044	0.047
		HYDR	0.039	0.008	0.050	0.000	0.000	0.000	0.001	0.000

OTHR: Loads other than thermal and hydrodynamic loads
TEMP: Thermal loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-19 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 7003

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab @ Drywell Head Opening	98120	OTHR	0.283	0.926	1.091	0.861	0.544	0.392	0.290	-0.798
		TEMP	-15.482	-25.691	-9.974	5.489	2.234	4.322	-2.021	-2.368
		SEIS	1.584	1.139	0.981	0.492	0.682	0.404	0.110	0.437
		HYDR	0.167	0.057	0.071	0.036	0.052	0.026	0.006	0.014
	98135	OTHR	-0.136	-0.322	-0.474	0.554	-0.221	0.183	0.155	-1.059
		TEMP	-32.537	-12.430	9.556	4.505	-0.194	-1.508	0.066	-0.258
		SEIS	2.606	0.408	0.619	0.703	0.385	0.195	0.091	0.383
		HYDR	0.259	0.037	0.053	0.049	0.015	0.012	0.004	0.006
	98104	OTHR	-0.195	2.182	-0.694	0.792	2.553	-0.289	-0.361	-0.602
		TEMP	-12.512	-34.938	8.362	0.044	4.959	-1.046	0.084	-0.255
		SEIS	0.429	2.013	0.613	0.255	1.629	0.294	0.079	0.422
		HYDR	0.047	0.201	0.077	0.015	0.089	0.019	0.004	0.032
16 Topslab @ Center	98149	OTHR	0.191	1.354	-0.308	0.230	-0.048	0.349	0.009	0.251
		TEMP	-28.675	-18.892	4.137	6.478	7.026	1.078	-2.189	-0.583
		SEIS	1.835	0.611	0.764	0.750	0.348	0.134	0.094	0.293
		HYDR	0.245	0.130	0.028	0.034	0.026	0.019	0.012	0.014
	98170	OTHR	0.218	0.971	-0.319	0.369	0.178	-0.020	-0.020	-0.131
		TEMP	-25.010	-15.923	1.978	5.084	6.564	-0.038	0.234	0.414
		SEIS	1.606	0.369	0.920	0.682	0.702	0.074	0.021	0.076
		HYDR	0.176	0.127	0.084	0.025	0.036	0.009	0.003	0.004
	98109	OTHR	0.348	1.457	-0.158	0.767	1.612	-0.231	-0.076	-0.318
		TEMP	-23.621	-24.363	2.681	3.361	4.562	0.150	0.762	-0.169
		SEIS	0.171	1.539	0.805	0.714	1.056	0.208	0.123	0.183
		HYDR	0.030	0.106	0.129	0.021	0.060	0.018	0.004	0.009
17 Topslab @ RCCV	98174	OTHR	0.766	1.170	-0.048	0.120	0.176	0.371	0.089	-0.091
		TEMP	-22.078	-8.288	0.121	9.502	11.524	-0.392	-0.423	0.969
		SEIS	1.598	1.092	0.763	0.763	0.581	0.341	0.216	0.118
		HYDR	0.208	0.134	0.049	0.078	0.086	0.057	0.028	0.026
	98197	OTHR	0.467	1.292	-0.199	-0.183	-1.351	-0.075	-0.049	-0.764
		TEMP	-32.845	-14.689	-0.677	3.897	4.991	0.352	0.353	-1.504
		SEIS	1.413	0.587	0.950	0.302	1.025	0.177	0.080	0.633
		HYDR	0.290	0.186	0.078	0.051	0.091	0.024	0.011	0.026
	98103	OTHR	0.576	1.630	-0.068	-0.649	0.436	-0.269	-0.662	-0.174
		TEMP	-26.644	-21.930	0.304	9.531	6.548	0.056	1.410	0.111
		SEIS	0.304	1.689	1.238	2.160	0.733	0.304	0.930	0.125
		HYDR	0.039	0.121	0.155	0.068	0.059	0.011	0.018	0.001
27 Slab EL27.0m @ RCCV	98472	OTHR	0.541	0.521	-0.068	0.159	0.239	-0.092	0.321	-0.342
		TEMP	-10.555	-5.730	14.877	-3.631	-2.841	-0.701	1.393	-1.882
		SEIS	1.176	1.193	0.615	0.578	0.794	0.492	0.399	0.483
		HYDR	0.075	0.036	0.103	0.045	0.059	0.029	0.035	0.038
	98514	OTHR	0.312	0.396	0.031	-0.011	-0.282	0.003	-0.010	-0.043
		TEMP	19.208	-5.647	-2.587	1.045	2.953	-0.194	0.107	-1.118
		SEIS	0.726	0.299	0.479	0.203	1.130	0.049	0.047	0.777
		HYDR	0.121	0.054	0.118	0.020	0.094	0.001	0.001	0.074
	98424	OTHR	-0.224	1.211	-0.021	-0.140	0.005	-0.107	-0.521	-0.042
		TEMP	-24.231	-6.952	-2.278	-10.190	-6.460	-0.167	-7.964	-0.108
		SEIS	1.028	1.165	5.763	0.759	0.269	0.223	1.468	0.128
		HYDR	0.028	0.084	0.064	0.033	0.044	0.013	0.117	0.003

Table 3G.5-19 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 7003 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
28 Pool Girder @ Storage Pool	123054	OTHR	0.254	0.062	0.883	0.063	0.032	-0.096	-0.040	-0.052
		TEMP	-0.796	-10.849	0.720	6.148	6.064	0.167	0.364	0.243
		SEIS	0.509	2.690	0.878	0.333	0.162	0.091	0.035	0.197
		HYDR	0.085	0.112	0.096	0.007	0.006	0.004	0.008	0.009
	123154	OTHR	0.469	-0.118	0.803	0.073	0.035	-0.096	-0.061	0.024
		TEMP	2.563	-3.589	1.883	6.336	3.560	-0.289	0.575	0.983
		SEIS	1.814	0.723	0.957	0.238	0.075	0.124	0.056	0.013
		HYDR	0.157	0.021	0.091	0.010	0.007	0.011	0.004	0.001
29 Pool Girder @ Well	123062	OTHR	0.359	-0.748	-0.884	0.004	0.130	0.007	0.034	0.079
		TEMP	-3.492	-7.610	-0.329	0.235	0.976	-0.143	0.144	0.349
		SEIS	0.623	1.105	0.433	0.163	0.219	0.052	0.090	0.138
		HYDR	0.088	0.010	0.070	0.006	0.008	0.003	0.003	0.002
	123162	OTHR	1.266	-0.294	-0.641	0.030	-0.001	0.004	-0.012	-0.011
		TEMP	-2.959	-6.337	-3.847	-0.450	0.157	0.052	0.056	0.215
		SEIS	1.619	0.928	0.272	0.279	0.099	0.033	0.160	0.027
		HYDR	0.233	0.010	0.066	0.012	0.008	0.002	0.008	0.002
30 Pool Girder @ Buffer Pool	123067	OTHR	0.253	0.356	-0.750	-0.024	-0.063	0.006	-0.059	-0.044
		TEMP	-1.268	-8.891	-3.861	-5.866	-6.788	0.001	-0.270	0.070
		SEIS	0.854	2.907	1.607	0.181	0.179	0.091	0.102	0.257
		HYDR	0.090	0.556	0.209	0.015	0.014	0.006	0.012	0.015
	123167	OTHR	-0.044	0.041	-0.769	0.005	-0.035	0.028	-0.062	0.004
		TEMP	-0.187	-3.829	-3.108	-6.192	-5.622	-0.821	0.411	-0.590
		SEIS	1.387	0.756	1.690	0.073	0.117	0.066	0.061	0.015
		HYDR	0.249	0.161	0.229	0.010	0.004	0.004	0.006	0.002
32 IC/PCCS Pool Wall in NS Direction	125051	OTHR	0.151	0.243	0.465	-0.034	0.004	0.001	-0.026	0.018
		TEMP	-1.590	-0.135	-1.056	-0.896	-0.957	0.021	-0.132	0.072
		SEIS	0.174	1.291	0.962	0.006	0.058	0.006	0.023	0.046
		HYDR	0.008	0.048	0.031	0.001	0.001	0.000	0.002	0.001
	125151	OTHR	0.235	0.020	0.367	-0.043	-0.010	0.000	-0.042	0.002
		TEMP	-1.514	-0.093	1.642	-0.781	-0.803	0.065	-0.132	-0.123
		SEIS	0.240	0.575	0.764	0.017	0.015	0.013	0.029	0.014
		HYDR	0.020	0.027	0.035	0.002	0.001	0.000	0.002	0.000
	125055	OTHR	0.188	-0.090	-0.086	0.016	0.058	0.002	0.024	0.041
		TEMP	-5.687	0.084	-0.180	-0.145	0.088	0.019	0.049	0.095
		SEIS	0.372	0.153	0.491	0.031	0.101	0.006	0.038	0.076
		HYDR	0.023	0.022	0.047	0.000	0.000	0.000	0.000	0.000
	125155	OTHR	0.472	-0.022	-0.065	0.001	-0.024	-0.002	-0.020	0.024
		TEMP	-6.471	-0.673	-0.245	-0.209	-0.233	-0.039	-0.277	0.218
		SEIS	0.722	0.105	0.419	0.020	0.033	0.008	0.044	0.047
		HYDR	0.039	0.008	0.050	0.000	0.000	0.000	0.001	0.000

OTHR: Loads other than thermal and hydrodynamic loads
TEMP: Thermal loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-20 *RB Upper Pools - Combined Forces and Moments, Selected Load Combination 7004*

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
15 Topslab	98120	OTHR	0.283	0.926	1.091	0.861	0.544	0.392	0.290	-0.798
@ Drywell Head		TEMP	-19.685	-9.620	-6.700	13.625	13.102	10.762	-0.910	-0.945
Opening		SEIS	1.584	1.139	0.981	0.492	0.682	0.404	0.110	0.437
		HYDR	0.167	0.057	0.071	0.036	0.052	0.026	0.006	0.014
	98135	OTHR	-0.136	-0.322	-0.474	0.554	-0.221	0.183	0.155	-1.059
		TEMP	-32.643	-9.465	3.312	21.679	2.367	-4.692	1.311	-1.131
		SEIS	2.606	0.408	0.619	0.703	0.385	0.195	0.091	0.383
		HYDR	0.259	0.037	0.053	0.049	0.015	0.012	0.004	0.006
	98104	OTHR	-0.195	2.182	-0.694	0.792	2.553	-0.289	-0.361	-0.602
		TEMP	-8.235	-7.644	3.764	4.770	25.728	-6.165	0.516	-0.138
		SEIS	0.429	2.013	0.613	0.255	1.629	0.294	0.079	0.422
		HYDR	0.047	0.201	0.077	0.015	0.089	0.019	0.004	0.032
16 Topslab	98149	OTHR	0.191	1.354	-0.308	0.230	-0.048	0.349	0.009	0.251
@ Center		TEMP	-21.295	-8.598	-2.582	17.374	16.424	1.478	-0.731	0.060
		SEIS	1.835	0.611	0.764	0.750	0.348	0.134	0.094	0.293
		HYDR	0.245	0.130	0.028	0.034	0.026	0.019	0.012	0.014
	98170	OTHR	0.218	0.971	-0.319	0.369	0.178	-0.020	-0.020	-0.131
		TEMP	-22.487	-9.601	-1.177	18.047	16.314	-0.099	0.184	0.965
		SEIS	1.606	0.369	0.920	0.682	0.702	0.074	0.021	0.076
		HYDR	0.176	0.127	0.084	0.025	0.036	0.009	0.003	0.004
	98109	OTHR	0.348	1.457	-0.158	0.767	1.612	-0.231	-0.076	-0.318
		TEMP	-14.161	-10.561	1.426	14.914	19.897	-0.725	0.771	-0.034
		SEIS	0.171	1.539	0.805	0.714	1.056	0.208	0.123	0.183
		HYDR	0.030	0.106	0.129	0.021	0.060	0.018	0.004	0.009
17 Topslab	98174	OTHR	0.766	1.170	-0.048	0.120	0.176	0.371	0.089	-0.091
@ RCCV		TEMP	-18.223	-10.690	1.049	17.510	16.987	0.904	-0.266	0.393
		SEIS	1.598	1.092	0.763	0.763	0.581	0.341	0.216	0.118
		HYDR	0.208	0.134	0.049	0.078	0.086	0.057	0.028	0.026
	98197	OTHR	0.467	1.292	-0.199	-0.183	-1.351	-0.075	-0.049	-0.764
		TEMP	-21.470	-6.681	-1.270	17.924	18.933	-0.016	-0.052	-0.217
		SEIS	1.413	0.587	0.950	0.302	1.025	0.177	0.080	0.633
		HYDR	0.290	0.186	0.078	0.051	0.091	0.024	0.011	0.026
	98103	OTHR	0.576	1.630	-0.068	-0.649	0.436	-0.269	-0.662	-0.174
		TEMP	-13.879	-12.975	-0.003	21.263	20.723	0.115	1.239	0.090
		SEIS	0.304	1.689	1.238	2.160	0.733	0.304	0.930	0.125
		HYDR	0.039	0.121	0.155	0.068	0.059	0.011	0.018	0.001
27 Slab	98472	OTHR	0.541	0.521	-0.068	0.159	0.239	-0.092	0.321	-0.342
EL27.0m		TEMP	-0.712	2.508	15.854	2.844	3.563	-1.727	1.485	-1.701
@ RCCV		SEIS	1.176	1.193	0.615	0.578	0.794	0.492	0.399	0.483
		HYDR	0.075	0.036	0.103	0.045	0.059	0.029	0.035	0.038
	98514	OTHR	0.312	0.396	0.031	-0.011	-0.282	0.003	-0.010	-0.043
		TEMP	8.714	-4.774	-2.722	1.284	5.685	0.103	-0.091	-2.673
		SEIS	0.726	0.299	0.479	0.203	1.130	0.049	0.047	0.777
		HYDR	0.121	0.054	0.118	0.020	0.094	0.001	0.001	0.074
	98424	OTHR	-0.224	1.211	-0.021	-0.140	0.005	-0.107	-0.521	-0.042
		TEMP	-12.877	1.351	-2.967	7.731	9.604	-0.006	-6.463	-0.087
		SEIS	1.028	1.165	5.763	0.759	0.269	0.223	1.468	0.128
		HYDR	0.028	0.084	0.064	0.033	0.044	0.013	0.117	0.003

Table 3G.5-20 RB Upper Pools - Combined Forces and Moments, Selected Load Combination 7004 (Continued)

Location	Element ID		Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
28 Pool Girder @ Storage Pool	123054	OTHR	0.254	0.062	0.883	0.063	0.032	-0.096	-0.040	-0.052
		TEMP	9.857	-7.176	3.794	0.061	-0.484	-0.222	0.790	-0.570
		SEIS	0.509	2.690	0.878	0.333	0.162	0.091	0.035	0.197
		HYDR	0.085	0.112	0.096	0.007	0.006	0.004	0.008	0.009
	123154	OTHR	0.469	-0.118	0.803	0.073	0.035	-0.096	-0.061	0.024
		TEMP	7.646	-1.589	2.072	0.291	0.127	-0.235	0.262	0.022
		SEIS	1.814	0.723	0.957	0.238	0.075	0.124	0.056	0.013
		HYDR	0.157	0.021	0.091	0.010	0.007	0.011	0.004	0.001
29 Pool Girder @ Well	123062	OTHR	0.359	-0.748	-0.884	0.004	0.130	0.007	0.034	0.079
		TEMP	11.194	0.038	-2.026	-0.395	0.719	0.207	1.138	-0.117
		SEIS	0.623	1.105	0.433	0.163	0.219	0.052	0.090	0.138
		HYDR	0.088	0.010	0.070	0.006	0.008	0.003	0.003	0.002
	123162	OTHR	1.266	-0.294	-0.641	0.030	-0.001	0.004	-0.012	-0.011
		TEMP	7.371	0.069	-1.416	-0.059	0.546	-0.247	0.304	-0.082
		SEIS	1.619	0.928	0.272	0.279	0.099	0.033	0.160	0.027
		HYDR	0.233	0.010	0.066	0.012	0.008	0.002	0.008	0.002
30 Pool Girder @ Buffer Pool	123067	OTHR	0.253	0.356	-0.750	-0.024	-0.063	0.006	-0.059	-0.044
		TEMP	7.387	-5.704	-5.204	0.309	-0.082	-0.083	-0.415	-0.377
		SEIS	0.854	2.907	1.607	0.181	0.179	0.091	0.102	0.257
		HYDR	0.090	0.556	0.209	0.015	0.014	0.006	0.012	0.015
	123167	OTHR	-0.044	0.041	-0.769	0.005	-0.035	0.028	-0.062	0.004
		TEMP	4.800	-1.367	-2.400	0.306	0.335	0.026	-0.128	0.066
		SEIS	1.387	0.756	1.690	0.073	0.117	0.066	0.061	0.015
		HYDR	0.249	0.161	0.229	0.010	0.004	0.004	0.006	0.002
32 IC/PCCS Pool Wall in NS Direction	125051	OTHR	0.151	0.243	0.465	-0.034	0.004	0.001	-0.026	0.018
		TEMP	3.473	-2.171	0.893	-0.574	-0.630	0.049	-0.282	-0.058
		SEIS	0.174	1.291	0.962	0.006	0.058	0.006	0.023	0.046
		HYDR	0.008	0.048	0.031	0.001	0.001	0.000	0.002	0.001
	125151	OTHR	0.235	0.020	0.367	-0.043	-0.010	0.000	-0.042	0.002
		TEMP	1.753	-1.442	-0.967	-0.439	-0.226	-0.016	-0.265	-0.069
		SEIS	0.240	0.575	0.764	0.017	0.015	0.013	0.029	0.014
		HYDR	0.020	0.027	0.035	0.002	0.001	0.000	0.002	0.000
	125055	OTHR	0.188	-0.090	-0.086	0.016	0.058	0.002	0.024	0.041
		TEMP	6.938	0.773	-0.207	0.007	-0.199	-0.001	0.298	0.181
		SEIS	0.372	0.153	0.491	0.031	0.101	0.006	0.038	0.076
		HYDR	0.023	0.022	0.047	0.000	0.000	0.000	0.000	0.000
	125155	OTHR	0.472	-0.022	-0.065	0.001	-0.024	-0.002	-0.020	0.024
		TEMP	3.393	0.481	0.012	0.006	-0.149	-0.010	0.012	-0.083
		SEIS	0.722	0.105	0.419	0.020	0.033	0.008	0.044	0.047
		HYDR	0.039	0.008	0.050	0.000	0.000	0.000	0.001	0.000

OTHR: Loads other than thermal and hydrodynamic loads
TEMP: Thermal loads
HYDR: Hydrodynamic loads
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 MNm/m = 2.248×10^5 lbf-ft/ft

Table 3G.5-21 RB Upper Pools – Sectional Thicknesses and Rebar Ratios Used in the Evaluation

Location	Element ID	Thickness (m)	Primary Reinforcement					Shear Tie	
			Position	N-S		E-W			
				Arrangement	Ratio (%)	Arrangement	Ratio (%)	Arrangement	Ratio (%)
15 Top slab @ Drywell Head Opening	98120	2.4	Top	3-#14@300	0.605	3-#14@300	0.605	#9@600x300	0.358
			Bottom	3-#14@300	0.605	3-#14@300	0.605		
	98135	2.4	Top	3-#14@300	0.605	3-#14@300	0.605	#9@600x300	0.358
			Bottom	3-#14@300 (+2-#14@300)	1.008	3-#14@300	0.605		
	98104	2.4	Top	3-#14@300	0.605	3-#14@300 (+2-#14@300 +1-#14@600)	1.109	#9@600x300	0.358
			Bottom	3-#14@300	0.605	3-#14@300 (+2-#14@300)	1.008		
16 Top slab @ Center	98149 93109	2.4	Top	3-#14@300 (+1-#14@300)	0.806	3-#14@300 (+1-#14@300 +1-#14@600)	0.907	#9@600x600	0.179
			Bottom	3-#14@300	0.605	3-#14@300	0.605		
	98170	2.4	Top	3-#14@300	0.605	3-#14@300	0.605	#9@600x600	0.179
			Bottom	3-#14@300	0.605	3-#14@300	0.605		
17 Top slab @ RCCV	98174	2.4	Top	3-#14@300 (+1-#14@300)	0.806	3-#14@300 (+1-#14@300 +1-#14@600)	0.907	#9@600x600	0.179
			Bottom	3-#14@300	0.605	3-#14@300	0.605		
	98197 98103	2.4	Top	3-#14@300 (+1-#14@300)	0.806	3-#14@300 (+1-#14@300 +1-#14@600)	0.907	#9@300x300	0.717
			Bottom	3-#14@300	0.605	3-#14@300	0.605		

Note: Rebar in parentheses indicates additional bars locally required.
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 m = 3.28 ft

Table 3G.5-21 RB Upper Pools – Sectional Thicknesses and Rebar Ratios Used in the Evaluation (Continued)

Location	Element ID	Thickness (m)	Primary Reinforcement					Shear Tie	
			Position	Horizontal		Vertical			
				Arrangement	Ratio (%)	Arrangement	Ratio (%)	Arrangement	Ratio (%)
27 Slab EL27.0m @RCCV	98472 98514	1.5	Top	3-#11@200 (+2-#11@200)	1.677	3-#11@200 (+2-#11@200)	1.677	#7@200x200	0.968
			Bottom	3-#11@200 (+3-#11@200)	2.013	3-#11@200 (+3-#11@200)	2.013		
	98424	2.4	Top	4-#11@200 (+2-#11@200)	1.258	4-#11@200 (+2-#11@200)	1.258	#7@200x200	0.968
			Bottom	4-#11@200 (+1-#11@200)	1.048	4-#11@200 (+1-#11@200)	1.048		
28 Pool Girder @ Storage Pool	123054 123154	1.6	Inside	3-#11@200	0.944	3-#11@200	0.944	#7@400x200	0.484
			Outside	3-#11@200 (+1-#11@200)	1.258	3-#11@200	0.944		
29 Pool Girder @ Well	123062 123162	1.6	Inside	3-#11@200	0.944	3-#11@200	0.944	#7@400x400	0.242
			Outside	3-#11@200	0.944	3-#11@200	0.944		
30 Pool Girder @ Buffer Pool	123067 123167	1.6	Inside	3-#11@200 (+1-#11@200)	1.258	3-#11@200 (+1-#11@200)	1.258	#7@400x200	0.484
			Outside	3-#11@200	0.944	3-#11@200	0.944		
32 IC/PCCS Pool Wall in NS Direction	125051 125151 125055 125155	1.0	Inside	1-#11@200 +1-#11@400	0.755	1-#11@200 +1-#11@400	0.755	#5@400x200	0.250
			Outside	2-#11@200	1.006	2#11@200 (+1-#11@400)	1.258		

Note: Rebar in parentheses indicates additional bars locally required.
SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 m = 3.28 ft

Table 3G.5-22 RB Upper Pools - Rebar and Concrete Stresses: Selected Load Combination 6001

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated				Allowable
		Calculated	Allowable	Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
15 Topslab	98120	-19.8	-29.5	-13.2	-54.0	-37.8	-56.0	337.4
@ Drywell Head	98135	-18.5	-29.5	-55.3	-97.7	-22.5	-6.5	337.4
Opening	98104	-20.4	-29.5	-17.6	-18.7	-23.6	-100.4	337.4
16 Topslab	98149	-16.3	-29.5	-47.0	-81.3	-6.4	-45.2	337.4
@ Center	98170	-15.1	-29.5	-44.4	-75.9	18.1	-42.8	337.4
	98109	-15.7	-29.5	-29.7	-59.6	-9.9	-68.1	337.4
17 Topslab	98174	-16.6	-29.5	-34.5	-76.8	34.5	-51.3	337.4
@ RCCV	98197	-15.4	-29.5	-52.2	-81.9	-9.3	-30.8	337.4
	98103	-15.8	-29.5	-27.6	-73.5	-10.7	-60.3	337.4
27 Slab	98472	-15.5	-27.3	21.8	161.4	48.2	157.1	357.4
EL27.0m	98514	-5.8	-29.0	60.6	94.3	-11.5	10.8	369.8
@ RCCV	98424	-16.0	-26.6	-85.6	0.7	-14.8	51.8	352.0
28 Pool Girder	123054	-16.3	-27.3	2.9	198.3	12.9	249.1	357.5
@ Storage Pool	123154	-5.8	-27.3	15.4	125.7	25.1	106.2	357.5
29 Pool Girder	123062	-5.4	-25.4	-14.8	-17.4	-25.1	-12.8	343.4
@ Well	123162	-5.1	-25.4	111.4	99.3	54.1	38.5	343.4
30 Pool Girder	123067	-13.8	-26.9	110.9	4.8	111.0	-36.0	354.1
@ Buffer Pool	123167	-13.3	-26.9	139.2	7.3	143.6	-11.2	354.1
32 IC/PCCS	125051	-2.5	-25.4	74.8	59.9	92.3	78.7	343.4
Pool Wall	125151	-5.4	-25.4	90.1	74.8	91.0	75.9	343.4
in NS Direction	125055	-4.8	-25.4	-31.1	-29.4	2.8	37.2	343.4
	125155	-4.4	-25.4	-29.8	-30.1	3.7	-0.1	343.4

Note: Negative value means compression.

*Note *: Top slab Direction1: N-S Direction2: E-W Slab Direction1: N-S, Direction2: E-W*
Pool Girder Direction1: Horizontal, Direction2: Vertical
IC/PCCS Pool Direction1: Horizontal, Direction2: Vertical

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.5-23 RB Upper Pools - Rebar and Concrete Stresses: Selected Load Combination 6002

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
15 Topslab	98120	-23.9	-29.8	-17.2	-66.5	-47.6	-66.4	339.2
@ Drywell Head	98135	-22.6	-29.8	-74.5	-120.1	-26.0	-8.1	339.2
Opening	98104	-23.6	-29.8	-21.8	-22.3	-35.3	-117.3	339.2
16 Topslab	98149	-19.4	-29.8	-59.5	-99.4	-13.3	-55.8	339.2
@ Center	98170	-20.7	-29.8	-68.4	-107.6	114.7	-30.6	339.2
	98109	-18.0	-29.8	-37.5	-69.4	-18.0	-81.4	339.2
17 Topslab	98174	-22.4	-31.0	31.0	-89.8	133.4	-34.7	346.3
@ RCCV	98197	-18.9	-32.7	113.4	-53.0	87.0	-19.7	356.9
	98103	-19.2	-29.8	-31.3	-89.3	-10.7	-67.4	339.2
27 Slab	98472	-21.9	-29.3	310.4	159.4	308.3	149.1	372.2
EL27.0m	98514	-12.2	-29.3	80.7	70.9	65.7	-59.2	372.2
@ RCCV	98424	-17.9	-26.8	-101.0	-17.9	-5.5	59.9	353.6
28 Pool Girder	123054	-18.2	-27.6	-1.9	102.1	-72.9	43.3	359.4
@ Storage Pool	123154	-13.0	-27.6	-4.9	149.3	-18.1	102.0	359.4
29 Pool Girder	123062	-6.1	-25.9	-18.1	-25.7	-35.8	-25.9	346.6
@ Well	123162	-6.2	-25.9	99.1	65.4	30.1	3.8	346.6
30 Pool Girder	123067	-6.7	-29.3	92.7	134.1	57.0	84.1	372.2
@ Buffer Pool	123167	-4.5	-29.3	49.6	106.1	46.9	88.6	372.2
32 IC/PCCS	125051	-6.6	-28.9	29.0	196.9	27.7	216.8	369.3
Pool Wall	125151	-7.3	-28.9	27.5	198.2	15.0	188.1	369.3
in NS Direction	125055	-9.8	-28.1	-5.0	133.3	-4.3	146.6	362.8
	125155	-8.4	-28.1	-6.1	143.5	4.0	88.3	362.8

Note: Negative value means compression.

*Note *: Top slab Direction1: N-S Direction2: E-W Slab Direction1: N-S, Direction2: E-W*
Pool Girder Direction1: Horizontal, Direction2: Vertical
IC/PCCS Pool Direction1: Horizontal, Direction2: Vertical

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.5-24 RB Upper Pools - Rebar and Concrete Stresses: Selected Load Combination 6003

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated				
		Calculated	Allowable	Direction 1*		Direction 2*		Allowable
				In/Top	Out/Bottom	In/Top	Out/Bottom	
15 Topslab	98120	-21.8	-29.5	-6.7	-55.4	-48.2	-64.3	337.4
@ Drywell Head	98135	-19.3	-29.5	-61.6	-100.2	-25.4	-8.4	337.4
Opening	98104	-22.0	-29.5	-20.7	-20.2	-37.6	-111.0	337.4
16 Topslab	98149	-18.7	-29.8	-43.3	-92.0	-2.9	-54.9	339.2
@ Center	98170	-16.0	-29.8	-42.0	-78.0	3.4	-51.4	339.2
	98109	-16.8	-29.5	-34.9	-63.9	-19.6	-76.0	337.4
17 Topslab	98174	-18.7	-31.0	-18.3	-87.2	126.1	-14.8	346.3
@ RCCV	98197	-16.6	-29.5	-63.3	-91.1	-11.8	-27.7	337.4
	98103	-17.7	-29.5	-32.0	-82.5	-15.2	-64.5	337.4
27 Slab	98472	-17.2	-27.3	-1.2	130.2	50.6	144.6	357.4
EL27.0m	98514	-6.9	-29.3	129.1	106.8	76.6	-79.6	372.2
@ RCCV	98424	-18.5	-26.6	-102.3	-11.1	-9.1	66.8	352.0
28 Pool Girder	123054	-18.8	-27.3	6.0	125.7	-59.5	94.5	357.5
@ Storage Pool	123154	-11.3	-27.3	17.7	184.8	-14.7	132.1	357.5
29 Pool Girder	123062	-7.8	-25.6	-8.2	-7.0	-44.1	-23.4	345.0
@ Well	123162	-7.1	-25.6	111.6	118.7	28.8	37.6	345.0
30 Pool Girder	123067	-22.7	-27.8	231.7	28.9	214.2	-50.1	361.2
@ Buffer Pool	123167	-16.2	-27.8	214.4	20.5	193.9	-20.3	361.2
32 IC/PCCS	125051	-8.0	-26.5	202.4	10.3	214.7	39.7	351.5
Pool Wall	125151	-6.5	-26.5	191.8	15.1	227.2	45.2	351.5
in NS Direction	125055	-5.4	-25.6	-31.9	-36.9	2.1	24.6	345.0
	125155	-6.1	-25.6	-30.7	-38.9	24.1	1.5	345.0

Note: Negative value means compression.

*Note *: Top slab Direction1: N-S Direction2: E-W Slab Direction1: N-S, Direction2: E-W*
Pool Girder Direction1: Horizontal, Direction2: Vertical
IC/PCCS Pool Direction1: Horizontal, Direction2: Vertical

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.5-25 RB Upper Pools - Rebar and Concrete Stresses: Selected Load Combination 6004

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated				Allowable
		Calculated	Allowable	Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
15 Topslab	98120	-25.5	-32.7	83.4	-62.9	194.8	-4.3	356.9
@ Drywell Head	98135	-30.7	-32.7	55.5	-135.4	-18.4	-3.3	356.9
Opening	98104	-26.4	-32.7	10.7	-17.1	339.3	-60.4	356.9
16 Topslab	98149	-22.6	-32.7	53.5	-86.3	150.1	-15.7	356.9
@ Center	98170	-24.4	-32.7	76.8	-83.6	188.7	-12.1	356.9
	98109	-23.3	-32.7	104.5	-44.7	241.3	-39.7	356.9
17 Topslab	98174	-23.9	-32.7	92.2	-67.2	155.7	-28.0	356.9
@ RCCV	98197	-21.7	-32.7	58.7	-83.8	110.9	2.8	356.9
	98103	-19.2	-32.7	73.6	-39.3	175.9	-39.5	356.9
27 Slab	98472	-20.9	-29.3	230.8	100.9	262.0	95.1	372.2
EL27.0m	98514	-11.7	-29.3	60.7	52.4	78.1	-58.0	372.2
@ RCCV	98424	-11.9	-29.0	22.8	-64.5	123.3	1.9	369.8
28 Pool Girder	123054	-7.3	-29.3	130.4	87.7	63.0	25.1	372.2
@ Storage Pool	123154	-4.9	-29.3	96.3	69.3	69.3	32.8	372.2
29 Pool Girder	123062	-3.3	-29.3	107.4	93.5	-7.1	67.7	372.2
@ Well	123162	-2.0	-29.3	143.9	160.6	42.0	72.9	372.2
30 Pool Girder	123067	-7.3	-29.3	110.7	146.0	67.7	90.0	372.2
@ Buffer Pool	123167	-4.0	-29.3	53.2	84.9	41.6	73.9	372.2
32 IC/PCCS	125051	-3.8	-29.3	189.6	47.7	197.7	39.1	372.2
Pool Wall	125151	-2.4	-29.3	141.0	43.2	106.5	16.3	372.2
in NS Direction	125055	-0.3	-29.3	108.6	96.6	57.5	41.8	372.2
	125155	-0.4	-29.3	103.0	84.4	52.9	18.0	372.2

Note: Negative value means compression.

*Note *: Top slab Direction1: N-S Direction2: E-W Slab Direction1: N-S, Direction2: E-W*
Pool Girder Direction1: Horizontal, Direction2: Vertical
IC/PCCS Pool Direction1: Horizontal, Direction2: Vertical

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.5-26 RB Upper Pools - Rebar and Concrete Stresses: Selected Load Combination 7001

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated				Allowable
		Calculated	Allowable	Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
15 Topslab	98120	-20.8	-29.5	-16.1	-54.7	-39.6	-60.4	337.4
@ Drywell Head	98135	-19.0	-29.5	-57.3	-99.8	-22.9	-8.3	337.4
Opening	98104	-20.9	-29.5	-18.0	-17.5	-33.6	-104.1	337.4
16 Topslab	98149	-16.6	-29.5	-47.8	-83.3	-8.6	-49.0	337.4
@ Center	98170	-15.5	-29.5	-44.7	-76.7	-5.1	-50.7	337.4
	98109	-16.3	-29.5	-33.9	-59.4	-15.5	-71.4	337.4
17 Topslab	98174	-17.2	-29.5	-36.6	-79.7	19.1	-56.0	337.4
@ RCCV	98197	-16.3	-29.5	-54.8	-83.5	-8.9	-41.7	337.4
	98103	-19.4	-29.5	-30.8	-86.7	-14.8	-65.8	337.4
27 Slab	98472	-18.3	-27.3	73.0	191.6	109.5	189.6	357.4
EL27.0m	98514	-7.3	-29.0	65.9	111.0	-23.0	26.6	369.8
@ RCCV	98424	-18.4	-26.6	-87.1	56.0	-12.7	95.4	352.0
28 Pool Girder	123054	-15.9	-27.3	-8.1	162.9	-24.8	238.9	357.5
@ Storage Pool	123154	-5.1	-27.3	41.3	188.3	49.8	129.1	357.5
29 Pool Girder	123062	-5.6	-25.4	-15.0	-20.5	-27.1	-13.4	343.4
@ Well	123162	-5.3	-25.4	63.9	91.0	38.7	41.3	343.4
30 Pool Girder	123067	-16.1	-26.9	75.9	-8.3	59.0	-60.6	354.1
@ Buffer Pool	123167	-14.4	-26.9	124.0	-1.4	133.7	-22.7	354.1
32 IC/PCCS	125051	-4.4	-25.4	-9.1	-8.0	-20.1	29.0	343.4
Pool Wall	125151	-5.8	-25.4	63.4	59.9	57.0	54.6	343.4
in NS Direction	125055	-5.3	-25.4	-33.9	-30.4	4.5	45.3	343.4
	125155	-5.6	-25.4	-36.8	-37.7	4.0	1.1	343.4

Note: Negative value means compression.

*Note *: Top slab Direction1: N-S Direction2: E-W Slab Direction1: N-S, Direction2: E-W*
Pool Girder Direction1: Horizontal, Direction2: Vertical
IC/PCCS Pool Direction1: Horizontal, Direction2: Vertical

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.5-27 RB Upper Pools - Rebar and Concrete Stresses: Selected Load Combination 7002

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
15 Topslab	98120	-24.9	-29.8	-20.1	-67.3	-49.4	-70.7	339.2
@ Drywell Head	98135	-23.1	-29.8	-76.5	-122.2	-26.3	-9.8	339.2
Opening	98104	-24.1	-29.8	-22.2	-21.1	-45.4	-121.0	339.2
16 Topslab	98149	-19.9	-29.8	-60.2	-101.4	-15.5	-59.5	339.2
@ Center	98170	-21.2	-29.8	-68.8	-108.5	69.1	-44.8	339.2
	98109	-18.6	-29.8	-41.7	-69.2	-23.6	-84.8	339.2
17 Topslab	98174	-22.7	-31.0	23.1	-93.3	100.7	-43.1	346.3
@ RCCV	98197	-19.9	-32.7	106.4	-50.8	132.6	-29.4	356.9
	98103	-22.8	-29.8	-34.5	-102.5	-15.4	-72.8	339.2
27 Slab	98472	-26.0	-29.3	344.0	193.5	343.9	159.3	372.2
EL27.0m	98514	-14.7	-29.3	85.6	85.3	108.3	-75.2	372.2
@ RCCV	98424	-19.9	-26.8	-102.9	22.2	-4.7	90.4	353.6
28 Pool Girder	123054	-19.5	-27.6	-4.9	102.3	-91.2	27.8	359.4
@ Storage Pool	123154	-13.5	-27.6	-14.2	150.7	-25.7	79.1	359.4
29 Pool Girder	123062	-6.4	-25.9	-18.3	-28.8	-37.8	-26.6	346.6
@ Well	123162	-8.0	-25.9	67.0	-24.1	17.7	-27.1	346.6
30 Pool Girder	123067	-8.5	-29.3	103.4	139.4	23.2	40.3	372.2
@ Buffer Pool	123167	-5.3	-29.3	38.1	90.8	33.6	78.0	372.2
32 IC/PCCS	125051	-9.0	-28.9	40.6	214.7	38.5	255.7	369.3
Pool Wall	125151	-8.8	-28.9	33.4	213.2	22.5	207.5	369.3
in NS Direction	125055	-9.7	-28.1	12.3	172.9	6.2	172.3	362.8
	125155	-8.2	-28.1	-17.6	171.7	10.0	110.7	362.8

Note: Negative value means compression.

*Note *: Top slab Direction1: N-S Direction2: E-W Slab Direction1: N-S, Direction2: E-W*
Pool Girder Direction1: Horizontal, Direction2: Vertical
IC/PCCS Pool Direction1: Horizontal, Direction2: Vertical

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.5-28 RB Upper Pools - Rebar and Concrete Stresses: Selected Load Combination 7003

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated				Allowable
		Calculated	Allowable	Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
15 Topslab	98120	-22.8	-29.5	-9.6	-56.2	-50.0	-68.6	337.4
@ Drywell Head	98135	-19.9	-29.5	-63.6	-102.3	-25.7	-10.1	337.4
Opening	98104	-22.5	-29.5	-21.1	-19.0	-47.6	-114.7	337.4
16 Topslab	98149	-19.2	-29.8	-43.8	-93.9	-8.1	-59.9	339.2
@ Center	98170	-16.7	-29.8	-43.0	-79.6	-7.0	-55.4	339.2
	98109	-17.4	-29.5	-39.2	-63.8	-25.2	-79.4	337.4
17 Topslab	98174	-19.4	-31.0	-18.4	-90.3	108.3	-22.4	346.3
@ RCCV	98197	-17.3	-29.5	-65.9	-92.7	-11.3	-38.6	337.4
	98103	-21.3	-29.5	-35.2	-95.5	-19.9	-70.0	337.4
27 Slab	98472	-19.7	-27.3	52.3	157.0	113.4	174.1	357.4
EL27.0m	98514	-19.7	-29.3	160.4	103.1	126.5	-79.7	372.2
@ RCCV	98424	-20.6	-26.6	-104.2	33.9	-8.5	97.7	352.0
28 Pool Girder	123054	-19.0	-27.3	8.2	121.8	-80.4	75.7	357.5
@ Storage Pool	123154	-10.5	-27.3	37.9	224.4	-23.3	89.0	357.5
29 Pool Girder	123062	-8.1	-25.6	-10.8	-7.7	-45.7	-24.5	345.0
@ Well	123162	-6.9	-25.6	72.0	111.8	25.3	33.3	345.0
30 Pool Girder	123067	-25.0	-27.8	202.5	19.9	160.2	-74.1	361.2
@ Buffer Pool	123167	-15.4	-27.8	162.5	10.6	150.3	-36.9	361.2
32 IC/PCCS	125051	-6.0	-26.5	163.1	-6.0	231.1	60.2	351.5
Pool Wall	125151	-7.4	-26.5	172.3	-8.1	178.1	28.9	351.5
in NS Direction	125055	-6.1	-25.6	-33.0	-40.5	11.6	20.5	345.0
	125155	-7.3	-25.6	-37.7	-46.3	18.2	1.5	345.0

Note: Negative value means compression.

*Note *: Top slab Direction1: N-S Direction2: E-W Slab Direction1: N-S, Direction2: E-W*
Pool Girder Direction1: Horizontal, Direction2: Vertical
IC/PCCS Pool Direction1: Horizontal, Direction2: Vertical

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only): 1 MPa = 145.038 psi

Table 3G.5-29 RB Upper Pools - Rebar and Concrete Stresses: Selected Load Combination 7004

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				Direction 1*		Direction 2*		
				In/Top	Out/Bottom	In/Top	Out/Bottom	
15 Topslab	98120	-26.2	-32.7	86.6	-65.5	179.9	-12.6	356.9
@ Drywell Head	98135	-30.0	-32.7	85.0	-132.7	-17.3	-4.2	356.9
Opening	98104	-25.4	-32.7	-5.5	-17.7	281.7	-69.3	356.9
16 Topslab	98149	-22.1	-32.7	58.2	-85.5	130.8	-21.0	356.9
@ Center	98170	-24.8	-32.7	79.5	-83.7	177.5	-15.4	356.9
	98109	-19.8	-32.7	93.5	-46.3	203.6	-49.0	356.9
17 Topslab	98174	-23.8	-32.7	91.1	-69.6	135.8	-33.8	356.9
@ RCCV	98197	-22.9	-32.7	61.1	-82.7	149.6	-12.8	356.9
	98103	-24.6	-32.7	180.3	-39.4	185.6	-42.6	356.9
27 Slab	98472	-25.0	-29.3	226.1	105.6	298.0	101.4	372.2
EL27.0m	98514	-14.0	-29.3	64.6	67.6	114.8	-72.2	372.2
@ RCCV	98424	-14.8	-29.0	130.1	-69.6	224.8	34.4	369.8
28 Pool Girder	123054	-8.0	-29.3	100.1	100.3	23.4	-17.0	372.2
@ Storage Pool	123154	-5.5	-29.3	151.3	134.4	71.7	29.3	372.2
29 Pool Girder	123062	-3.4	-29.3	107.3	110.8	15.7	47.5	372.2
@ Well	123162	-1.9	-29.3	122.4	169.2	31.7	43.9	372.2
30 Pool Girder	123067	-8.9	-29.3	117.4	149.0	33.4	41.8	372.2
@ Buffer Pool	123167	-5.2	-29.3	93.9	152.1	51.4	91.2	372.2
32 IC/PCCS	125051	-6.9	-29.3	166.7	71.1	87.9	-16.9	372.2
Pool Wall	125151	-3.2	-29.3	116.4	45.1	35.4	-6.4	372.2
in NS Direction	125055	-1.2	-29.3	145.2	126.7	138.8	46.1	372.2
	125155	-1.3	-29.3	135.2	118.5	95.8	39.0	372.2

Note: Negative value means compression.
Note *: Top slab Direction1: N-S Direction2: E-W Slab Direction1: N-S, Direction2: E-W
Pool Girder Direction1: Horizontal, Direction2: Vertical
IC/PCCS Pool Direction1: Horizontal, Direction2: Vertical

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MPa = 145.038 psi

Table 3G.5-30 RB Upper Pools - Transverse Shear; RCCV

Location	Element ID	LOAD ID	Shear Force Q (MN/m)	d (m)	Shear Stress (MN/m)			Shear Tie Ratio (%)	
					Vu	Vc	Vs	required	provided
15 Topslab	98120	6004	1.79	1.95	1.08	1.11	0.00	0.000	0.358
@ Drywell Head	98135	6004	3.10	1.94	1.88	2.87	0.00	0.000	0.358
Opening	98104	7004	0.24	1.97	0.14	0.14	0.00	0.000	0.358
16 Topslab	98149	7003	2.36	1.93	1.44	3.57	0.00	0.000	0.179
@ Center	98170	7002	1.46	1.95	0.88	2.65	0.00	0.000	0.179
	98109	7004	0.67	1.97	0.40	1.22	0.00	0.000	0.179
17 Topslab	98174	7002	2.12	1.96	1.27	3.74	0.00	0.000	0.179
@ RCCV	98197	6004	1.62	1.99	0.96	1.16	0.00	0.000	0.717
	98103	7004	1.05	1.93	0.64	1.24	0.00	0.000	0.717

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MPa = 145.038 psi
1 MN/m = 6.852×10^4 lbf/ft
1 m = 3.28 ft

Table 3G.5-31 RB Upper Pools - Transverse Shear; RB

Location	Element ID	Load ID	d (m)	pv (%)	Shear Force (MN/m)				Vu/ϕVn
					Vu	Vc	Vs	ϕVn	
27 Slab	98472	7004	1.21	0.968	1.41	0.58	4.72	4.50	0.314
EL27.0m	98514	7004	1.21	0.968	3.50	1.95	4.72	5.67	0.617
@ RCCV	98424	7002	2.11	0.968	10.27	7.08	8.23	13.01	0.789
28 Pool Girder	123054	7001	1.25	0.484	1.20	1.41	2.50	3.32	0.362
@ Storage Pool	123154	6002	1.25	0.484	0.94	1.38	2.50	3.30	0.285
29 Pool Girder	123062	7004	1.22	0.242	0.12	0.14	1.22	1.15	0.101
@ Well	123162	6004	1.23	0.242	0.05	0.06	1.23	1.10	0.044
30 Pool Girder	123067	7002	1.24	0.484	0.10	0.12	2.49	2.21	0.046
@ Buffer Pool	123167	6001	1.27	0.484	0.21	0.25	2.55	2.38	0.089
32 IC/PCCS	125051	7004	0.81	0.250	0.12	0.14	0.84	0.83	0.139
Pool Wall	125151	6001	0.80	0.250	0.12	0.14	0.83	0.83	0.148
in NS Direction	125055	7002	0.79	0.250	0.08	0.10	0.82	0.78	0.105
	125155	6004	0.83	0.250	0.05	0.06	0.86	0.78	0.061

SI to U.S. Customary units conversion (SI units are the controlling units and U.S. Customary units are for reference only):
1 MN/m = 6.852×10^4 lbf/ft
1 m = 3.28 ft

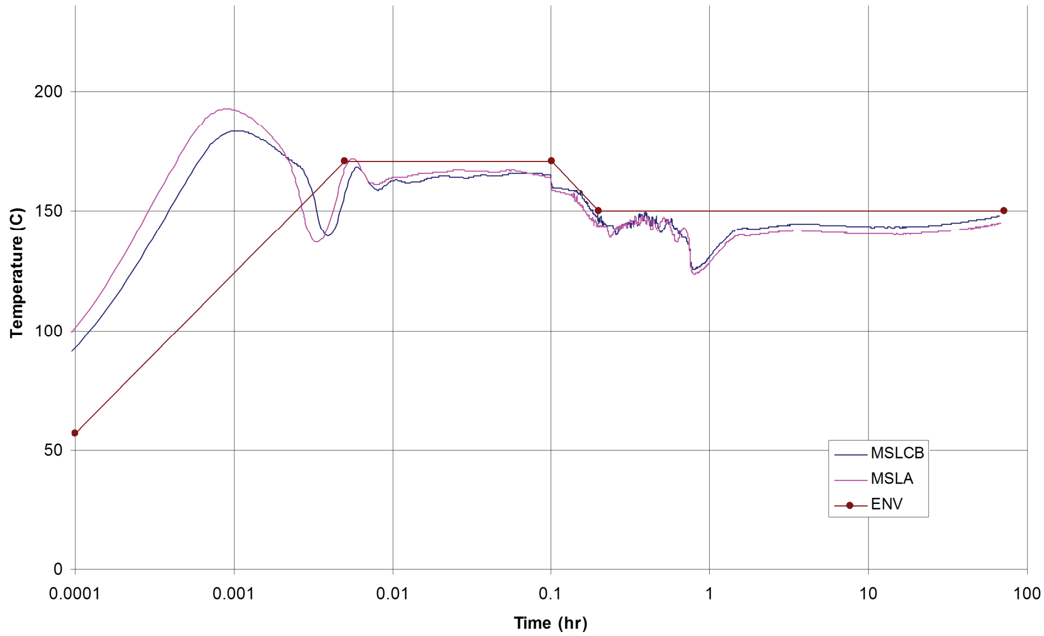


Figure 3G.5-1. DW Design Temperature Curve (ENV) vs. RACG Short-Term Bounding Temperature Curve

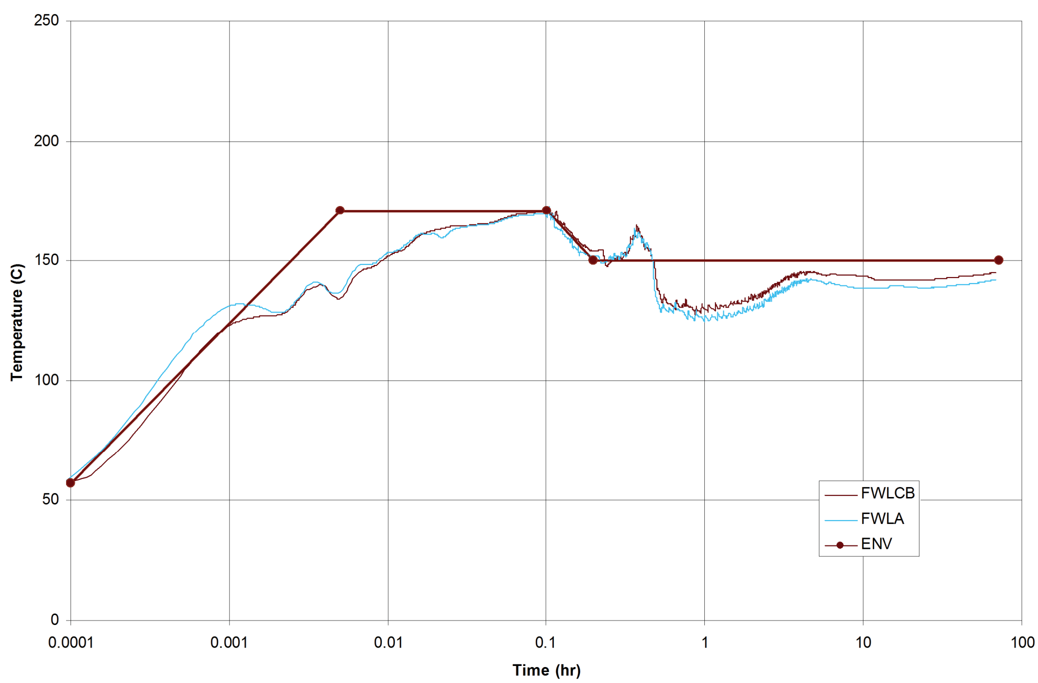


Figure 3G.5-2. DW Design Temperature Curve (ENV) vs. TRACG Medium-Term Bounding Temperature Curve

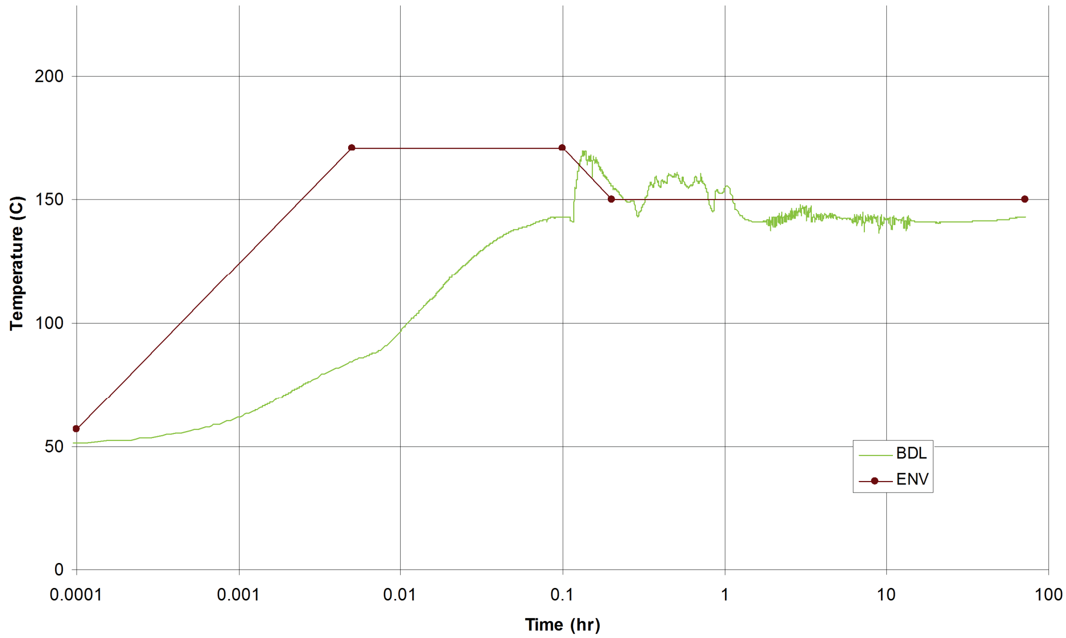


Figure 3G.5-3. DW Design Temperature Curve (ENV) vs. TRACG Long-Term Bounding Temperature Curve

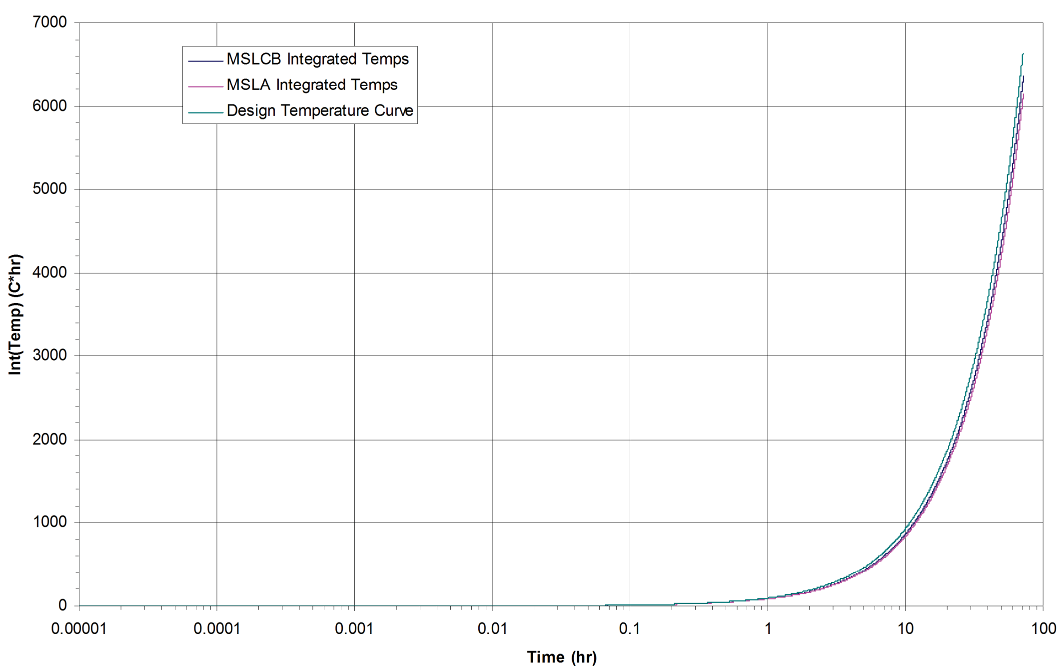


Figure 3G.5-4. DW Integrated Design Temperature Curve vs. TRACG Short-Term Bounding Temperature Curve

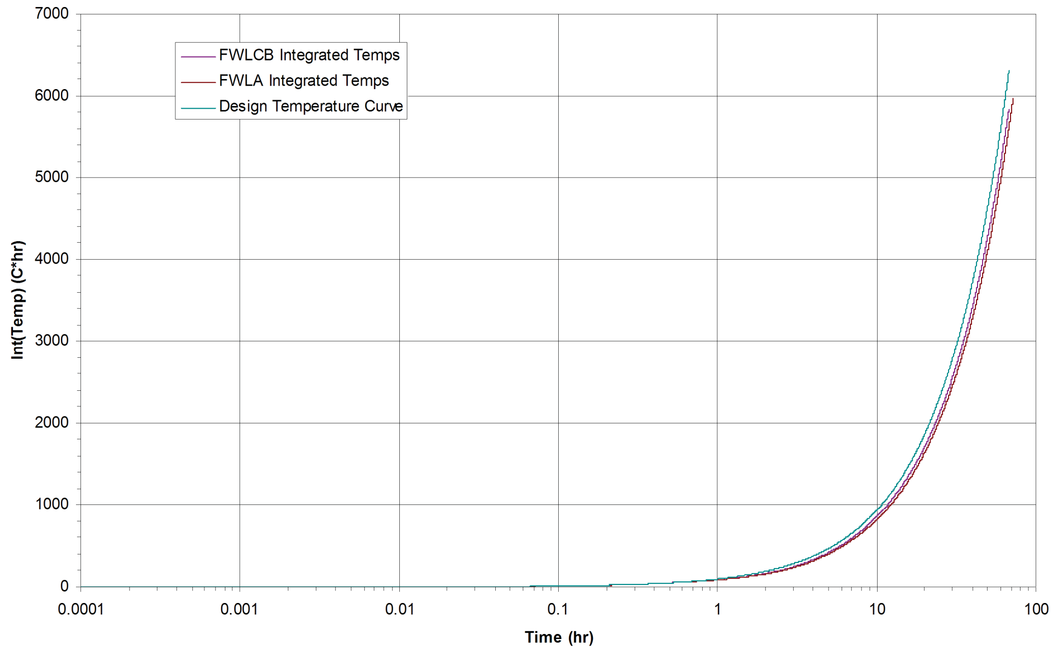


Figure 3G.5-5. DW Integrated Design Temperature Curve vs.TRACG Medium-Term Bounding Temperature Curve

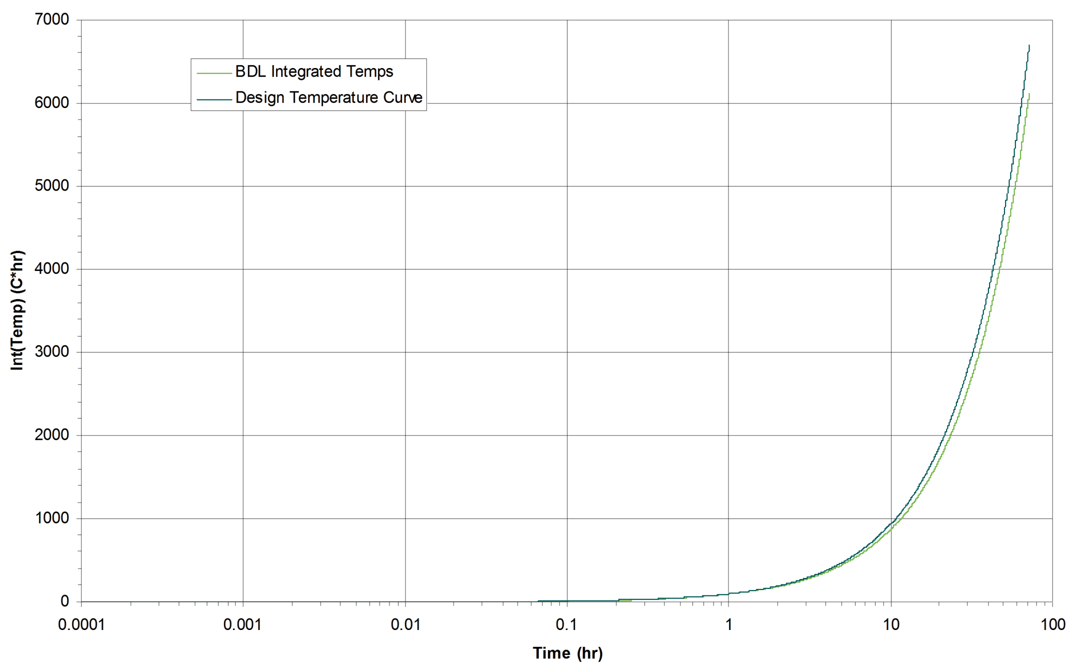


Figure 3G.5-6. DW Integrated Design Temperature Curve vs. TRACG Long-Term Bounding Temperature Curve

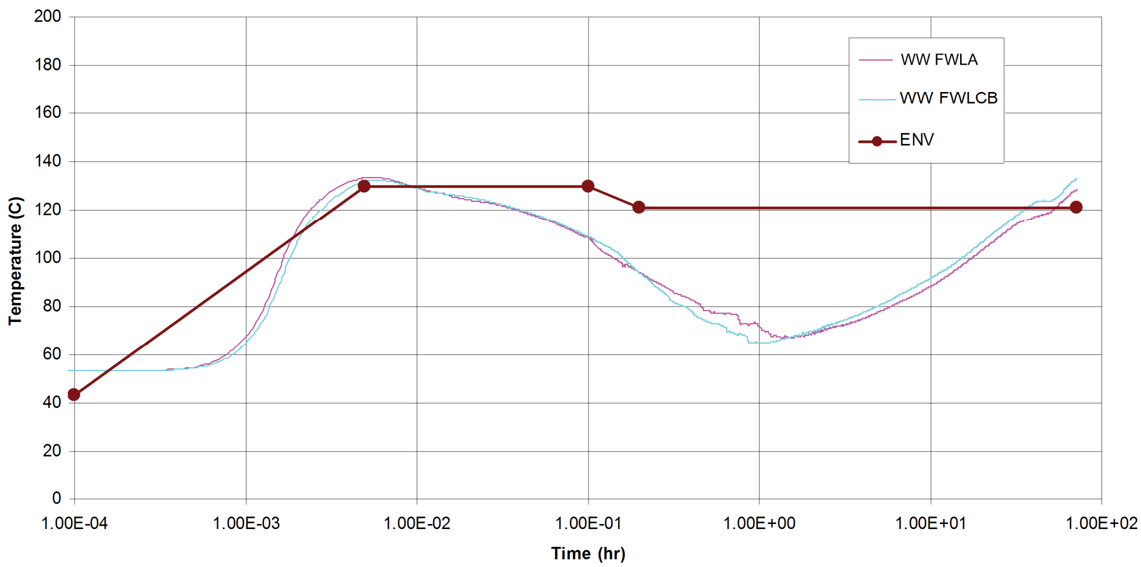


Figure 3G.5-7. WW Design Temperature Curve (ENV) vs. TRACG Short-Term Bounding Temperature Curve

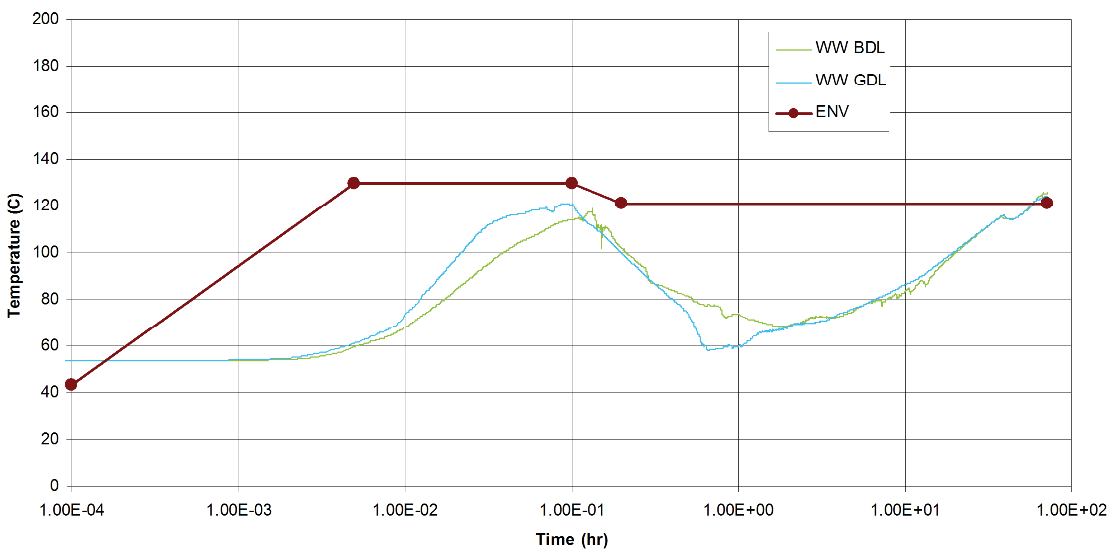


Figure 3G.5-8. WW Design Temperature Curve (ENV) vs. TRACG Medium-Term Bounding Temperature Curve

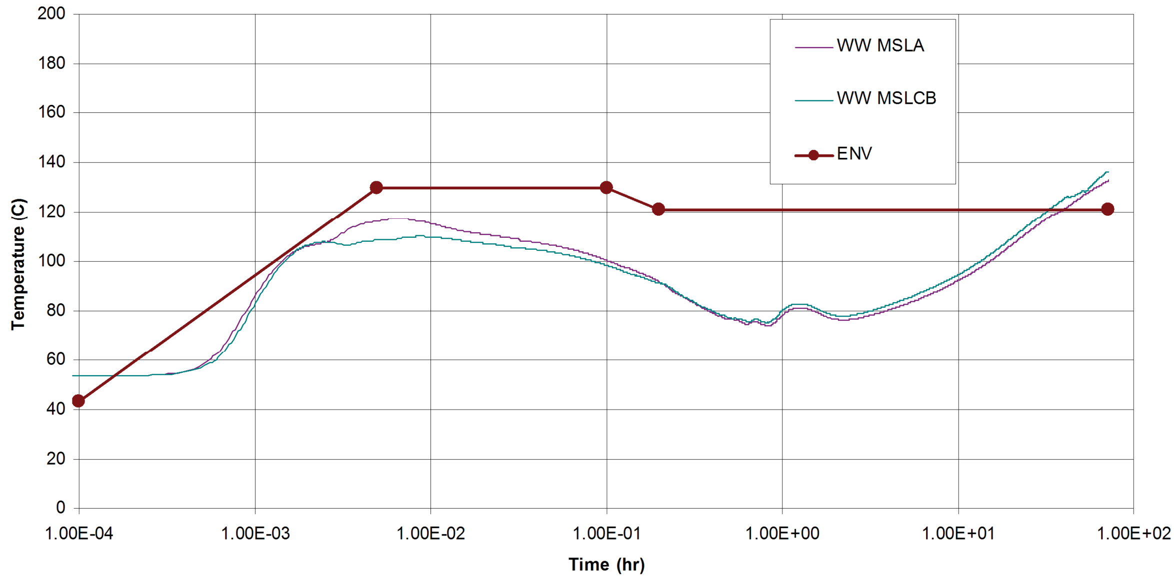


Figure 3G.5-9.   WW Design Temperature Curve (ENV) vs. TRACG Long-Term Bounding Temperature Curve

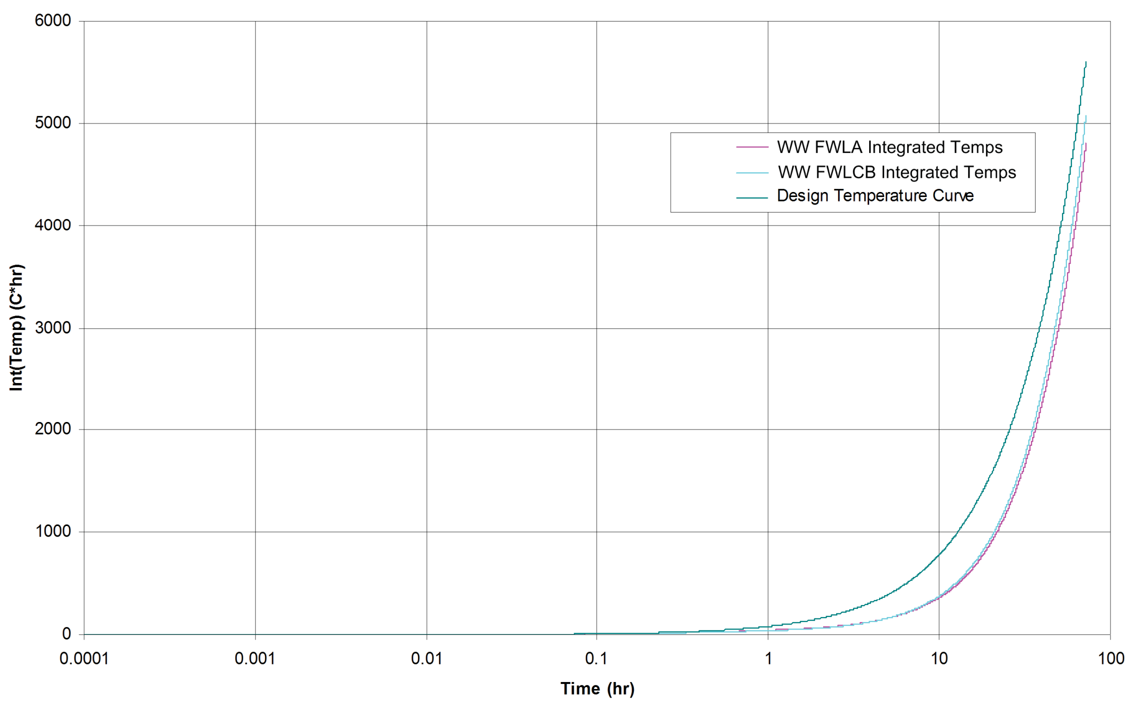


Figure 3G.5-10.   WW Integrated Design Temperature Curve vs. TRACG Short-Term Bounding Temperature Curve

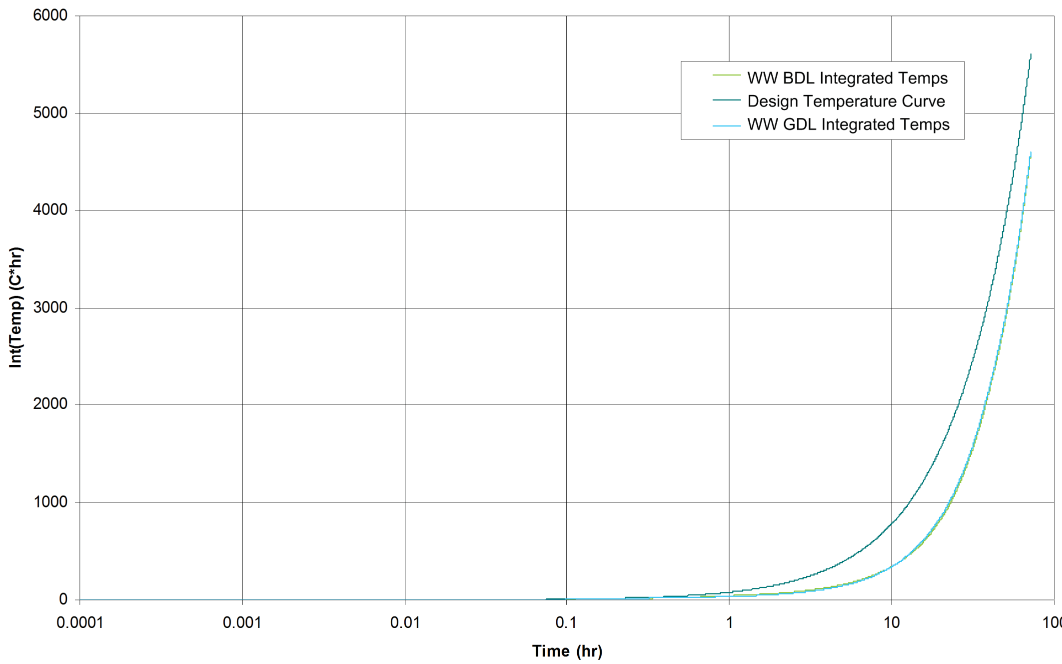


Figure 3G.5-11. WW Integrated Design Temperature Curve vs.TRACG Medium-Term Bounding Temperature Curve

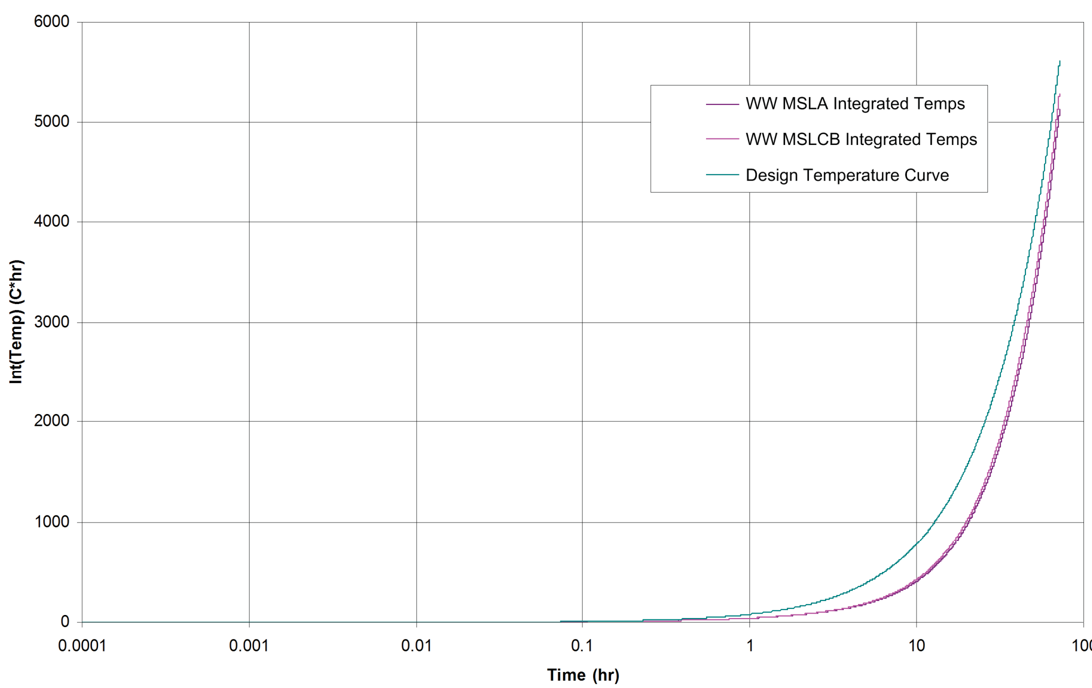
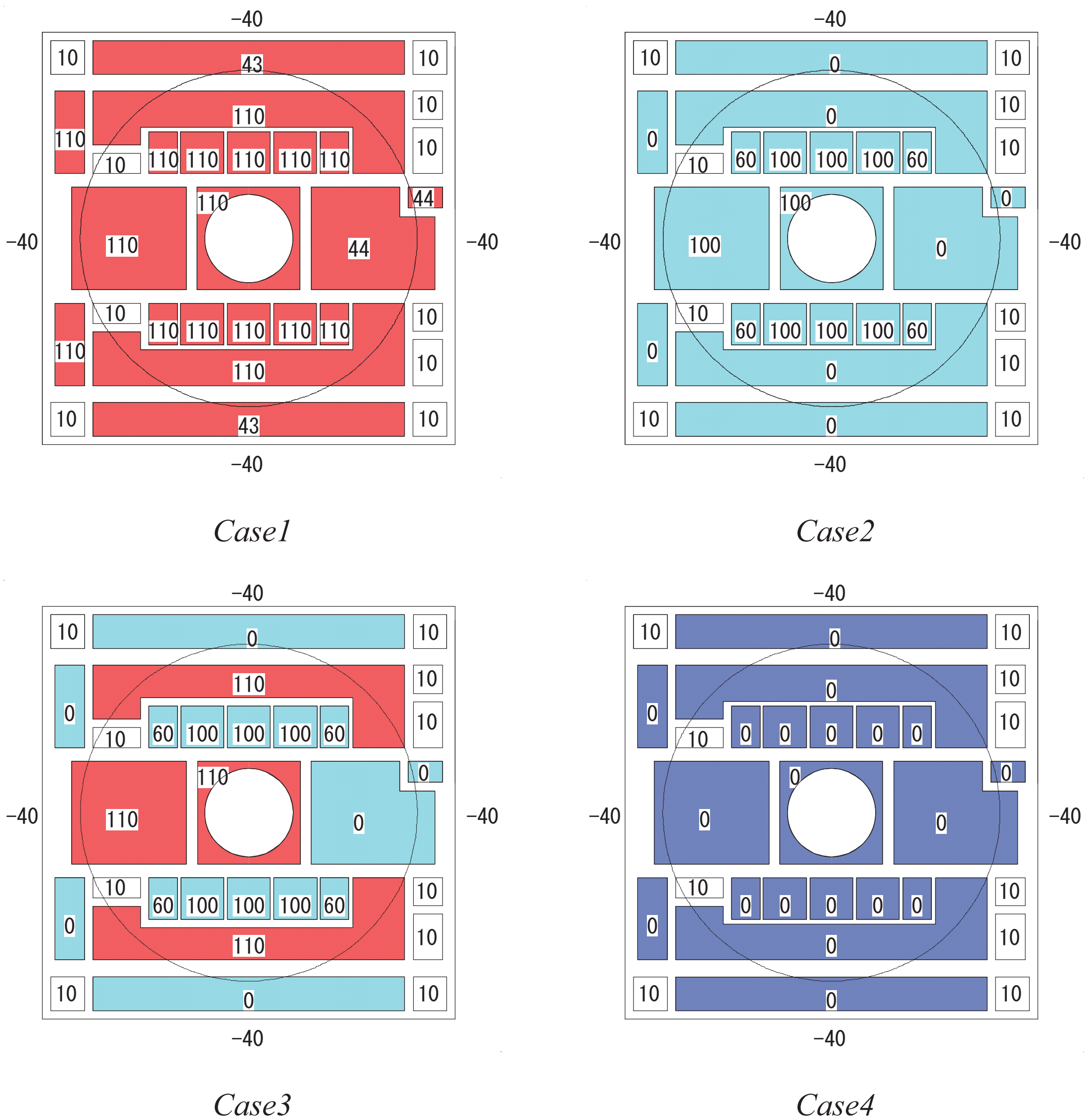
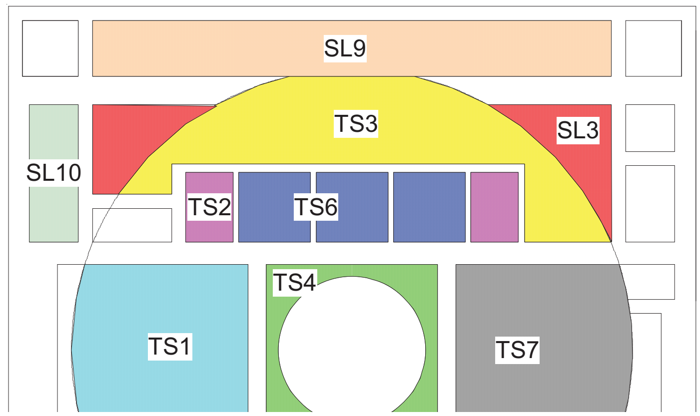


Figure 3G.5-12. WW Integrated Design Temperature Curve vs. TRACG Long-Term Bounding Temperature Curve

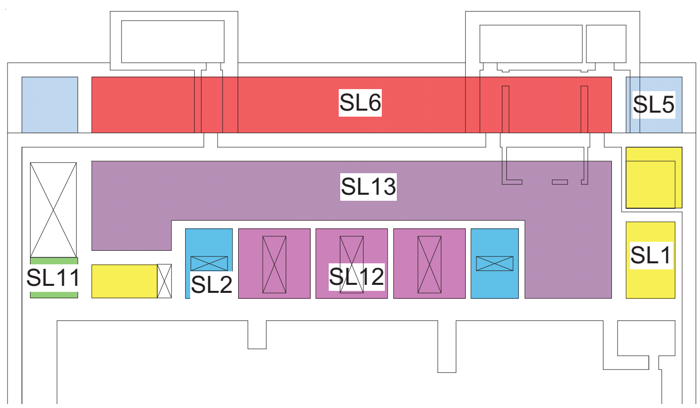


Units: ºC

Figure 3G.5-13. Temperature Distributions in RB Upper Pools



(EL27.0m)



(EL34.0m)

Figure 3G.5-14. RB Upper Pools - Slab Sections for Heat Transfer Calculation

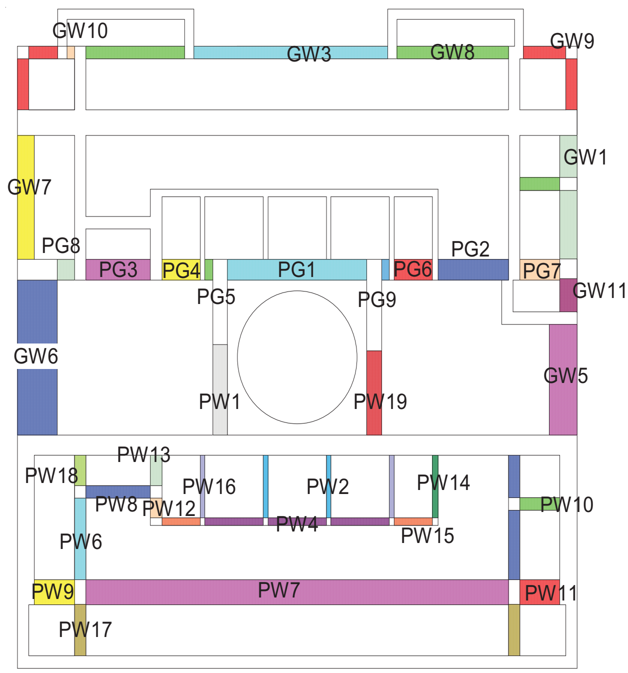


Figure 3G.5-15. RB Upper Pools - Wall Sections for Heat Transfer Calculation

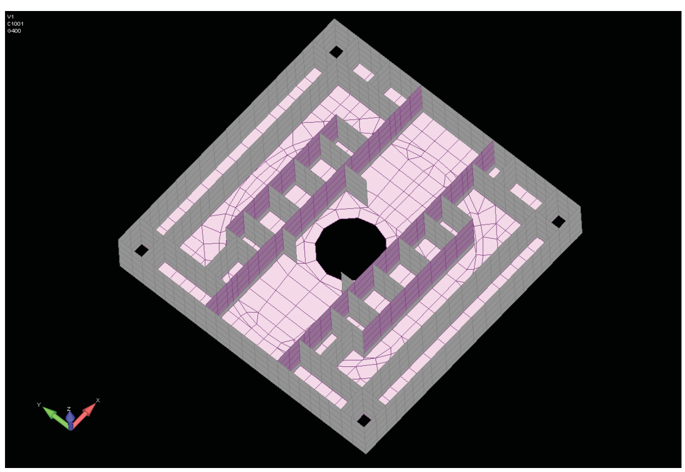


Figure 3G.5-16. Finite Element Model Around RB Upper Pools

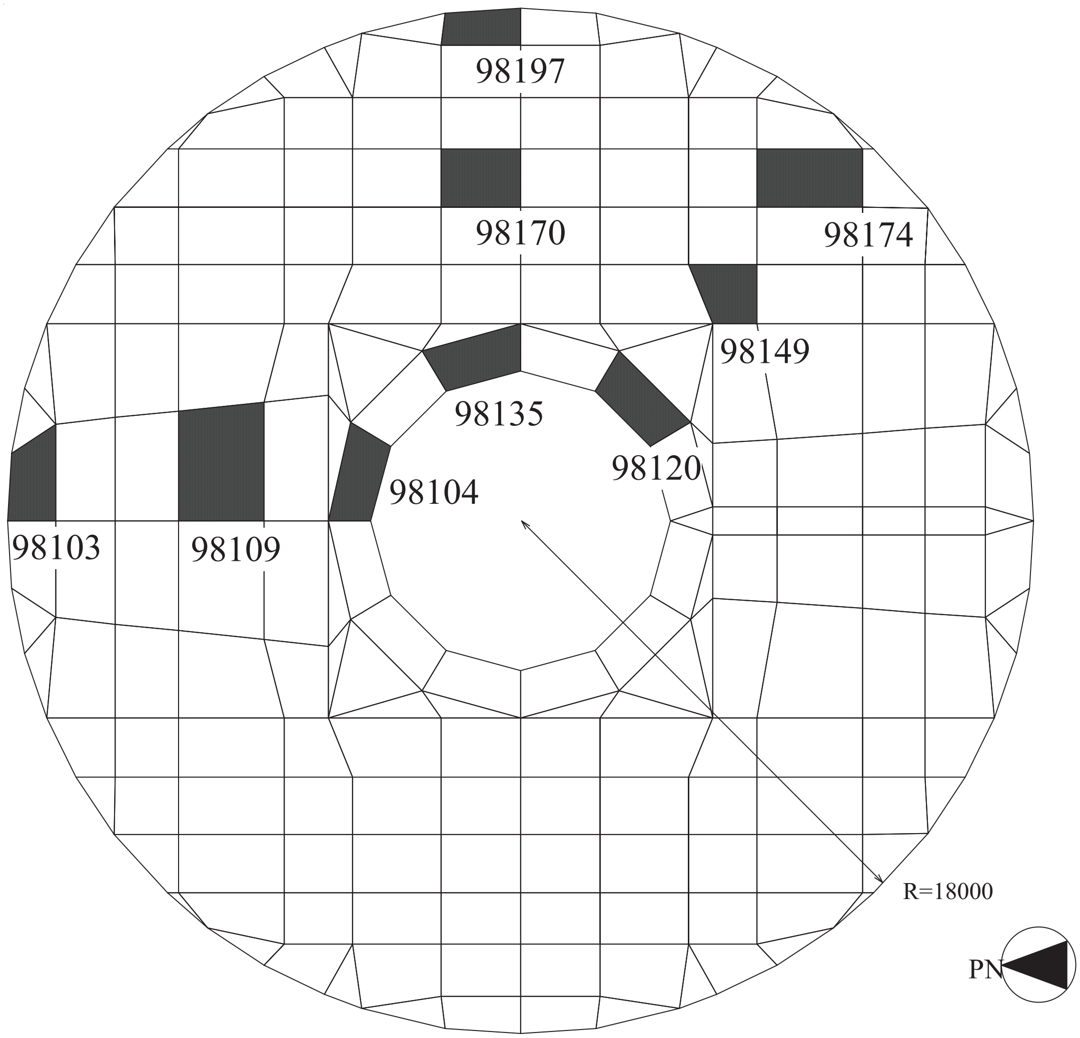


Figure 3G.5-17. RB Upper Pools - Elements Selected for Evaluation (Top Slab)

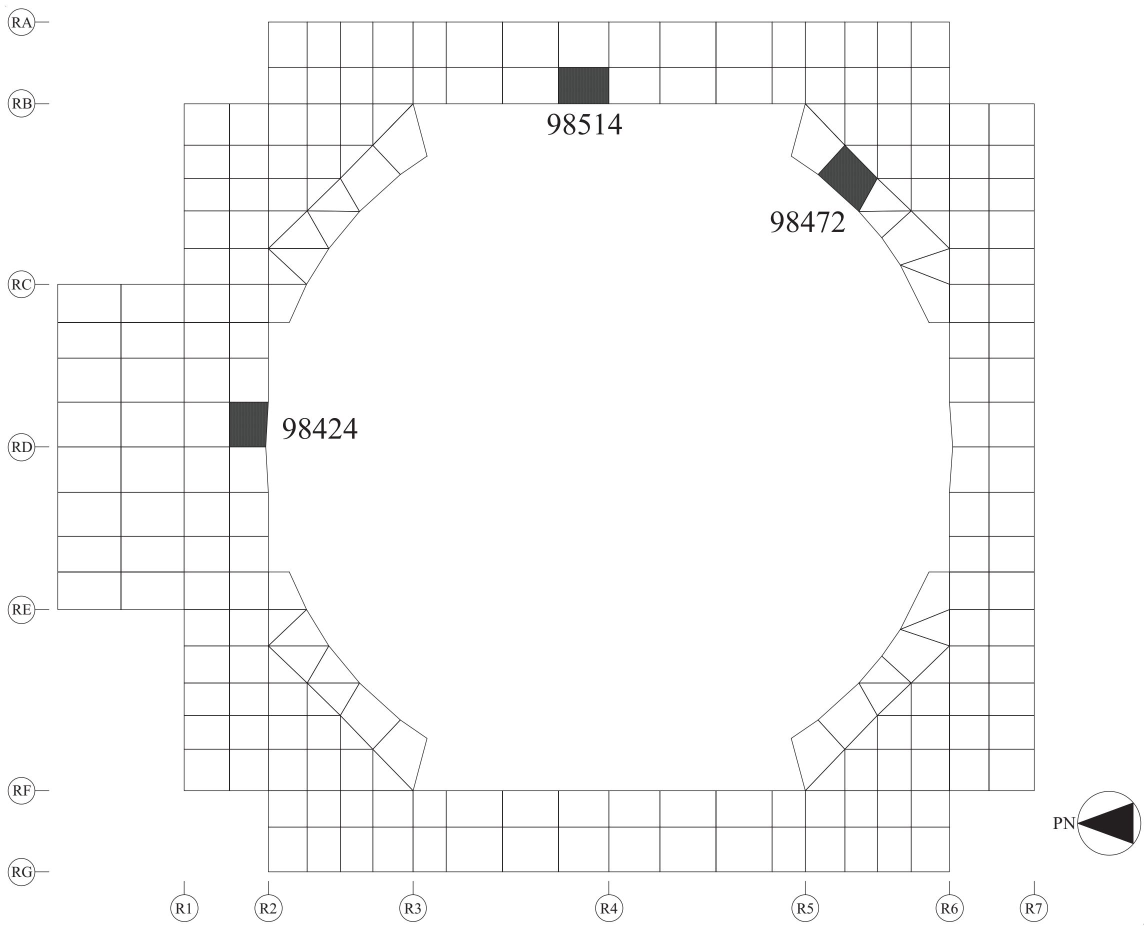


Figure 3G.5-18. RB Upper Pools - Elements Selected for Evaluation (Floor Slab at EL27000)

Figure 3G.5-19. RB Upper Pools - Elements Selected for Evaluation (Pool Girder)

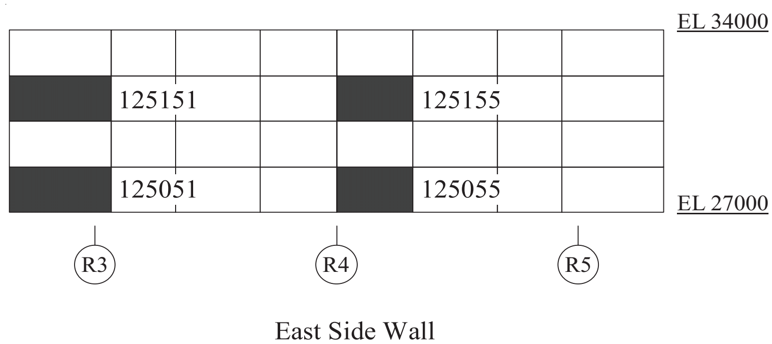


Figure 3G.5-20. RB Upper Pools - Elements Selected for Evaluation (IC/PCCS Pool Wall in NS Direction)

3G.6 *CRITICAL DIMENSIONS AND TOLERANCES*

The critical dimensions and acceptable tolerances are provided in Tables 3G.6-1, 3G.6-2 and 3G.6-3 for the RB, CB and FB, respectively. The locations labeled in these tables are illustrated in Figures 3G.6-1 through 3G.6-11 for the RB, 3G.6-12 through 3G.6-16 for the CB and 3G.6-17 through 3G.6-22 for the FB.

Table 3G.6-1 Critical Dimensions of Reactor Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
	Concrete Containment				
101	RPV Pedestal Cylinder	Not Applicable	From -10400 to 4650	2500 (8'-2⅜")	+60,-0 (+2⅜",-0")
102	RCCV Cylinder	Not Applicable	From 4650 to 24600	2000 (6'-6¾")	+60,-0 (+2⅜",-0")
103	Containment Basemat	Below RPV Pedestal Cylinder	-10400	5100 (16'-8¾")	+50,-20 (+2",-¾")
104	Suppression Pool Slab	Between RPV Pedestal Cylinder and RCCV Cylinder	4650	2000 (6'-6¾")	+60,-0 (+2⅜",-0")
105	Top Slab	From DW Head to RCCV Cylinder	27000	2400 (7'-10½")	+60,-0 (+2⅜",-0")
	Outside Concrete Containment				
1	Wall at Column Line R1	From RA to RG	From -11500 to 3650	2000 (6'-6¾")	+25,-20 (+1",-¾")
2	Wall at Column Line R7	From RA to RG	From -11500 to 3650	2000 (6'-6¾")	+25,-20 (+1",-¾")
3	Wall at Column Line RA	From R1 to R7	From -11500 to 3650	2000 (6'-6¾")	+25,-20 (+1",-¾")
4	Wall at Column Line RG	From R1 to R7	From -11500 to 3650	2000 (6'-6¾")	+25,-20 (+1",-¾")
5	Wall between Column Lines R1 and R2	From between RA and RB to RC	From -11500 to -7400	1000 (3'-3⅜")	+25,-20 (+1",-¾")
6	Wall between Column Lines R1 and R2	From RE to between RF and RG	From -11500 to -7400	1000 (3'-3⅜")	+25,-20 (+1",-¾")
7	Wall between Column Lines RA and RB	From between R1 and R2 to R3	From -11500 to -7400	1000 (3'-3⅜")	+25,-20 (+1",-¾")

Table 3G.6-1 Critical Dimensions of Reactor Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
8	Wall between Column Lines RF and RG	From between R1 and R2 to R3	From -11500 to -7400	1000 (3'-3⅜")	+25,-20 (+1",-¾")
9	Cylinder below RCCV	Not Applicable	From -11500 to 2650	2000 (6'-6¾")	+60,-0 (+2⅜",-0")
10	Cylinder between RPV Pedestal and Cylinder below RCCV	Northeast Quadrant	From -11500 to -1700	1400 (4'-7⅛")	Minimum
11	Cylinder between RPV Pedestal and Cylinder below RCCV	Northwest Quadrant	From -11500 to -1700	1400 (4'-7⅛")	Minimum
12	Cylinder between RPV Pedestal and Cylinder below RCCV	Southwest Quadrant	From -11500 to -1700	600 (1'-11⅝")	Minimum
13	Cylinder between RPV Pedestal and Cylinder below RCCV	Southeast Quadrant	From -11500 to -7400	600 (1'-11⅝")	Minimum
14	Cylinder between RPV Pedestal and Cylinder below RCCV	Southeast Quadrant	From -6400 to -1900	1350 (4'-5⅛")	Minimum
15	Wall at Column Line R1	From RA to RG	From 4650 to 16500	1500 (4'-11")	+25,-20 (+1",-¾")
16	Wall at Column Line R7	From RA to RG	From 4650 to 16500	1500 (4'-11")	+25,-20 (+1",-¾")
17	Wall at Column Line RA	From R1 to R7	From 4650 to 25500	1500 (4'-11")	+25,-20 (+1",-¾")
18	Wall at Column Line RG	From R1 to R7	From 4650 to 25500	1500 (4'-11")	+25,-20 (+1",-¾")
19	Wall at Column Line R1	From RA to RC	From 17500 to 25500	1500 (4'-11")	+25,-20 (+1",-¾")
20	Wall at Column Line R1	From RE to RG	From 17500 to 25500	1500 (4'-11")	+25,-20 (+1",-¾")
21	Wall at Column Line R7	From RA to RC	From 17500 to 25500	1500 (4'-11")	+25,-20 (+1",-¾")

Table 3G.6-1 Critical Dimensions of Reactor Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
22	Wall at Column Line R7	From between RD and RE to RG	From 17500 to 25500	1500 (4'-11")	+25,-20 (+1",-¾")
23	Main Steam Tunnel Wall	East side	From 17500 to 24600	1300 (4'-3⅛")	+25,-20 (+1",-¾")
24	Main Steam Tunnel Wall	West side	From 17500 to 24600	1300 (4'-3⅛")	+25,-20 (+1",-¾")
25	Wall at Column Line R1	From RA to RB	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
26	Wall at Column Line R1	From RB to RC	From 27000 to 33000	1500 (4'-11")	+25,-20 (+1",-¾")
27	Wall at Column Line R1	From RC to RE	From 27000 to 34000	3500 (11'-5¾")	+25,-20 (+1",-¾")
28	Wall at Column Line R1	From RE to RF	From 27000 to 33000	1500 (4'-11")	+25,-20 (+1",-¾")
29	Wall at Column Line R1	From RF to RG	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
30	Wall at Column Line R2	From RA to RC	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
31	Wall at Column Line R2	From RE to RG	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
32	Wall at Column Line R6	From RA to RC	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
33	Wall at Column Line R6	From RE to RG	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
34	Wall at Column Line R7	From RA to RB	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
35	Wall at Column Line R7	From RB to between RC and RD	From 27000 to 33000	1500 (4'-11")	+25,-20 (+1",-¾")
36	Wall at Column Line R7	From between RC and RD to RE	From 27000 to 34000	2440 (8'-0")	+25,-20 (+1",-¾")

Table 3G.6-1 Critical Dimensions of Reactor Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
37	Wall at Column Line R7	From RE to RF	From 27000 to 33000	1500 (4'-11")	+25,-20 (+1",-¾")
38	Wall at Column Line R7	From RF to RG	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
39	Wall at Column Line RA	From R1 to R7	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
40	Wall at Column Line RB	From R1 to R7	From 27000 to 33000	2000 (6'-6¾")	+25,-20 (+1",-¾")
41	Wall between Column Lines RB and RC	From R6 to R7	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
42	Wall at Column Line RC (Pool Girder)	From R1 to R7	From 27000 to 33000	1600 (5'-3")	+25,-20 (+1",-¾")
43	Wall at Column Line RE (Pool Girder)	From R1 to R7	From 27000 to 33000	1600 (5'-3")	+25,-20 (+1",-¾")
44	Wall between Column Lines RE and RF	From R6 to R7	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
45	Wall at Column Line RF	From R1 to R7	From 27000 to 33000	2000 (6'-6¾")	+25,-20 (+1",-¾")
46	Wall at Column Line RG	From R1 to R7	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
47	Reactor Cavity Wall (Northeast side)	From RC to between RC and RD	From 27000 to 34000	1600 (5'-3")	+25,-20 (+1",-¾")
48	Reactor Cavity Wall (Northwest side)	From between RD and RE to RE	From 27000 to 34000	1600 (5'-3")	+25,-20 (+1",-¾")
49	Reactor Cavity Wall (Southeast side)	From RC to between RC and RD	From 27000 to 34000	1600 (5'-3")	+25,-20 (+1",-¾")
50	Not used				
51	IC/PCCS Pool Wall between Column Lines R2 and R3	From between RB and RC to RC	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")

Table 3G.6-1 Critical Dimensions of Reactor Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
52	IC/PCCS Pool Wall between Column Lines R2 and R3	From RE to between RE and RF	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
53	IC/PCCS Pool Wall at Column Line R3	From between RB and RC to RC	From 27000 to 33000	400 (1'-3¾")	+15,-10 (+½",-⅜")
54	IC/PCCS Pool Wall at Column Line R3	From RE to between RE and RF	From 27000 to 33000	400 (1'-3¾")	+15,-10 (+½",-⅜")
55	IC/PCCS Pool Wall between Column Lines R3 and R4	From between RB and RC to RC	From 27000 to 33000	400 (1'-3¾")	+15,-10 (+½",-⅜")
56	IC/PCCS Pool Wall between Column Lines R3 and R4	From RE to between RE and RF	From 27000 to 33000	400 (1'-3¾")	+15,-10 (+½",-⅜")
57	IC/PCCS Pool Wall between Column Lines R4 and R5	From between RB and RC to RC	From 27000 to 33000	400 (1'-3¾")	+15,-10 (+½",-⅜")
58	IC/PCCS Pool Wall between Column Lines R4 and R5	From RE to between RE and RF	From 27000 to 33000	400 (1'-3¾")	+15,-10 (+½",-⅜")
59	IC/PCCS Pool Wall at Column Line R5	From between RB and RC to RC	From 27000 to 33000	400 (1'-3¾")	+15,-10 (+½",-⅜")
60	IC/PCCS Pool Wall at Column Line R5	From RE to between RE and RF	From 27000 to 33000	400 (1'-3¾")	+15,-10 (+½",-⅜")
61	IC/PCCS Pool Wall between Column Lines R5 and R6	From between RB and RC to RC	From 27000 to 33000	470 (1'-6½")	+15,-10 (+½",-⅜")
62	IC/PCCS Pool Wall between Column Lines R5 and R6	From RE to between RE and RF	From 27000 to 33000	470 (1'-6½")	+15,-10 (+½",-⅜")
63	IC/PCCS Pool Wall between Column Lines RB and RC	From between R2 and R3 to between R5 and R6	From 27000 to 33000	1000 (3'-3⅜")	+15,-10 (+½",-⅜")
64	IC/PCCS Pool Wall at Column Line RC	From R2 to between R2 and R3	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
65	IC/PCCS Pool Wall at Column Line RE	From R2 to between R2 and R3	From 27000 to 33000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
66	IC/PCCS Pool Wall between Column Lines RE and RF	From between R2 and R3 to between R5 and R6	From 27000 to 33000	1000 (3'-3⅜")	+15,-10 (+½",-⅜")

Table 3G.6-1 Critical Dimensions of Reactor Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
67	Wall at Column Line R1	From RB to RF	From 34000 to 52000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
68	Wall at Column Line R7	From RB to RF	From 34000 to 52000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
69	Wall at Column Line RB	From R1 to R7	From 34000 to 52000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
70	Wall at Column Line RF	From R1 to R7	From 34000 to 52000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
71	Basemat excluding Containment Basemat	From R1 to R7 and RA and RG	-11500	4000 (13'-1½")	+50,-20 (+2",-¾")
72	Floor inside Cylinder below RCCV	Northeast Quadrant	-6400	600 (1'-11⅝")	+15,-10 (+½",-⅜")
73	Floor inside Cylinder below RCCV	Northwest Quadrant	-6400	600 (1'-11⅝")	+15,-10 (+½",-⅜")
74	Floor inside Cylinder below RCCV	Southeast Quadrant	-6400	1000 (3'-3⅜")	+25,-20 (+1",-¾")
75	Floor inside Cylinder below RCCV	Southwest Quadrant	-6400	600 (1'-11⅝")	+15,-10 (+½",-⅜")
76	Floor outside Cylinder below RCCV	From R1 to R7 and RA and RG	-6400	1000 (3'-3⅜")	+25,-20 (+1",-¾")
77	Floor inside Cylinder below RCCV	Northeast Quadrant	-1000	700 (2'-3⅝")	+15,-10 (+½",-⅜")
78	Floor inside Cylinder below RCCV	Northwest Quadrant	-1000	700 (2'-3⅝")	+15,-10 (+½",-⅜")
79	Floor inside Cylinder below RCCV	Southeast Quadrant	-1000	900 (2'-11½")	+15,-10 (+½",-⅜")
80	Floor inside Cylinder below RCCV	Southwest Quadrant	-1000	700 (2'-3⅝")	+15,-10 (+½",-⅜")
81	Floor outside Cylinder below RCCV	From R1 to R7 and RA to RG	-1000	1000 (3'-3⅜")	+25,-20 (+1",-¾")

Table 3G.6-1 Critical Dimensions of Reactor Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
82	Floor	From R1 to R7 and RA to RG	4650	1000 (3'-3⅜")	+25,-20 (+1",-¾")
83	Floor	From R1 to R7 and RA to RG	9060	1000 (3'-3⅜")	+25,-20 (+1",-¾")
84	Floor	From R1 to R7 and RA to RG	13570	1000 (3'-3⅜")	+25,-20 (+1",-¾")
85	Main Steam Tunnel Floor	From RC to RE	17500	1600 (5'-3")	+25,-20 (+1",-¾")
86	Floor excluding Main Steam Tunnel Floor	From R1 to R7 and RA to RG	17500	1000 (3'-3⅜")	+25,-20 (+1",-¾")
87	Main Steam Tunnel Roof	From RC to RE	27000	2400 (7'-10½")	+25,-20 (+1",-¾")
88	Floor	From R1 to R7 and RA to RC	27000	1500 (4'-11")	+25,-20 (+1",-¾")
89	Floor	From R1 to R7 and RE to RG	27000	1500 (4'-11")	+25,-20 (+1",-¾")
90	Floor	From R1 to R7 and RA to RC	34000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
91	Floor	From R1 to R7 and RE to RG	34000	1000 (3'-3⅜")	+25,-20 (+1",-¾")
92	Roof	From R1 to R7 and RB to RF	52700	700 (2'-3⅝")	+15,-10 (+½",-⅜")

* SI units are the controlling units and English units are for reference only.

Table 3G.6-1 Critical Dimensions of Reactor Building – Part 2

Key Dimension	Reference Dimension	Nominal Dimension* mm (ft-in)	Tolerance* mm (in)
Distance from RPV Centreline to Outside Surface of Wall at Column Line RA when Measured at Column Line R1	X1 (Figure 3G.6-1)	24500 (80'-4½")	±300 (±12")
Distance from RPV Centreline to Outside Surface of Wall at Column Line RG when Measured at Column Line R1	X2 (Figure 3G.6-1)	24500 (80'-4½")	±300 (±12")
Distance from RPV Centreline to Outside Surface of Wall at Column Line R1 when Measured at Column Line RA	X3 (Figure 3G.6-1)	24500 (80'-4½")	±300 (±12")
Distance from RPV Centreline to Outside Surface of Wall at Column Line R7 when Measured at Column Line RA	X4 (Figure 3G.6-1)	24500 (80'-4½")	±300 (±12")
Distance from Top of Basemat Outside Containment to Design Plant Grade	X5 (Figure 3G.6-10.)	16150 (52'-11⅞")	±300 (±12")
Distance from Design Plant Grade to Top Surface of Roof	X6 (Figure 3G.6-10.)	48050 (157'-7¾")	±300 (±12")

* SI units are the controlling units and English units are for reference only.

Table 3G.6-2 Critical Dimensions of Control Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
1	Wall at Column Line C1	From CA to CD	From -7400 to 8560	900 (2'-11½")	+15,-10 (+½",-⅜")
2	Wall at Column Line C5	From CA to CD	From -7400 to 8560	900 (2'-11½")	+15,-10 (+½",-⅜")
3	Wall at Column Line CA	From C1 to C5	From -7400 to 8560	900 (2'-11½")	+15,-10 (+½",-⅜")
4	Wall at Column Line CD	From C1 to C5	From -7400 to 8560	900 (2'-11½")	+15,-10 (+½",-⅜")
5	Wall at Column Line C3	From CA to CB	From -7400 to -2500	1000 (3'-3⅜")	+25,-20 (+1",-¾")
6	Wall at Column Line C3	From CC to CD	From -7400 to -2500	1000 (3'-3⅜")	+25,-20 (+1",-¾")
7	Wall at Column Line C1	From CA to CD	From 9060 to 13100	700 (2'-3⅝")	+15,-10 (+½",-⅜")
8	Wall at Column Line C5	From CA to CD	From 9060 to 13100	700 (2'-3⅝")	+15,-10 (+½",-⅜")
9	Wall at Column Line CA	From C1 to C5	From 9060 to 13100	700 (2'-3⅝")	+15,-10 (+½",-⅜")
10	Wall at Column Line CD	From C1 to C5	From 9060 to 13100	700 (2'-3⅝")	+15,-10 (+½",-⅜")
11	Basemat	From C1 to C5 and CA to CD	-7400	3000 (9'-10")	+50,-20 (+2",-¾")
12	Floor	From C1 to C5 and CA to CD	-2000	500 (1'-7¾")	+15,-10 (+½",-⅜")
13	Floor	From C1 to C5 and CA to CD	4650	500 (1'-7¾")	+15,-10 (+½",-⅜")
14	Floor	From C1 to C5 and CA to CD	9060	500 (1'-7¾")	+15,-10 (+½",-⅜")
15	Roof	From C1 to C5 and CA to CD	13800	700 (2'-3⅝")	+15,-10 (+½",-⅜")

* SI units are the controlling units and English units are for reference only.

Table 3G.6-2 Critical Dimensions of Control Building – Part 2

Key Dimension	Reference Dimension	Nominal Dimension* mm (ft-in)	Tolerance* mm (in)
Distance from Outside Surface of Wall at Column Line CA to Column Line CB when Measured at Column Line C1	*X1 (Figure 3G.6-12)*	*10400 (34'-1⅜")*	*±300 (±12")*
Distance from Outside Surface of Wall at Column Line CD to Column Line CB when Measured at Column Line C1	*X2 (Figure 3G.6-12)*	*13400 (43'-11½")*	*±300 (±12")*
Distance from Outside Surface of Wall at Column Line C1 to Column Line C3 when Measured at Column Line CA	*X3 (Figure 3G.6-12)*	*15150 (49'-8½")*	*±300 (±12")*
Distance from Outside Surface of Wall at Column Line C5 to Column Line C3 when Measured at Column Line CA	*X4 (Figure 3G.6-12)*	*15150 (49'-8½")*	*±300 (±12")*
Distance from Top of Basemat to Design Plant Grade	*X5 (Figure 3G.6-16)*	*12050 (39'-6½")*	*±300 (±12")*
Distance from Design Plant Grade to Top Surface of Roof	*X6 (Figure 3G.6-16)*	*9150 (30'-0¼")*	*±300 (±12")*

* *SI units are the controlling units and English units are for reference only.*

Table 3G.6-3 Critical Dimensions of Fuel Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
1	Wall at Column Line F3	From FA to between FB and FC	From -10000 to 3350	3640 (11'-11¼")	+25,-20 (+1",-¾")
2	Wall at Column Line F3	From between FB and FC to FF	From -11500 to 3350	2000 (6'-6¾")	+25,-20 (+1",-¾")
3	Wall at Column Line FA	From F1 to F3	From -10000 to 3350	2000 (6'-6¾")	+25,-20 (+1",-¾")
4	Wall at Column Line FF	From F1 to F3	From -11500 to 3350	2000 (6'-6¾")	+25,-20 (+1",-¾")
5	Wall between Column Lines F1 and F2	From FA to FB	From -10000 to 4650	4500 (14'-9⅛")	+25,-20 (+1",-¾")
6	Wall between Column Lines F1 and F2	From FB to between FB and FC	From -10000 to 4650	1935 (6'-4⅛")	+25,-20 (+1",-¾")
7	Wall between Column Lines F1 and F2	From between FB and FC to FC	From -10000 to -6400	2000 (6'-6¾")	+25,-20 (+1",-¾")
8	Wall between Column Lines F1 and F2 (Wall between Cask Pit and Incline Fuel Transfer Tube Pit)	From between FB and FC to FC	From -10000 to 4650	1000 (3'-3⅜")	+25,-20 (+1",-¾")
9	Wall between Column Lines F1 and F2	From FE to FF	From -11500 to -7200	1000 (3'-3⅜")	+25,-20 (+1",-¾")
10	Wall at Column Line F2	From between FE and FF to FF	From -11500 to -7200	1000 (3'-3⅜")	+25,-20 (+1",-¾")
11	Wall between Column Lines F2 and F3	From between FB and FC to FC	From -10000 to -1300	1150 (3'-9¼")	+25,-20 (+1",-¾")
12	Wall between Column Lines F2 and F3	From FE to FF	From -11500 to -7200	1000 (3'-3⅜")	+25,-20 (+1",-¾")
13	Wall between Column Lines FB and FC	From between F1 and F2 to F3	From -10000 to 4650	1500 (4'-11")	+25,-20 (+1",-¾")
14	Wall at Column Line FC	From F1 to between F1 and F2	From -11500 to 4650	1500 (4'-11")	+25,-20 (+1",-¾")
15	Wall at Column Line FC	From between F1 and F2 to F3	From -11500 to 3350	1000 (3'-3⅜")	+25,-20 (+1",-¾")

Table 3G.6-3 Critical Dimensions of Fuel Building – Part 1

Label	Wall or Section Description	Column Line or Region	Floor Elevation or Elevation Range (EL: mm)	Concrete Thickness* mm (ft-in)	Tolerance* mm (in)
16	Wall at Column Line FE	From between F1 and F2 to F2 and F3	From -11500 to -7200	1000 (3'-3⅜")	+25,-20 (+1",-¾")
17	Wall at Column Line FE	From between F2 and F3 to F3	From -11500 to -7200	600 (1'-11⅝")	+15,-10 (+½",-⅜")
18	Wall between Column Lines FB and FC	From F1 to F1 and F2	From -6400 to 4650	2000 (6'-6¾")	+25,-20 (+1",-¾")
19	Wall between Column Lines F2 and F3	From between FB and FC to FC	From -1300 to 3350	1000 (3'-3⅜")	+25,-20 (+1",-¾")
20	Wall at Column Line F3	From FA to FF	From 4650 to 21800	1000 (3'-3⅜")	+25,-20 (+1",-¾")
21	Wall at Column Line FA	From F1 to F3	From 4650 to 21800	1000 (3'-3⅜")	+25,-20 (+1",-¾")
22	Wall at Column Line FF	From F1 to F3	From 4650 to 21800	1000 (3'-3⅜")	+25,-20 (+1",-¾")
23	Basemat of Spent Fuel Pool, Cask Pit, and Incline Fuel Transfer Tube Pit	Not Applicable	-10000	5500 (18'-0½")	+50,-20 (+2",-¾")
24	Basemat excluding Spent Fuel Pool, Cask Pit, and Incline Fuel Transfer Tube Pit	Not Applicable	-11500	4000 (13'-1½")	+50,-20 (+2",-¾")
25	Floor	From F1 to F3 and FC to FF	-6400	800 (2'-7½")	+15,-10 (+½",-⅜")
26	Floor	From F1 to F3 and FC to FF	-1000	800 (2'-7½")	+15,-10 (+½",-⅜")
27	Floor (Cask Pit)	Not Applicable	-1300	1150 (3'-9¼")	+25,-20 (+1",-¾")
28	Floor	From F1 to F3 and FC to FF	4650	1300 (4'-3⅛")	+25,-20 (+1",-¾")
29	Roof	From F1 to F3 and FA to FF	22500	700 (2'-3⅝")	+15,-10 (+½",-⅜")

* SI units are the controlling units and English units are for reference only.

Table 3G.6-3 Critical Dimensions of Fuel Building – Part 2

Key Dimension	Reference Dimension	Nominal Dimension* mm (ft-in)	Tolerance* mm (in)
Distance from Outside Surface of Wall at Column Line FA to Column Line FC when Measured at Column Line F1	*X1 (Figure 3G.6-17)*	*21700 (71'-2⅜")*	*+300,-200 (+12",-7⅞")*
Distance from Outside Surface of Wall at Column Line FF to Column Line FC when Measured at Column Line F1	*X2 (Figure 3G.6-17)*	*27300 (89'-6¾")*	*±300 (±12")*
Distance between Outside Surface of Walls at Column Lines R7 and F3 when Measured at Column Line FA	*X3 (Figure 3G.6-17)*	*21000 (68'-10¾")*	*+300,-200 (+12",-7⅞")*
Distance from Top of Basemat to Design Plant Grade (Basemat excluding Spent Fuel Pool, Cask Pit, and Incline Fuel Transfer Tube Pit)	*X4 (Figure 3G.6-22)*	*16150 (52'-11⅞")*	*±300 (±12")*
Distance from Design Plant Grade to Top Surface of Roof (Excluding C-II Portion)	*X5 (Figure 3G.6-22)*	*17850 (58'-6¾")*	*±300 (±12")*

* *SI units are the controlling units and English units are for reference only.*

Figure 3G.6-1. RB Concrete Outline Plan at EL –11500

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-2. RB Concrete Outline Plan at EL –6400

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-3. RB Concrete Outline Plan at EL –1000

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-4. RB Concrete Outline Plan at EL 4650

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-5. RB Concrete Outline Plan at EL 9060

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Figure 3G.6-6. RB Concrete Outline Plan at EL 13570

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-7. RB Concrete Outline Plan at EL 17500

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-8. RB Concrete Outline Plan at EL 27000

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-9. RB Concrete Outline Plan at EL 34000

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-10. RB Concrete Outline N-S Section

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-11. RB Concrete Outline E-W Section

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-12. CB Concrete Outline Plan at EL –7400

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Figure 3G.6-13. CB Concrete Outline Plan at EL –2000

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-14. CB Concrete Outline Plan at EL 4650

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-15. CB Concrete Outline Plan at EL 9060

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-16. CB Concrete Outline E-W Section

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-17. FB Concrete Outline Plan at EL –11500

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-18. FB Concrete Outline Plan at EL –6400

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-19. FB Concrete Outline Plan at EL –1000

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-20. FB Concrete Outline Plan at EL 4650

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Figure 3G.6-21. FB Concrete Outline Plan at EL 22500

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Figure 3G.6-22. FB Concrete Outline N-S Section

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

Appendix 3H EQUIPMENT QUALIFICATION DESIGN ENVIRONMENTAL CONDITIONS

3H.1 INTRODUCTION

This appendix specifies plant environmental conditions, which envelop the actual environment expected over the plant life, for which safety-related equipment (Section 3.11) is designed and qualified. The plant conditions considered in defining the environmental conditions are normal operation including anticipated operational occurrences, and accident conditions including post-accident operations. The accident condition considered is a hypothesized single event (not reasonably expected during the course of plant operation) that has the potential to cause severe environmental conditions for safety-related equipment. The specified accident conditions are based on significantly conservative assumptions.

The primary environmental parameters addressed are pressure, temperature, relative humidity, radiation, and chemical conditions. Safety-related equipment inside containment is designed and qualified for the environmental conditions resulting from the most limiting Design Basis Accident (DBA) and meets the Environmental Qualification (EQ) program acceptance criteria. The parameters specified in this appendix do not include margins that may be required to satisfy applicable codes and standards for equipment qualification. The radiation data specified in this appendix is intended to provide a conservative basis for equipment qualification and is not intended to limit or justify personnel access.

The following areas containing safety-related equipment are considered for equipment qualification purposes:

- Containment Vessel
- Reactor Building (RB)
- Control Building (CB)

3H.2 PLANT ZONES

3H.2.1 Containment Vessel

The containment vessel is divided into a drywell region and a wetwell region with an interconnecting vent system. The containment vessel is shown in Figure 6.2-1a. The drywell volume is divided into an upper drywell and lower drywell by the Reactor Pressure Vessel (RPV) supports and support pedestal. The upper and lower drywell is interconnected. Table 3.2-1 identifies the safety-related equipment located within the containment vessel.

For normal operating conditions, the containment vessel is divided into three thermodynamic and four radiation zones to represent the enveloping levels of the environmental conditions. The environmental zones are shown in Table 3H-2 and Table 3H-5.

3H.2.2 Outside Containment Vessel

The area outside the containment vessel includes:

- Control Building
- Reactor Building outside containment

The region inside the RB surrounding the containment encloses penetrations through the containment. The Control Room Habitability Area (CRHA) includes the main control room and areas adjacent to the control room containing operator facilities. Also located in the CB are safety-related Distributed Control and Information System (DCIS) rooms, located at elevation -7400 mm. Major equipment zones are shown on the RB arrangement drawing (Figures 1.2-1 to 1.2-9).

3H.3 ENVIRONMENTAL CONDITIONS

Table 3H-1 contains a cross listing of the environmental data tables arranged by location and by type of condition.

3H.3.1 Plant Normal Operating Conditions

Tables 3H-2 through 3H-4 define the thermodynamic conditions (pressure, temperature and humidity) for normal operating conditions for areas containing safety-related equipment. Figures showing equipment location and system configurations are referenced in each table. Section 12.3 defines the radiation conditions for the Reactor Building and Control Building for normal operating conditions. Table 3H-5 specifies the radiation environmental conditions inside the containment vessel for normal operating conditions. Specific radiation environment conditions for equipment are determined through the equipment qualification program based on actual location. Section 9.4 defines the Fuel Building thermodynamic conditions for normal operating conditions.

3H.3.2 Accident Conditions

Thermodynamic conditions for safety-related equipment in the containment vessel, CB and RB are presented in Tables 3H-8 through 3H-10 for accident conditions. Heat loads for the evaluated post accident periods are specified in Table 3H-12. In general, the most severe environmental conditions result from a postulated reactor coolant line break inside the containment, Loss-Of-Coolant-Accident (LOCA) (bounding case) plus Loss Of Offsite Power (LOOP), see Chapter 6 for detailed information. However, accident conditions were also considered for ruptures occurring in the steam tunnel and breaks in the RWCU/SDC System outside the containment, High Energy Line Break (HELB) plus LOOP, see Chapter 6 for detailed information. Tables 3H-6 and 3H-7 list typical radiation environmental qualification conditions inside the RB and the CB. Table 3H-11 specifies the radiation environment conditions inside the containment vessel. The EQ program confirms explicit radiation and thermodynamic conditions during accidents. The limiting thermodynamic conditions in the Fuel Building results from the boiling of the spent fuel pool. The

thermodynamic conditions during an accident when the spent fuel pool boils is a limiting temperature of 104°C (219°F), with 100% relative humidity and a limiting pressure consistent with the full tornado pressure drop described in Subsection 3.3.2.2.

3H.3.2.1 Transient Room Temperature Analysis

The performance evaluation for environmental qualification show conformance to the requirements identified in Section 3.11. The maximum temperature Control Building and Reactor Building Environmental Temperature Analysis for ESBWR is presented in Reference 3H.4-8 and is summarized below. Reference 3H.4-8 is designated as Tier 2*. Prior NRC approval is required to change Tier 2* information. The Control Room Habitability Area Minimum Temperature Analysis and high humidity analysis is also summarized below.

Acceptance Criteria

The design meets the following Acceptance Criteria:

- **Environmental Qualification Maximum Temperatures** – The maximum temperature limit for which the safety-related equipment is qualified is not exceeded. The maximum temperature limit is specified in Tables 3H-9 and 3H-10.
- **Control Room Habitability Area Temperature** – The maximum bulk average temperature meets the acceptance criteria stated in Section 6.4. The minimum bulk average air temperature remains at or above 13ºC (55ºF) for 72 hours after an accident.

Analysis Assumptions

The analysis event assumptions are summarized below. Initial conditions and assumptions can be found in Table 3H-14. Heat loads used in the analysis are found in Table 3H-12.

- The event presented is the most limiting between LOCA or HELB with each concurrent with LOOP.
- Normal Heating, Ventilation and Air Conditioning (HVAC) heating and/or cooling is lost for the first 72 hours of the accident.
- After 72 hours the safety-related equipment heat loads are no longer accounted for because the safety-related equipment needed to maintain safe shutdown no longer requires power to perform their safety-related functions. Normal HVAC mitigates the safety-related equipment heat loads when power is available.
- During the first 2 hours of the event the nonsafety-related heat loads in the RB and in the CB outside of the CRHA powered by the nonsafety-related batteries are considered in the analysis.
- Safety-related heat loads are considered throughout the duration of the event when power is available.

- The CRHA calculation considers safety-related heat loads and additional heat loads for some nonsafety-related equipment. Select nonsafety-related equipment deenergizes if active cooling is not available.
- Room to room interactions are considered in all calculations.
- Outside air intake from the emergency filter unit (EFU) is considered for the CRHA calculation during maximum and minimum temperature conditions.

Analysis Results

As shown in Table 3H-15, the environmental qualification temperatures for safety-related equipment is not exceeded during the limiting event based on the detailed Control Building and Reactor Building Environmental Temperature Analysis for ESBWR performed with CONTAIN 2.0. The CRHA minimum bulk average air temperature acceptance criteria is met based on the detailed Control Room Habitability Area Minimum Temperature Analysis performed, which is benchmarked against the Control Building CONTAIN maximum temperature analysis in Reference 3H.4-8. The CRHA Wet Bulb Globe Temperature (WBGT) index acceptance criteria are met. When rooms are located on the same level and have similar dimensions and internal heat loads, the most unfavorable room is taken to be the representative room for that group of rooms. Solar heat loads were applied to rooms located above grade. Table 3H-15 summarizes the representative room temperatures and locations of the room groups.

During the transient event concurrent with LOOP and loss of normal HVAC the heat generated in the rooms is absorbed by the surrounding walls, floor and ceiling. The building concrete acts as a heat sink for passive heat removal. The room temperature rises quickly because the heat absorption capacity of air is very low. The heat transfer to the walls, floor and ceiling maintain the environmental temperatures below the qualification temperature.

> During wintertime conditions the RB and CB are isolated and equipment room cool down is insignificant. The case for the CRHA post 72 hours presented in Table 3H-15 which accounts for heat loads from people and minimal lighting only, demonstrates that the cool down for the RB and CB are inconsequential. The injection of ambient air at wintertime conditions when safety-related heat loads are not present provides a faster cool down rate than the other rooms located in the RB and CB. See Subsection 3H.3.2.1.1 for environmental conditions used for maximum temperature analysis, see Subsection 3H.3.2.1.2 for environmental conditions used for minimum temperature analysis and see Subsection 3H.3.2.1.3 for environmental conditions used for high humidity analysis.

The temperature in the CRHA remains below the temperature acceptance criteria outlined in Section 6.4. The temperature and humidity profiles for the 0% exceedance coincident maximum temperature case are presented in Figures 3H-2 and 3H-3 respectively. Cases were considered to ensure that the 0% exceedance maximum outside air temperature was bounding and 100% relative

humidity with additional moisture created by CRHA occupants (latent load) would not lead to a 72 hour CRHA air temperature higher than the 0% exceedance coincident maximum temperature case, and ensure the heat absorbed by the CRHA structures would not be adversely impacted by the condensation created. The results of this analysis show that higher humidity ratios, and subsequently higher specific enthalpy, do not affect the maximum temperature reached with little condensation occurring on the walls of the control room. The concrete heat sink provides enough thermal mass to keep the CRHA within limits during the limiting event by absorbing heat loads or heating ambient air during summer or winter conditions.

3H.3.2.1.1 Maximum Temperature Analysis Conditions

For the summer conditions the 0% exceedance maximum dry bulb and coincident wet bulb ambient outside air temperature [47.2°C (117°F) DBt and 26.7°C (80°F) WBt] was considered. The Daily Temperature Range applied for this analysis is Δ 15°C (27°F).

> The Daily Temperature Range for summer conditions is defined as the dry bulb temperature difference between the 0% exceedance maximum dry bulb temperature and the dry bulb temperature that corresponds to the higher of the two lows occurring within 24 hours before and after that maximum.
>
> The Maximum Average Dry Bulb Temperature for the 0% Exceedance Maximum Temperature Day is defined as the average of the 0% exceedance maximum dry bulb temperature of 47.2ºC (117°F) and the dry bulb temperature resulting from a daily temperature range of 15ºC (27°F), which is 39.7ºC (103.5°F).

3H.3.2.1.2 Minimum Temperature Analysis Conditions

For the winter conditions the Control Room Habitability Area Minimum Temperature Analysis considers the 0% exceedance minimum dry bulb ambient outside air temperature (-40°C/°F). The Daily Temperature Range applied for this analysis is Δ 15°C (27°F).

> The Daily Temperature Range for winter conditions is defined as the dry bulb temperature difference between the 0% exceedance minimum dry bulb temperature and the dry bulb temperature that corresponds to the lower of the two highs occurring within 24 hours before and after that minimum.
>
> The Minimum Average Dry Bulb Temperature for 0% Exceedance Minimum Temperature Day is the average of the 0% exceedance minimum dry bulb temperature of –40ºC (-40°F) and the dry bulb temperature resulting from a daily temperature range of 15ºC (27°F), which is -32.5ºC (–26.5°F).

3H.3.2.1.3 High Humidity Analysis Conditions

For high humidity conditions the 0% exceedance non-coincident maximum wet bulb temperature [31.1ºC (88ºF) WBt] and High Humidity Diurnal Swing [Δ 4.4ºC (8ºF) DBt] are applied to the methodology for the analysis presented in Reference 3H.4-8.

> The High Humidity Diurnal Swing is defined as the dry bulb temperature range determined by the maximum and the minimum wet bulb temperatures for the worst three-day period over which the 0% exceedance wet bulb temperature occurs. The maximum wet bulb temperature (31.1ºC/88ºF) has a coincident dry bulb temperature of (33.3ºC/92ºF). These temperatures define the maximum dry bulb and wet bulb temperatures for three days in the analysis. The minimum dry bulb temperature is defined as the coincident dry bulb temperature (28.9ºC/84ºF) for the highest of six low wet bulb temperatures (27.2ºC/81ºF) occurring in each of the three 24-hour periods before and after the 0% coincident maximum wet bulb temperature. The High Humidity Diurnal Swing is the difference between the coincident maximum dry bulb temperature (33.3ºC/92ºF) and the highest daily low dry bulb temperature (28.9ºC/84ºF).

The overnight low wet bulb temperature in the high humidity CONTAIN analysis is 28.9ºC (84ºF), which is conservative relative to the 27.2ºC (81ºF) wet bulb temperature in the High Humidity Diurnal Swing.

> The WBGT index value is determined by the dry bulb temperature multiplied by 0.3 plus the wet bulb temperature multiplied by 0.7.

> The Maximum High Humidity Average Wet Bulb Globe Temperature Index for 0% Exceedance Maximum Wet Bulb Temperature Day is defined as the average of the WBGT index values for the temperatures used to determine the High Humidity Diurnal Swing. The WBGT index value for the maximum dry bulb 33.3ºC (92ºF) and wet bulb 31.1ºC (88ºF) temperatures is 31.8ºC (89.2ºF). The WBGT index value for the minimum dry bulb 28.9ºC (84ºF) and wet bulb 28.9ºC (84ºF) temperatures is 28.9ºC (84ºF). The average of the WBGT index values is then 30.3ºC (86.6ºF).

3H.3.3 Water Quality

Reactor water design quality characteristics during normal operation are:

- pH range: 5.6 to 8.6
- Silica (as SiO_2) ≤ 200 ppb (100 ppb operating target)
- Conductivity at 25°C (77ºF) ≤ 0.1 µS/cm (0.08 µS/cm operating target)
- Dissolved Oxygen (as O_2) ≤ 300 ppb
- Corrosion product metals ≤ 6 ppb

The Standby Liquid Control (SLC) System injects borated water into the RPV during DBA LOCA. Although there is no caustic spray in the ESBWR design, the post-accident suppression pool pH can vary due to the production of cesium-hydroxide and radiation-induced acids, as described in detail in Subsection 15.4.4.

3H.3.4 Locations of Safety-Related Equipment

Table 3H-12 identifies the potential location for safety-related equipment assumed for each room or set of rooms and the evaluated heat load capacity. This table also contains the evaluated heat load for nonsafety-related rooms, because nonsafety-related equipment is conservatively assumed to continue to be powered by nonsafety-related batteries during the first 2 hours of LOOP and thus contributes to the room heat up during LOOP and a DBA. The EQ program confirms equipment locations and heat loads do not cause temperatures to exceed the specified acceptance criteria.

3H.3.5 Mild Environment Conditions

The environment parameter limits that constitute mild environment conditions are identified in Table 3H-13.

3H.3.6 Combined License (COL) Information

None.

3H.4 REFERENCES

3H.4-1 10 CFR 50 Appendix J, “Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors.”

3H.4-2 NUREG-1465, “Accident Source Terms for Light-Water Nuclear Power Plants,” February 1995.

3H.4-3 Not used.

3H.4-4 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena.”

3H.4-5 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Dynamic Effects Design Bases.”

3H.4-6 10 CFR Part 50, 50.49, "Environmental Qualification of Electric Equipment Important to Safety of Nuclear Power Plants.”

3H.4-7 Regulatory Guide 1.209, “Guidelines for Environmental Qualification of Safety-Related Computer-Based Instrumentation and Control Systems in Nuclear Power Plants.”

3H.4-8 *GE-Hitachi Nuclear Energy, “Control Building and Reactor Building Environmental Temperature Analysis for ESBWR,” NEDE-33536P, Class III (Proprietary), Revision 1, October 2010, NEDO-33536, Class I (Non-proprietary), Revision 1, October 2010.*

Table 3H-1 Cross Reference of Plant Environmental Data and Location

Plant Environmental Data	Location		
	Containment Vessel	Reactor Building	Control Building
Thermodynamic (Normal Conditions)	Table 3H-2	Table 3H-3	Table 3H-4
Thermodynamic (Accident Conditions)	Table 3H-8	Table 3H-9	Table 3H-10
Radiation	Table 3H-5 (Normal Conditions) Table 3H-11 (Accident Conditions)	Table 3H-6	Table 3H-7
Room Heat Loads	Table 3H-12	Table 3H-12	Table 3H-12
Thermodynamic/Radiation (Mild Environment Limits)	Table 3H-13	Table 3H-13	Table 3H-13
Thermodynamic Analytical Initial Conditions and Assumptions	Chapter 6	Table 3H-14	Table 3H-14
Thermodynamic Analysis Results	Chapter 6	Table 3H-15	Table 3H-15

Table 3H-2 Thermodynamic Environment Conditions Inside Containment Vessel for Normal Operating Conditions

Plant Zone/Typical Equipment[(1)]	**Pressure**[(2)(3)] kPaG (psig)	**Temperature**[(3)] °C (°F)	**Relative Humidity**[(3)] %
Upper drywell and upper area of lower drywell (Figure 6.2-1a)	9.0 (1.3)	57 (135) Ave 65 (150) Max	Not Controlled
Lower area of lower drywell (Figure 6.2-1a)	9.0 (1.3)	57 (135) Ave 60 (140) Max	Not Controlled
Wetwell - pool and gas space (Figure 6.2-1a)	5.3 (0.76) Nom 9.0 (1.3) Max 0 (0) Min	43 (110) Max[(4)]	100

(1) *The containment atmosphere is nitrogen.*

(2) *The containment vessel is pressurized during leak rate tests once per refueling outage in accordance with 10 CFR 50, Appendix J.*

(3) *The worst combination of conditions in the table sets the design requirements of equipment.*

(4) *The suppression pool water may reach 46°C (115°F) during testing. The maximum abnormal temperature is 49°C (120°F).*

Table 3H-3 Thermodynamic Environment Conditions Inside Reactor Building for Normal Operating Conditions

Plant Zone/Typical Equipment	Pressure[1]	Temperature °C (°F)	Relative Humidity
Hydraulic Control Unit (HCU) Rooms HCU, Reactor Protection System (RPS) solenoids and RPV water level instrument racks Room Nos 1110, 1120, 1130, 1140 (Figure 1.2-1)	Negative Pressure	29 (85) Max 18 (65) Min	Not controlled
Battery Rooms Div 1, 2, 3 and 4 batteries Room Nos 1210, 1220, 1230, 1240 (Figure 1.2-2)	Negative Pressure	29 (85) Max 18 (65) Min	Not controlled
Div 1, 2, 3 and 4 commodity chases Electrical cables Room Nos 1211, 1221, 1231, 1241 (Figure 1.2-2)	Positive Pressure	40 (104) Max 10 (50) Min	Not controlled
Electrical Division Rooms Div 1, 2, 3 and 4 electrical and electronic equipment Room Nos 1311, 1321, 1331, 1341 (Figure 1.2-3)	Positive Pressure	29 (85) Max 18 (65) Min	Not controlled
Lower drywell non-divisional electrical and mechanical penetration Outboard containment isolation valves Room Nos 1300, 1301, 1302, 1303 (Figure 1.2-3)	Positive Pressure	40 (104) Max 10 (50) Min	Not controlled
Div 1, 2, 3 and 4 electrical penetration rooms Electrical cables and penetrations Room Nos 1312, 1322, 1332, 1342 (Figure 1.2-3)	Positive Pressure	40 (104) Max 10 (50) Min	Not controlled
Remote shutdown panel Room Nos 1313, 1323 (inside rooms 1311 and 1321) (Figure 1.2-3)	Positive Pressure	29 (85) Max 18 (65) Min	Not controlled
Non-divisional electrical equipment Safety-related DCIS panels Room Nos 1500, 1501, 1502, 1503 (Figure 1.2-5)	Positive Pressure	29 (85) Max 18 (65) Min	Not controlled
Div 1, 2, 3 and 4 electrical penetrations Electrical cables and penetration Room Nos 1610, 1620, 1630, 1640 (Figure 1.2-6)	Negative Pressure	40 (104) Max 10 (50) Min	Not controlled
Div 1, 2, 3 and 4 corridors rooms (access to penetration area), divisional electrical cables and safety-related DCIS Remote Multiplexing Units (RMUs) Room Nos 1710, 1720, 1730, 1740 (Figure 1.2-7)	Negative Pressure	29 (85) Max 18 (65) Min	Not controlled

Table 3H-3 Thermodynamic Environment Conditions Inside Reactor Building for Normal Operating Conditions

Plant Zone/Typical Equipment	Pressure[1]	Temperature °C (°F)	Relative Humidity
Div 1, 2, 3 and 4 electrical penetration and Mechanical penetrations Electrical cables and penetrations. Outboard isolation valves Room Nos 1711, 1721, 1731, 1741 and 1712, 1722, 1732, 1742 (Figure 1.2-7)	Negative Pressure	40 (104) Max 10 (50) Min	Not controlled
SLC tank rooms SLC tank instrumentation Room Nos 1713, 1723 (Figure 1.2-7)	Negative Pressure	29 (85) Max 18 (65) Min	Not controlled
Main Steam Tunnel Main Steamline (MSL) isolation valves MSL drain isolation valves Feedwater (FW) isolation valves Room No 1770 (Figure 1.2-7)	Negative Pressure	40 (104) Max 10 (50) Min	Not controlled
IC/PCCS pools Isolation Condenser System (ICS) pools instrumentation Room Nos 18P3A/B/C/D, 18P4A/B/C/D/E/F, 18P5A/B/C, 18P6A/B/C (Figure 1.2-8)	Negative Pressure	40 (104) Max 10 (50) Min	100/Water

(1) Relative to surrounding areas.

Table 3H-4 Thermodynamic Environment Conditions Inside Control Building for Normal Operating Conditions

Plant Zone/Typical Equipment	Pressure[1]	Temperature °C (°F)	Relative Humidity %
Safety-related portions of CRHA Ventilation Subsystem Room Nos 3406, 3407 (Figure 1.2-5)	Positive Pressure	40 (104)Max 10 (50) Min	60 Max 25 Min
Electrical chases Room Nos 3250, 3261 (Figures 1.2-2 to 1.2-5)	Positive Pressure	25.6 (78) Max 18.3 (65) Min	60 Max 25 Min
Control Room Habitability Area Main control room panels (Outlined area on Figure 3H-1)	Positive Pressure	23.3 (74) Max 21.1 (70) Min	60 Max 25 Min
Div 1, 2, 3 and 4 electrical rooms Safety-related DCIS panels Room Nos 3110, 3120, 3130 and 3140 (Figure 1.2-2)	Positive Pressure	25.6 (78) Max 18.3 (65) Min	60 Max 25 Min

(1) *Relative to surrounding areas.*

Table 3H-5 Radiation Environment Conditions Inside Containment Vessel for Normal Operating Conditions

Plant Zone/Typical Equipment	Operating Dose Rate(1)(2)		Integrated Dose(2)(3)	
	Gamma (R/h)	Beta(4) (R/h)	Gamma (R)	Beta(4) (R)
Upper drywell (Figure 6.2-1a)	2.61 E+1	Negl.	1.4 E+7	Negl.
Upper area of lower drywell (Figure 6.2-1a)	2.61 E+1	Negl.	1.4 E+7	Negl.
Lower area of lower drywell (Figure 6.2-1a)	1.98 E+1	Negl.	1.0 E+7	Negl.
Wetwell - Suppression pool and gas space (Figure 6.2-1a)	< 1.4	Negl.	7.4 E+5	Negl.

(1) *Nominal operating dose rate is at 100% rated power and located at 30 cm (0.98 ft) from radiation source. Specific radiation environment conditions for equipment are determined through the equipment qualification program based on actual location.*

(2) *The operating dose rates and integrated dose are based on ABWR plant operating conditions and adjusted for ESBWR using appropriate scaling factors.*

(3) *Integrated dose means the integrated value over 60 years.*

(4) *Negl.- Value less than 0.001 mR/h*

Table 3H-6 Typical Radiation Environment Qualification Conditions Inside Reactor Building

Plant Zone/Typical Equipment	Integrated gamma dose (rads)
Hydraulic Control Unit (HCU) Rooms HCU, RPS solenoids and RPV water level instrument racks Rooms No 1110, 1120, 1130, 1140 (Figure 1.2-1)	$< 10^{4(1)}$ $< 10^{6}$
Battery Rooms Div 1, 2, 3 and 4 batteries Room Nos 1210, 1220, 1230, 1240 (Figure 1.2-2)	$< 10^{6}$
Div 1, 2, 3 and 4 commodity chases Electrical cables Room Nos 1211, 1221, 1231, 1241 (Figure 1.2-2)	$< 10^{6}$
Electrical Division Rooms Div 1, 2, 3 and 4 electrical and electronic equipment Room Nos 1311, 1321, 1331, 1341 (Figure 1.2-3)	$< 10^{4(1)}$ $< 10^{6}$
Lower drywell non-divisional electrical and mechanical penetration Outboard containment isolation valves Room Nos 1300, 1301, 1302, 1303 (Figure 1.2-3)	$< 10^{6}$
Div 1, 2, 3 and 4 electrical penetration rooms Electrical cables and penetrations Room Nos 1312, 1322, 1332, 1342 (Figure 1.2-3)	$< 10^{6}$
Remote shutdown panel Room Nos 1313, 1323 (inside rooms 1311 and 1321) (Figure 1.2-3)	$< 10^{4(1)}$ $< 10^{6}$
Non-divisional electrical equipment Safety-related DCIS panels Room Nos 1500, 1501, 1502, 1503 (Figure 1.2-5)	$< 10^{4(1)}$ $< 10^{6}$
Div 1, 2, 3 and 4 electrical penetrations Electrical cables and penetration Room Nos 1610, 1620, 1630, 1640 (Figure 1.2-6)	$< 10^{6}$
Div 1, 2, 3 and 4 corridors rooms (access to penetration area), divisional electrical cables and safety-related DCIS RMUs Room Nos 1710, 1720, 1730, 1740 (Figure 1.2-7)	$< 10^{4(1)}$ $< 10^{6}$

Table 3H-6 Typical Radiation Environment Qualification Conditions Inside Reactor Building

Plant Zone/Typical Equipment	Integrated gamma dose (rads)
Div 1, 2, 3 and 4 Electrical penetration and Mechanical penetrations Electrical cables and penetrations. Outboard isolation valves Room Nos 1711, 1721, 1731, 1741 and 1712, 1722, 1732, 1742 (Figure 1.2-7)	$< 10^6$
SLC tank rooms SLC tank instrumentation Room Nos 1713, 1723 (Figure 1.2-7)	$< 10^4$(1) $< 10^6$
Main Steam Tunnel Main Steamline (MSL) isolation valves MSL drain isolation valves FW isolation valves Room No 1770 (Figure 1.2-7)	$< 10^7$
IC/PCCS pools ICS pools instrumentation Room Nos 18P3A/B/C/D, 18P4A/B/C/D/E/F, 18P5A/B/C, 18P6A/B/C (Figure 1.2-8)	$< 10^4$

(1) *Electronic equipment is qualified for gamma dose $< 10^4$ rads, other equipment is qualified for gamma dose $< 10^6$ rads. In locations within these zones where the calculated dose is greater than 10^4 rads the qualification is done for the actual calculated doses plus 10%, or equipment is protected from radiation.*

Table 3H-7 Typical Radiation Environment Qualification Conditions Inside Control Building

Plant Zone/Typical Equipment	Integrated gamma dose (rads)
Safety-related portions of CRHA Ventilation Subsystem Room Nos 3406, 3407 (Figure 1.2-5)	$< 10^{3}$
Control Room Habitability Area Main control room panels (Outlined area on Figure 3H-1)	$< 10^{3}$
Div 1, 2, 3 and 4 electrical rooms Safety-related DCIS panels Room Nos 3110, 3120, 3130 and 3140 (Figure 1.2-2)	$< 10^{3}$

Table 3H-8 Thermodynamic Environment Conditions Inside Containment Vessel for Accident Conditions

Plant Zone		
Upper and lower drywell [1] (Figure 6.2-1a)	Time [2] Bulk Temp. °C (°F) Time [2] Bulk Temp. °C (°F) Time [2] Press. kPaG (psig) Humidity %	0 h – 0.01 h 193 (379) Max. >0.01 h – 72 h 171 (340) Max. 0 h – 72 h 310 (45) Max. Steam
Wetwell Gas Space (Figure 6.2-1a)	Time [2] Bulk Temp. °C (°F) Press. kPaG (psig) Humidity %	0 h – 72 h 137 (278) Max. 310 (45) Max. 100

(1) For a pipe failure inside the containment vessel, water accumulates in the lower drywell. The amount depends upon the break location.

(2) Time denotes the time after the occurrence of LOCA.

Table 3H-9 Thermodynamic Environment Conditions Inside Reactor Building for Accident Conditions

Plant Zone/Typical Equipment[3]			
Hydraulic Control Unit (HCU) Rooms HCU, RPS solenoids and RPV water level instrument racks Room Nos 1110, 1120, 1130, 1140 (Figure 1.2-1)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 50 (122) Max Not controlled Not controlled	96 h - 100 days 40 (104) Negative Pressure Not controlled
Battery Rooms Div 1, 2, 3 and 4 batteries Room Nos 1210, 1220, 1230, 1240 (Figure 1.2-2)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 50 (122) Max Not controlled Not controlled	96 h - 100 days 40 (104) Positive Pressure Not controlled
Div 1, 2, 3 and 4 commodity chases Electrical cables Room Nos 1211, 1221, 1231, 1241 (Figure 1.2-2)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 110 (230) Max Not controlled Not controlled	96 h - 100 days 50 (122) Positive Pressure Not controlled
Electrical Division Rooms Div 1, 2, 3 and 4 electrical and electronic equipment Room Nos 1311, 1321, 1331, 1341 (Figure 1.2-3)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 50 (122) Max Not controlled Not controlled	96 h - 100 days 40 (104) Positive Pressure Not controlled
Lower drywell non-divisional electrical penetration Outboard containment isolation valves Room Nos 1300, 1301, 1302, 1303 (Figure 1.2-3)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 110 (230) Max Not controlled Not controlled	96 h - 100 days 50 (122) Positive Pressure Not controlled
Div 1, 2, 3 and 4 electrical penetration rooms Electrical cables and penetrations Room Nos 1312, 1322, 1332, 1342 (Figure 1.2-3)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 110 (230) Max Not controlled Not controlled	96 h - 100 days 50 (122) Positive Pressure Not controlled
Remote shutdown panel Room Nos 1313, 1323 (inside rooms 1311 and 1321) (Figure 1.2-3)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 50 (122) Not controlled Not controlled	96 h - 100 days 40 (104) Positive Pressure Not controlled
Non-divisional electrical equipment Safety-related DCIS panels Room Nos 1500, 1501, 1502, 1503 (Figure 1.2-5)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 50 (122) Max Not controlled Not controlled	96 h - 100 days 40 (104) Positive Pressure Not controlled
Div 1, 2, 3 and 4 electrical penetrations Electrical cables and penetration Room Nos 1610, 1620, 1630, 1640 (Figure 1.2-6)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 110 (230) Max Not controlled Not controlled	96 h - 100 days 50 (122) Positive Pressure Not controlled

Table 3H-9 Thermodynamic Environment Conditions Inside Reactor Building for Accident Conditions

Plant Zone/Typical Equipment[3]			
Div 1, 2, 3 and 4 corridors rooms (access to penetration area), divisional electrical cables and safety-related DCIS RMUs Room Nos 1710, 1720, 1730, 1740 (Figure 1.2-7)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 50 (122) Max Not controlled Not controlled	96 h - 100 days 40 (104) Negative Pressure Not controlled
Div 1, 2, 3 and 4 electrical penetration and Mechanical penetrations. Electrical cables and penetrations. Outboard isolation valves Room Nos 1711, 1721, 1731, 1741 and 1712, 1722, 1732, 1742 (Figure 1.2-7)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 110 (230) Max Not controlled Not controlled	96 h - 100 days 50 (122) Negative Pressure Not controlled
SLC tank rooms SLC tank instrumentation Room Nos 1713, 1723 (Figure 1.2-7)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 50 (122) Max Not controlled Not controlled	96 h - 100 days 40 (104) Negative Pressure Not controlled
Main Steamline (MSL) isolation valves MSL drain isolation valves FW isolation valves Room No 1770 (Figure 1.2-7)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 117 (243) Max 76 (11) 100	96 h - 100 days 60 (140) Negative Pressure Not controlled
IC/PCCS pools ICS pools instrumentation Room Nos 18P3A/B/C/D, 18P4A/B/C/D/E/F, 18P5A/B/C, 18P6A/B/C (Figure 1.2-8)	Time[1] Temp. °C (°F) [2] Press. kPaG (psig) Humidity %	0 h - 72 h 112 (234) Max 49 (7.1) 100	96 h - 100 days 100 (212) Positive Pressure 100

(1) *Time indicates the time after the occurrence of the accident.*

(2) *After 72h, the temperature decreases to the temperature value shown for 96h.*

(3) *Electronic equipment is qualified for 50ºC (122ºF) during 72 hours; other equipment could be qualified for higher temperatures according to the above values. In locations within these zones where room temperature is higher than 50°C (122ºF), electronic equipment is qualified for the actual calculated temperature within the zone, or the equipment is protected from high temperatures.*

Table 3H-10 Thermodynamic Environment Conditions Inside Control Building for Accident Conditions

Plant Zone/Typical Equipment [3]			
Safety-related portions of CRHA Ventilation Subsystem Room Nos 3406, 3407 (Figure 1.2-5)	Time[1] Temp. °C (°F) Press. Pa (psi) Humidity	0 h - 72 h 50 (122)Max Not controlled Not controlled	10 days – 100 days 26 (79) Max Positive Pressure Not controlled
Electrical chases Room Nos 3250, 3261 (Figures 1.2-2 to 1.2-5)	Time [1] Temp. °C (°F) Press. Pa (psi) Humidity	0 h – 72 h 110 (230) Max Not controlled Not controlled	10 days – 100 days 26 (79) Max Positive Pressure Not controlled
Control Room Habitability Area Main control room panels (Outlined area on Figure 3H-1)	Time[1] Temp. °C (°F)[2] Press. Pa (psi) Humidity	0 – 72 h 33.9 (93) Average Bulk Max allowed 31 (4.5E-3) Positive Not controlled	10 days 23.3 (74) max 31 (4.5E-3) Positive 60% Max
Div 1, 2, 3 and 4 electrical rooms Safety-related DCIS panels Room Nos 3110, 3120, 3130 and 3140 (Figure 1.2-2)	Time[1] Temp. °C (°F) Press. Pa (psi) Humidity	0 h - 72 h 45 (113)Max Not controlled Not controlled	10 days – 100 days 26 (79) Max Positive Pressure Not controlled

(1) Time indicates the time after the occurrence of the accident.

(2) After 72h, the temperature decreases to the temperature value shown for 10 days.

(3) Electronic equipment is type tested for 60°C (140°F) during 72 hours; other equipment could be type tested for higher temperatures according to the above values.

Table 3H-11 Radiation Environment Conditions Inside Containment Vessel for Accident Conditions

Plant Zone/Typical Equipment	Maximum Post-Accident Dose Rate(1)		Integrated Dose(3)	
	Gamma (Rad/h)	Beta (Rad/h)	Gamma (Rad)	Beta (Rad)
Upper drywell (Figure 6.2-1a)	3.45 E+6	2.09 E+7	1.84 E+8	1.59 E+9
Upper area of lower drywell (Figure 6.2-1a)	2.77 E+6	1.27 E+7	2.29 E+8	1.13 E+9
Lower area of lower drywell (Figure 6.2-1a)	1.97 E+6	2.09 E+7	6.57 E+7	1.59 E+9
Wetwell - Suppression pool and gas space (Figure 6.2-1a)	3.47 E+6	2.09 E+7	6.41 E+7	1.59 E+9

(1) *The accident dose rates are based on ESBWR plant accident conditions and calculated in accordance with RG 1.183 and NUREG-1465.*

(2) *(Deleted)*

(3) *Integrated dose is for 100 days.*

Table 3H-12 Room Heat Loads

Rooms[4]	Contain safety-related equipment	Heat Load W (BTU/h)[1]			Remarks
		0 – 2 hr	2 – 24 hr	24 – 72 hr	
1110, 1120, 1130, 1140	Yes	2300 (7848)	2300 (7848)	2300 (7848)	
1101, 1103, 1150, 1151, 1152, 1160, 1161, 1162, 1195	No	1800 (6142) HELB	HELB	HELB	Heat load for LOCA with station blackout (SBO) scenario. Rooms bounded by HELB conditions, see Section 6.2
1100, 1102	Yes[5]	1800 (6142) HELB	HELB	HELB	Heat load for LOCA with station blackout (SBO) scenario. Rooms bounded by HELB conditions see Section 6.2
1106, 1107, 1196, 1197, 1198	No	Negligible	0	0	No heat load and no heat sink (conservative assumption)
1250, 1251, 1252, 1260, 1261, 1262, 1293, 1294, 1295, 1296	No	1800 (6142) HELB	HELB	HELB	Heat load for LOCA with SBO scenario. Rooms bounded by HELB conditions, see Section 6.2
1210, 1220, 1230, 1240	Yes	7200 (24567)	6000 (20473)	6000 (20473)	
1211, 1221, 1231, 1241	Yes	500 (1706)	500 (1706)	500 (1706)	
1203, 1204	No	Negligible	0	0	No heat load and no heat sink (conservative assumption)
1311, 1321, 1331, 1341	Yes	10140 (34599)	8140 (27774)	8140 (27774)	
1304, 1305, 1306, 1307, 1308	No	HELB	HELB	HELB	Rooms bounded by HELB conditions, see Section 6.2
1300, 1301, 1302, 1303	Yes	1700/500 (5800/1706)	1700/500 (5800/1706)	1700/500 (5800/1706)	The higher heat load applies to the rooms in which the RWCU/SDC piping is located.
1312, 1322, 1332, 1342	Yes	500 (1706)	500 (1706)	500 (1706)	
1313, 1323	Yes	500 (1706)	500 (1706)	500 (1706)	
1400, 1401, 1402, 1403	No	5500 (18767)	0	0	
1500, 1501, 1502, 1503	Yes	17500 (59712)	2000 (6824)	2000 (6824)	
1600/1601	No	150 (512)/150 (512)	0	0	Rooms 1600 and 1601 are considered to be the same room in the analysis.
1610, 1620, 1630, 1640	Yes	500 (1706)	500 (1706)	500 (1706)	
1710, 1720, 1730, 1740	Yes	3450/2250 (11772/7677)	3450/2250 (11772/767 7)	3450/2250 (11772/767 7)	The higher heat load applies to the rooms in which the RWCU/SDC piping is located.
1711, 1721, 1731, 1741	Yes	500 (1706)	500 (1706)	500 (1706)	

Table 3H-12 Room Heat Loads

Rooms[4]	Contain safety-related equipment	Heat Load W (BTU/h)[1]			Remarks
		0 – 2 hr	2 – 24 hr	24 – 72 hr	
1712, 1722, 1732, 1742	Yes	1200 (4095)	1200 (4095)	1200 (4095)	
1713, 1723	Yes	200 (682)	200 (682)	200 (682)	
1770	Yes	HELB	HELB	HELB	Room bounded by HELB conditions, see Section 6.2
18P3A/B/C/D, 18P4A/B/C/D/E/F, 18P5A/B/C, 18PA/B/C	Yes	HELB	HELB	HELB	Rooms bounded by HELB conditions, see Section 6.2
3110, 3120, 3130, 3140	Yes	5720 (19517)	4675 (15952)	3080 (10509)	
3100, 3101	No	0	0	0	No heat loads during a 0 - 72 hour period (heat sink)
CRHA (Outlined area on Figure 3H-1)	Yes	9630 (32859)	9630 (32859)	9630 (32859)	240 l/s (509 cfm)of outside air are considered (see Table 9.4-1 for minimum).[2]
(Deleted)					
3200,3203, 3277	No	0	0	0	No heat loads during a 0-72 hour period (heat sink)
3250, 3261	Yes	500 (1706)	500 (1706)	500 (1706)	
3251, 3260	No	0	0	0	No heat loads during a 0-72 hour period (heat sink)
3301, 3302	No	See Note 3	See Note 3	See Note 3	Louver for each room maintains a maximum temperature of 50°C (122°F) during LOOP. See Figures 1.2-4, 1.2-5 and 1.2-11.
3401, 3402, 3403, 3404 & corridors	No	0	0	0	No heat loads during a 0-72 hour period (heat sink)
3406, 3407	Yes	500 (1706)	500 (1706)	500 (1706)	

(1) *Heat Loads provided per room except as noted.*

(2) *A uniform temperature distribution in the CRHA provides an adequate representation of the average bulk temperature. Heat load provided is for the overall CRHA. There is a cooling system sized to remove the nonsafety-related heat loads for two hours (See Subsection 9.4.1). However, this nonsafety-related cooling system is not credited in the analysis, and additional heat load for some nonsafety-related equipment is included for the duration of the 72-hr period.*

(3) *The analysis assumes that the N-DCIS rooms reach a temperature of 60ºC (140ºF) in the first 2 hours and remains constant for the period of interest.*

(4) *See Figures 1.2-1 to 1.2-8 for room locations.*

(5) *The safety related equipment located in these rooms performs its safety related function before a temperature increase, is not needed during a HELB event, qualified for HELB temperatures or protected against HELB environment.*

Table 3H-13 Typical Mild Environment Parameter Limits

Parameter	**Limits**	**Notes**
Temperature	50°C (122°F) 63°C (145°F)	Normal Abnormal
Pressure	Atmospheric	Nominal
Humidity	30 – 65% ≤ 95%	Typical Abnormal
Radiation	≤ 1E4 Rads Gamma ≤ 1E3 Rads Gamma	 Electronics
Chemistry	None	
Submergence	None	

Table 3H-14 Input Parameters, Initial Conditions and Assumptions used in Reactor Building and Control Building Temperature Analyses

Parameter	Analytical Value	Design Value
Initial Ground Temperature °C (°F)(1)	30 (86)	15.5 (60)
HELB Temperatures	See Section 6.2 Analysis	See Section 6.2
LOCA Temperatures	See Section 6.2 Analysis	See Section 6.2
Heat Sink Initial Temperature(2)	Table 3H-15	Table 3H-15
CRHA Day and Night Daily Temperature Range for 0% Exceedance Dry Bulb Temperature Δ °C (°F)(3)	15 (27)	15 (27)
CRHA Day and Night High Humidity Diurnal Swing for 0% Exceedance Wet Bulb Temperature ΔDBt °C (°F) (5)	4.4 (8)	4.4 (8)
EFU Outside Air Supply into CRHA l/s (cfm)	240(509) Maximum	See Table 9.4-1Minimum
Concrete Thermal Conductivity for RB and CB W/m°C (Btu·in/h·ft²·°F)(4)	0.865 (6.00)	1.63 (11.3)
Concrete Specific Heat J/kg·°C (Btu/lb°F)(4)	653.1 (0.156)	879.2 (0.210)
Concrete Density kg/m³ (lb/ft³)(4)	1922.2 (120.00)	2394.8 (149.50)
CRHA Heat Sink Perimeter m (ft)	103 (338)	103 (338)
CRHA Heat Sink Perimeter Wall Thickness in Contact with the Ground m (ft)	0.90 (2.95)	0.90 (2.95)
CRHA Heat Sink Perimeter Wall Thickness in Contact with the Corridor m (ft)	0.50 (1.64)	0.50 (1.64)
CRHA Heat Sink Thickness of Internal Walls and Walls not in contact with the Ground or Corridor m (ft)	0.30 (0.98)	0.30 (0.98)
CRHA Heat Sink Height m (ft)	6.15 (20.2)	6.15 (20.2)
CRHA Heat Sink Ceiling/Floor Area m² (ft²)	443 (4769)	443 (4769)
CRHA Heat Sink Ceiling/Floor Thickness m (ft)	0.50 (1.64)	0.50 (1.64)
CRHA Room Volume m³ (ft³)	2724 (96197)	2724 (96197)

(1) During wintertime conditions the CB calculation uses 15.5°C (60°F) as the ground temperature. This temperature is used to set the initial temperature of the concrete heat sink.

(2) Initially a linear temperature distribution across the walls is used. The CRHA internal walls, floors and ceiling are exposed to an air temperature of 29.4ºC (85ºF) for an eight-hour period. The resulting concrete temperatures are used as the starting point for the CB analysis.

(3) During summertime conditions the maximum CB design temperature is used 47.2°C (117°F), during wintertime conditions the minimum CB design temperature is used – 40°C/°F. The dry bulb Daily Temperature Range used in the analyses is conservative because the actual Daily Temperature Range is larger. The Daily Temperature Range for a day with a high of 47.2°C (117°F) or minimum of -40ºC (-40ºF) is greater than 15ºC (27ºF).

(4) Combinations of thermal concrete properties were used for the RB calculation. The most limiting value is presented in the results.

(5) The High Humidity Diurnal Swing determined for a maximum wet bulb temperature of 31.1ºC (88ºF) is a maximum temperature of 33.3ºC (92ºF) dry bulb/31.1ºC (88ºF) wet bulb and a minimum temperature of 28.9ºC (84ºF) dry bulb/27.2ºC (81ºF) wet bulb, which is a dry bulb temperature swing of 4.4ºC (8ºF).

Table 3H-15 Analytical Room Environment Temperatures

Rooms[5]	Temperature ºC (ºF)			
	Normal Operation (Analytical)[1]	72 hrs	168 hrs	Max Environment Temperature from Table 3H-9
Hydraulic Control Unit (HCU) Rooms HCU, RPS solenoids and RPV water level instrument racks Room Nos 1110, 1120, 1130, 1140 Representative Room: 1130	30 (86)	44 (111)	Safe Shutdown	50 (122)
Battery Rooms Div 1, 2, 3 and 4 batteries Room Nos 1210, 1220, 1230, 1240 Representative Room: 1220	25 (77)	42 (108)	Safe Shutdown	50 (122)
Div 1, 2, 3 and 4 commodity chases Electrical cables Room Nos 1211, 1221, 1231, 1241 Representative Room: 1241	41 (106)	58 (136)	Safe Shutdown	110 (230)
Electrical Division Rooms Div 1, 2, 3 and 4 electrical and electronic equipment Room Nos 1311, 1321, 1331, 1341 Representative Room: 1341	30 (86)	47 (117)	Safe Shutdown	50 (122)
Lower drywell non-divisional electrical and mechanical penetration Outboard containment isolation valves Room Nos 1300, 1301, 1302, 1303 Representative Room: 1302	41 (106)	67 (153)	Safe Shutdown	110 (230)
Div 1, 2, 3 and 4 electrical penetration rooms Electrical cables and penetrations Room Nos 1312, 1322, 1332, 1342 Representative Room: 1312	41 (106)	59 (138)	Safe Shutdown	110 (230)
Remote shutdown panel Room Nos 1313, 1323 (inside rooms 1311 and 1321) Representative Room: 1323	30 (86)	45 (113)	Safe Shutdown	50 (122)
Non-divisional electrical equipment Safety-related DCIS panels Rooms Nos 1500, 1501, 1502, 1503 Representative Room: 1501	30 (86)	46 (115)	Safe Shutdown	50 (122)
Div 1, 2, 3 and 4 electrical penetrations Electrical cables and penetrations Room Nos 1610, 1620, 1630, 1640 Representative Room: 1610	41 (106)	62 (144)	Safe Shutdown	110 (230)

Table 3H-15 Analytical Room Environment Temperatures

Rooms[5]	Temperature ºC (ºF)			
	Normal Operation (Analytical)[1]	72 hrs	168 hrs	Max Environment Temperature from Table 3H-9
Div 1and 4 corridors rooms (access to penetration area), divisional electrical cables and safety-related DCIS RMUs Room Nos 1710, 1740 Representative Room: 1740	30 (86)	48 (118)	Safe Shutdown	50 (122)
Div 2 and 3 corridors rooms (access to penetration area), divisional electrical cables and safety-related DCIS RMUs Room Nos 1720, 1730 Representative Room: 1720	30 (86)	49 (120)	Safe Shutdown	50 (122)
Div 1, 2, 3 and 4 electrical penetrations Electrical cables and penetrations. Room Nos 1711, 1721, 1731, 1741 Representative Room: 1741	41 (106)	54 (129)	Safe Shutdown	110 (230)
Mechanical penetrations Outboard isolation valves Room Nos 1712, 1722, 1732, 1742 Representative Room: 1712	41 (106)	61 (142)	Safe Shutdown	110 (230)
SLC tank rooms SLC tank instrumentation Room Nos 1713, 1723 Representative Room: 1723	30 (86)	39 (102)	Safe Shutdown	50 (122)
Main Steam Tunnel Main Steamline (MSL) isolation valves MSL drain isolation valves FW isolation valves Room No 1770 Accident Conditions	43 (109)	Section 6.2 Analysis	Section 6.2 Analysis	117 (243)
IC/PCCS pools ICS pools instrumentation Room Nos 18P3A/B/C/D, 18P4A/B/C/D/E/F, 18P5A/B/C, 18P6A/B/C Accident Conditions	43 (109)	Section 6.2 Analysis	Section 6.2 Analysis	112 (234)
Control Room Habitability Area Main control room panels Outlined area on Figure 3H-1 Summertime Conditions	23.3 (74)	33 (92)[4]	<33.9 (93)	33.9 (93) Average Bulk Max for 72 hrs
Control Room Habitability Area Main control room panels Outlined area on Figure 3H-1 Wintertime Conditions	22.78 (73)[2]	16 (61)[3]	13 (55)	Unspecified

Table 3H-15 Analytical Room Environment Temperatures

Rooms[5]	Temperature ºC (ºF)			
	Normal Operation (Analytical)[1]	72 hrs	168 hrs	Max Environment Temperature from Table 3H-9
Div 1, 2, 3 and 4 electrical rooms Safety-related DCIS panels Room Nos 3110, 3120, 3130 and 3140	25.6 (78)[2]	37 (99)	Safe Shutdown	45 (113)
Safety-related portions of CRHA Ventilation Subsystem Room Nos 3406, 3407	40 (104)[2]	43 (109)	Safe Shutdown	50 (122)
Electrical Chases Room Nos 3250, 3261	25.6 (78)[2]	35 (95)	Safe Shutdown	110 (230)

(1) *All rooms in the RB and CB are evaluated at higher than expected normal operating temperatures unless otherwise shown in the table to be at normal operating temperatures. The HVAC equipment rooms start at a temperature of 40°C (104°F) as stated in Subsection 9.4.1.*

(2) *During winter conditions the CB room initial temperatures, with the exception of the CRHA, are set to 18.3°C (65°F).*

(3) *The CRHA heat loads considered during this period is 2821 Watts (9626 BTU/h).*

(4) *For high humidity conditions the CRHA has a maximum Wet Bulb Globe Temperature (WBGT) index of 31.2ºC (88.1ºF).*

(5) *See Figures 1.2-1 to 1.2-8 for room locations.*

Figure 3H-1. Control Room Habitability Area

{{{Security-Related Information - Withhold Under 10 CFR 2.390}}}

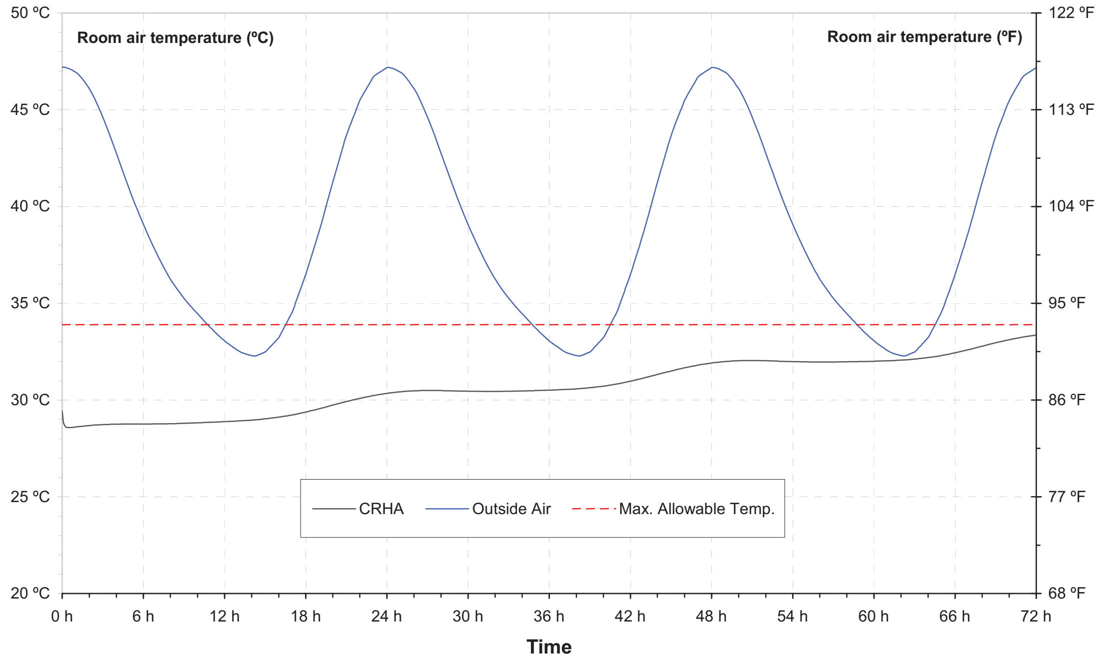


Figure 3H-2. Control Room Habitability Area Transient Analysis Heat up Profile – 0% Exceedance Maximum Temperature Case

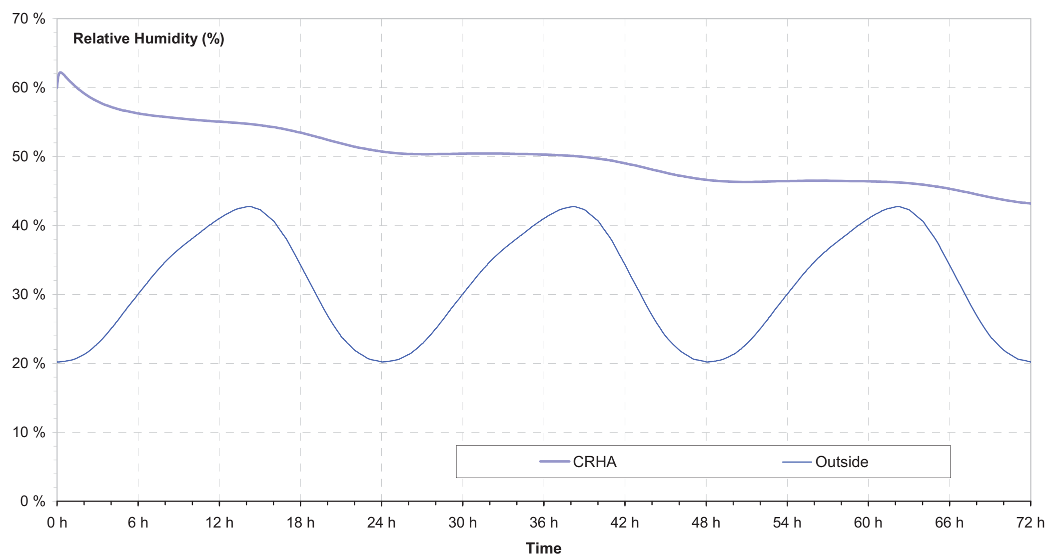


Figure 3H-3. Control Room Habitability Area Transient Analysis Relative Humidity Profile– 0% Exceedance Maximum Temperature Case

Appendix 3I DESIGNATED NEDE-24326-1-P MATERIAL WHICH MAY NOT CHANGE WITHOUT PRIOR NRC APPROVAL

This appendix identifies the NEDE-24326-1-P (Reference 3I-1) “General Electric Environmental Qualification Program” material that is designated as Tier 2* material. (See Section 3.10.)

3I.1 GENERAL REQUIREMENTS FOR DYNAMIC TESTING

(Paragraph 4.4.2.5.1 of Ref. 3I-1)

(a) *Mounting – Specimens to be tested will be mounted in a manner that adequately simulates the installed configuration or as described in the applicable GE mounting documentation.* Mounting will be specified in the Product Performance Qualification Specification (PPQS).

(b) Monitoring – Sufficient monitoring equipment will be used to evaluate the performance of the specimen before, during, and after the test. Monitoring product is used to allow determination of applied vibration levels and equipment responses. The location of monitoring sensors shall be specified by the PPQS and *will be documented in the test report.*

When required by the PPQS, *the response of the product will be measured using accelerometers. When required* by the PPQS, *the accelerometers shall be located at a sufficient number of locations on the product to define the mode shapes and/or frequencies which would be required to allow dynamic qualification of individual safety-related components and devices, to support analytical extrapolation of test results, or to verify frequency requirements.*

*(c) **Exploratory Tests** – Exploratory vibration tests may be performed on the product to aid in the determination of the test method that will best qualify or determine the dynamic characteristics of the product. If it can be shown that the equipment is not resonant at any frequency within the expected frequency range, it may be considered a rigid body and tested according to methods and procedures discussed in Subsection 4.4.2.5.6 of Reference 3I-1 or analyzed according to the methods of Subsection 4.4.4.1.4.5 of Reference 3I-1.*

If the product contains a single resonance or multiple resonances, one of the methods outlined in Subsection 4.4.2.5.3 of Reference 3I-1 will be used to qualify the product by test.

The exploratory test may be performed in the form of a low-level, continuous sinusoidal sweep at a rate no greater than 2 octave per minute over the frequency range equal to or greater than that to which the equipment is to be qualified. All resonances will be recorded for use in determining the test method to be used or the dynamic characteristics of the equipment. If the configuration of the product is such that critical natural frequencies cannot be ascertained, dynamic qualification will be accomplished by testing by the Response Spectrum method as specified in Paragraph 4.4.2.5.3.b of Reference 3I-1. An acceptable alternative qualification method is a fragility test as described in Subsection 4.4.2.5.7 of Reference 3I-1.

(d) ***Dynamic Event Aging Tests*** *– The dynamic tests simulate the effect of low level earthquake loads combined with Service Level B Reactor Building Vibration (RBV) dynamic loads. The dynamic tests are performed on aged products unless otherwise justified. (See Section 3.10)*

The test sequence to be used will be:

(1) Vibration aging (if required);

(2) Low level earthquake loads combined with Service level B RBV dynamic loads; and

(3) SSE loads combined with Service level D RBV dynamic loads

Because most testing is biaxial rather than triaxial, the above sequence and durations are applied twice with the equipment being rotated 90 degrees on the table between the two tests. (See Section 3.10)

The Test Response Spectra (TRS) will envelop the Required Response Spectra (RRS) as specified in 4.2.2.a(6) of Reference 3I-1. (See Section 3.10)

(e) *Loading – Dynamic tests will be performed with the product subjected to nominal operating service conditions. If significant, normal operating loads such as electrical, mechanical, pressure, and thermal will be included. Where normal operating loads cannot be included in the dynamic tests, supplemental analysis will be used to qualify the product for those effects.* (See Section 3.10)

3I.2 PRODUCT AND ASSEMBLY TESTING

(Paragraph 4.4.2.5.2 of Ref. 3I-1)

(a) *Products will be tested simulating nominal operating conditions. In addition, dynamic coupling between interacting equipment will be considered.* See Section 3.10. The product shall be mounted on the shaker table as stated in Paragraph 4.4.2.5.1(a) of Reference 3I-1. If the product is intended to be mounted on a panel, the panel will be included in the test mounting.

Alternatively, the response at the product mounting location may be measured in the assembly test as specified in Paragraph 4.4.2.5.2(b) of Reference 3I-1. Then the product will be mounted directly to the shaker table, with the dynamic input being that which was determined at the product mounting location.

3I.3 MULTIPLE-FREQUENCY TESTS

(Paragraph 4.4.2.5.3 of Ref. 3I-1)

(a) ***General*** *– When the dynamic ground motion has not been strongly filtered, the mounting location retains the broadband characteristics. In this case, multi-frequency testing is applicable to dynamic qualification.* (See Section 3.10)

(b) **Response Spectrum Test** – Testing shall be performed by applying artificially generated input excitation to the product, the amplitude of which is controlled in 1/3 octave or narrower bands. *The excitation will be controlled to provide a test response spectrum (TRS) which meets or exceeds the RRS. The peak value of the input excitation equals or exceeds the zero period acceleration (ZPA) of the RRS.* (See Section 3.10)

3I.4 SINGLE- AND MULTI-AXIS TESTS

(Paragraph 4.4.2.5.4 of Ref. 3I-1)

Single-axis tests may be allowed if the tests are designed to conservatively reflect the dynamic event at the equipment mounting locations or if the product being tested can be shown to respond independently in each of the three orthogonal axis or otherwise withstand the dynamic event at its mounting location.

If the preceding considerations do not apply, multi-axis testing will be used. The minimum is biaxial testing with simultaneous inputs in a principal horizontal axis and the vertical axis. Independent random inputs are preferred, and, if used, the test will be performed in two steps with the equipment rotated 90° in the horizontal plane for the second step. If independent random inputs are not used (such as with single frequency tests), four tests would be run; first, with the inputs in phase; second, with one input 180° out of phase; third, with the equipment rotated 90° horizontally and the inputs in phase; and, finally, with the same equipment orientation as in the third step but with one input 180° out of phase. (See Section 3.10)

3I.5 SINGLE FREQUENCY TESTS

(Paragraph 4.4.2.5.6 of Ref. 3I-1)

If it can be shown that the products, as defined in Regulatory Guide 1.92 have no resonances, or only one resonance, or if resonances are widely spaced and do not interact to reduce the fragility level in the frequency range of interest or, if otherwise justified, single frequency tests may be used to fully test the product. (See Section 3.10)

3I.6 DAMPING

(Paragraph 4.4.2.5.8 of Ref. 3I-1)

*The product damping value used for dynamic qualification shall be established. See (*Reference 3I-1*) Section 5 of IEEE-344.* (Also see Subsections 3.9.2.2, 3.9.3, and 3.10)

3I.7 QUALIFICATION DETERMINATION

(Paragraph 4.4.3.3 of Ref. 3I-1)

In order for equipment to be qualified by reason of operating experience, documented data will be available confirming that the following criteria have been met:

(a) the product providing the operating experience is identical or justifiably similar to the equipment to be qualified;

(b) the product providing the operating experience has operated under service conditions which equal or exceed, in severity, the service conditions and performance requirements for which the product is to be qualified; and

(c) *the installed product must, in general, be removed from service and subjected to partial type testing to include the dynamic and design basis event environments for which the product is to be qualified.* (See Section 3.10)

3I.8 DYNAMIC QUALIFICATION BY ANALYSIS

(Paragraph 4.4.4.1.4 of Ref. 3I-1)

(a) The analytical procedures described in this section may be used for dynamic qualification of products.

(b) Many factors control the design of a qualification program. Paragraphs 4.2.2.c(3) and 4.2.2.d(1) of Reference 3I-1 provide general guidelines on dynamic analysis techniques. Analytical techniques and modeling assumptions will, when possible, be based on a correlation of the analytical approach with testing or operating experience performed on similar equipment or structures. *Analysis may be used as a qualification method for the following conditions:*

    (1) *if maintaining structural integrity is the only required assurance of the safety-related function* (see Section 3.10);

    (2) if the response of the equipment is linear or has a simple nonlinear behavior which can be predicted by conservative analytical methods; or

    (3) if the product is too large to test.

3I.9 REQUIRED RESPONSE SPECTRA

(Paragraph 4.4.4.1.4.6.2 of Ref. 3I-1)

(a) *The required response spectra that define the dynamic criteria for the location(s) of the product under consideration are to be given in the PPQS. If the equipment under consideration is attached to the structural system at more than one location, then the dynamic analysis performed takes into consideration the different response spectra at the different support locations. The effect of multiple support attachment points or multiple locations of the particular product can also be accounted for by selecting a single spectrum which will effectively produce the critical maximum responses due to different accelerations existing at different points.* (See Section 3.10.) This may be conservatively accomplished by enveloping the response spectra for the different applicable locations. Alternatively, actual multi-support excitation effects may be taken into account by performing a multi-support excitation analysis.

3I.10 TIME HISTORY ANALYSIS

(Paragraph 4.4.4.1.4.6.3 of Ref. 3I-1)

Time history analysis will be performed when conditions arise invalidating the response spectrum method of analysis due to nonlinear phenomena, or when generation of in-equipment response spectra or a more exact result is desired. To integrate or differentiate, the analysis will be done by an applicable numerical integration technique. The largest time step used in the analysis will be 1/10 of the period of the highest significant mode of vibration of the equipment. *The dynamic input will be the time history motion at the equipment support location.* (See Section 3.10.) For products supported at several locations, the responses will be determined by simultaneous excitations using appropriate time history input at each support location. The scaled time interval will be varied as per Paragraph 4.2.2.a(6) of Reference 3I-1.

If the product frequency is within the range of the supporting structure, then a time interval will be chosen such that the peak of the response spectrum shall be at the product resonance frequency. The total time interval range will be provided with the time history.

3I.11 REFERENCES

3I-1 General Electric Company, “General Electric Environmental Qualification Program,” NEDE-24326-1-P, Proprietary Document, January 1983.

Appendix 3J EVALUATION OF POSTULATED RUPTURES IN HIGH ENERGY PIPES

3J.1 BACKGROUND AND SCOPE

The need for an evaluation of the dynamic effects of fluid dynamic forces resulting from postulated ruptures in high energy piping systems is established by Standard Review Plan (SRP) Sections 3.6.1 and 3.6.2. The criteria for performing this evaluation are defined in Subsections 3.6.1and 3.6.2, SRP Sections 3.6.1 and 3.6.2 and ANS 58.2.

This Appendix defines an acceptable procedure for performing these evaluations.

The evaluation is performed in four major steps:

1. *Identify the location of the postulated rupture and whether the rupture is postulated as circumferential or longitudinal.*
2. Select the type and location of the pipe whip restraints.
3. Perform a complete system dynamic analysis or a simplified dynamic analysis, as appropriate, of the ruptured pipe and its pipe whip restraints to determine the total movement of the ruptured pipe, the loads on the pipe, strains in the pipe whip restraint, and, if applicable, the stresses in the piping in the penetration area.
4. Evaluate safety-related equipment that may be impacted by the ruptured pipe or the target of the pipe rupture jet impingement.

The criteria for locations where pipe ruptures must be postulated and the criteria for defining the configuration of the pipe rupture are defined in Subsection 3.6.2. Also defined in Subsection 3.6.2 are:

- the fluid forces acting at the rupture location and in the various segments of the ruptured pipe
- the jet impingement effects including jet shape and direction and jet impingement load

The high energy fluid systems are defined within Subsection 3.6.2.1, and identified in Tables 3.6-3 and 3.6-4. Safety-related systems, components and equipment, or portions thereof, specified in Tables 3.6-1 and 3.6-2, are protected from pipe break effects that would impair their ability to facilitate safe shutdown of the plant.

The information contained in Subsections 3.6.1 and 3.6.2 and in the SRPs and ANS 58.2 is not repeated in this appendix.

3J.2 IDENTIFICATION OF RUPTURE LOCATIONS AND RUPTURE GEOMETRY

3J.2.1 Ruptures in Containment Penetration Area

Postulation of pipe ruptures in the portion of piping in the containment penetration area is not allowed. This includes the piping between the inner and outer isolation valves. Therefore, the final stress analysis of the piping system is examined to confirm that, for piping in the containment

penetration areas, the design stress and fatigue limits specified in Subsection 3.6.2.1 are not exceeded.

3J.2.2 Ruptures in Areas other than Containment Penetration.

Breaks in Class 1 piping are postulated in accordance with Subsection 3.6.2.1.1.

Breaks in Class 2 and 3 piping are postulated in accordance with Subsection 3.6.2.1.1.

Breaks in seismically analyzed non-ASME Class piping are postulated in accordance with the above requirements for Class 2 and 3 piping.

3J.2.3 Determination of the Type of Pipe Break

Determination of whether the high energy line break is longitudinal or circumferential is in accordance with Subsection 3.6.2.1.3.

3J.3 DESIGN AND SELECTION OF PIPE WHIP RESTRAINTS

3J.3.1 Preliminary Selection of Pipe Whip Restraint

The load carrying capability of the General Electric (GE) U-Bar pipe whip restraint is determined by the number, size, bend radius and the straight length of the U-bars. The pipe whip restraint must resist the thrust force at the pipe rupture location and the impact force of the pipe. The magnitude of these forces is a function of the pipe size, fluid temperature, and operating pressure.

A preliminary selection of one of the standard GE pipe whip restraints is made by matching the thrust force at the rupture location with a pipe whip restraint capable of resisting this thrust force. The GE REDEP computer file contains a set of tables for selecting the design of pipe whip restraint components. This file correlates the pipe size and the resulting thrust force at the pipe rupture with the U-bar pipe whip restraints designed to carry the thrust force. REDEP then supplies the force/deflection data for each pipe whip restraint. The REDEP file data is maintained in accordance with GEH quality requirements.

3J.3.2 Preparation of Simplified Computer Model of Piping-Pipe Whip Restraint System

A simplified computer model of the piping system is prepared as described in Subsection 3J.4.2.1 and as shown in Figure 3J-1 and Figure 3J-2. Critical variables are the length of pipe, type of end condition, distance of pipe from structure and location of the pipe whip restraint. The pipe whip restraint is located as near as practical to the ruptured end of the pipe, but so as to minimize interference to in-service inspection.

3J.3.3 Piping Dynamic Analysis

The Pipe Dynamic Analysis (PDA) computer program is run using the following input:

- The information from the simplified piping model, including pipe length, diameter, wall thickness and pipe whip restraint location.

- Piping information such as pipe material type, stress/strain curve and pipe material mechanical properties.
- Pipe whip restraint properties such as force-deflection data and elastic plastic displacements.
- Force time-history of the thrust at the pipe rupture location.

3J.3.4 Selection of Pipe Whip Restraint for Pipe Whip Restraint Analysis

PDA provides displacements of pipe and pipe whip restraint, pipe whip U-bar strains, pipe forces and moments at fixed end, time at peak load and lapsed time to achieve steady state using thrust load and pipe characteristics.

The displacements at the pipe broken end and at the pipe whip restraint are checked and the loads on the piping and the strains of pipe whip restraint U-bars are compared to allowable loads and strains. If the output results are not satisfactory, PDA is rerun with different pipe whip restraint parameters.

3J.4 PIPE RUPTURE EVALUATION

3J.4.1 General Approach

There are several analytical approaches that may be used in analyzing the pipe/pipe whip restraint system for the effects of pipe rupture. This procedure defines two acceptable approaches.

1. **Dynamic Time-History Analysis With Simplified Model -** A dynamic time history analysis of a portion of a piping system may be performed in lieu of a complete system analysis when it can be shown to be conservative by test data or by comparison with a more complete system analysis. For example, in those cases where pipe stresses in the containment penetration region need not be calculated, it is acceptable to model only a portion of the piping system as a simple cantilever with a fixed or pinned end or as a beam with both ends fixed or with one end pinned and one end fixed.

   When a circumferential break is postulated, the pipe system is modeled as a simple cantilever, the thrust load is applied opposite the fixed (or pinned) end and the pipe whip restraint acts between the fixed (or pinned) end and the thrust load. It is then assumed that deflection of the pipe is in one plane. As the pipe moves a resisting bending moment in the pipe is created and later a restraining force at the pipe whip restraint. Pipe movement stops when the resisting moments about the fixed (or pinned) end exceed the applied thrust moment.

   When a longitudinal break is postulated, the pipe system has both ends supported. To analyze this case, two simplifications are made to allow the use of the cantilever model described above. First, an equivalent point mass is assumed to exist at D (Figure 3J-2) instead of pipe length DE. The inertia characteristics of this mass, as it rotates about point B, are calculated to be identical to those of pipe length DE, as it rotates about point E. Second, an equivalent resisting force is calculated (from the bending moment-angular

deflection relationships for end DE) for any deflection for the case of a built-in end. This equivalent force is subtracted from the applied thrust force when calculating the net energy.

See Figure 3J-1 and Figure 3J-2 for the models described above.

2. **Dynamic Time-History Analysis with Detailed Piping Model**—In many cases it is necessary to calculate stresses in the ruptured pipe at locations remote from the pipe whip restraint location. For example, the pipe in the containment penetration area must meet the limits of SRP 3.6.2. In these cases it is required that the ruptured piping, the pipe supports, and the pipe whip restraints be modeled in sufficient detail to reflect their dynamic characteristics. A time-history analysis using the fluid forcing functions at the point of rupture and the fluid forcing functions of each pipe segment is performed to determine deflections, strains, loads to structure and equipment and pipe stresses.

3J.4.2 Procedure For Dynamic Time-History Analysis With Simplified Model

3J.4.2.1 Modeling of Piping System

For many piping systems, required information on the response to a postulated pipe rupture can be determined by modeling a portion of the piping system as a cantilever with either a fixed or pinned end. The fixed end model, as shown in Figure 3J-1, is used for piping systems where the stiffness of the piping segment located between A and B is such that the slope of the pipe length, BD, at B, would be approximately zero. The pinned end model, as shown in Figure 3J-1, is used for piping systems where the slope of the pipe length, BD, at B, is much greater than zero. The pinned end model is also used whenever it is not clear that the pipe end is fixed.

A simplified cantilever model may also be used for a postulated longitudinal break in a pipe supported at both ends, as shown in Figure 3J-2. The pipe can have both ends fixed or have pinned end at B and a fixed end at E, as shown in Figure 3J-2. Subsection 3J.4.1(1) discusses the simplification techniques used to allow the use of a cantilever model. A fixed end is used when rotational stiffness of the piping at that location is such that the slope of the pipe at that end is approximately zero. A pinned end is used when the pipe slope at that end is much greater than zero. If it is not clear whether an end is fixed or pinned, the end condition giving more conservative results should be assumed.

The pipe whip restraint is modeled as two components acting in series; the restraint itself and the structure to which the restraint is attached. The restraint and piping behave as determined by an experimentally or analytically determined force-deflection relationship. The structure deflects as a simple linear spring of representative spring constant.

The model must account for the maximum clearance between the restraint and the piping. The clearance is equal to the maximum distance from the pipe during normal operation to the position of the pipe when the pipe whip restraint starts picking up the rupture load. This simplified model is not used if the piping has snubbers or restraints strong enough to affect the pipe movement following a postulated rupture.

3J.4.2.2 Dynamic Analysis of Simplified Piping Model

When the thrust force (as defined in Subsection 3.6.2.2) is applied at the end of the pipe, rotational acceleration would occur about the fixed (or pinned) end. As the pipe moves, the net rotational acceleration would be reduced by the resisting bending moment at the fixed end and by the application of the restraining force at the pipe whip restraint. The kinetic energy would be absorbed by the deflection of the restraint and the bending of the pipe. Movement would continue until equilibrium is reached. The primary acceptance criteria is the pipe whip restraint deflection or strain must not exceed the design strain limit of 50% of the restraint material ultimate uniform strain capacity.

The analysis may be performed by a general purpose computer program with capability for nonlinear time-history analysis such as ANSYS, or by a special purpose computer program especially written for pipe rupture analysis such as the GE computer program, “Pipe Dynamic Analysis”.

3J.4.3 Procedure For Dynamic Time-History Analysis Using Detailed Piping Model

3J.4.3.1 Modeling of Piping System

In general, the rules for modeling the ruptured piping system are the same as the modeling rules followed when performing seismic/dynamic analysis of Seismic Category I piping. These rules are outlined in Subsection 3.7.3.3. The piping, pipe supports and pipe whip restraints are modeled in sufficient detail to reflect their dynamic characteristics. Inertia and stiffness effects of the system and gaps between piping and the restraints must be included.

If the snubbers or other seismic restraints are included in the piping model they should be modeled with the same stiffness used in the seismic analysis of the pipe. However, credit for seismic restraints cannot be taken if the applied load exceeds the Level D rating.

The pipe whip restraints are modeled the same as for the simplified model described in Subsection 3J.4.2.1. For piping designed with the GE U-Bar pipe whip restraints, the selected size and dimensions, and the resulting force-deflection and elastic/plastic stiffness are first determined according to the procedure previously defined in Section 3J.3.

3J.4.3.2 Dynamic Analysis using Detail Piping Model

The pipe break nonlinear time-history analysis can be performed by ANSYS or other NRC approved non-linear computer programs. The force time histories acting at the break location and in each of the segments of the ruptured pipe are determined according to the criteria defined in ANS 58.2. The time step used in the analysis must be sufficiently short to obtain convergence of the solution. GE has shown that for a rupture of the main steam pipe a time step of 0.001 second is adequate for convergence. The analysis must not stop until the peaks of the dynamic load and the pipe response are over.

The primary acceptance criteria are:

- The piping stresses between the primary containment isolation valves are within the allowable limits specified in Subsection 3.6.2.1.
- The pipe whip restraint loads and displacements due to the postulated break are within the design limits.
- Specified allowable loads on safety-related valves or equipment to which the ruptured piping is attached are not exceeded.

3J.5 JET IMPINGEMENT ON SAFETY-RELATED PIPING

Postulated pipe ruptures result in a jet of fluid emanating from the rupture point. Safety-related systems and components require protection if they are not designed to withstand the results of the impingement of this jet. Subsection 3.6.2.3.1 provides the criteria and procedure for:

(1) defining the jet shape and direction
2. defining the jet impingement load, temperature and impingement location
3. analysis to determine effects of jet impingement on safety-related equipment

The paragraphs below provide some additional criteria and procedure for the analysis required to determine the effects of jet impingement on piping.

- Jet impingement is a faulted load and the primary stresses it produces in the piping must be combined with the stresses caused by safe shutdown earthquake (SSE) to meet the faulted stress limits for the designated ASME class of piping.
- If a pipe is subjected to more than one jet impingement load, each jet impingement load is applied independently to the piping system and the load which supplies the largest bending moment at each node is used for evaluation.
- A jet impingement load may be characterized as a two part load applied to the piping system—a dynamic portion when the applied force varies with time and a static portion which is considered steady state.

For the dynamic load portion, when static analysis methods are used, a dynamic load factor of two is applied. Snubbers are assumed to be activated. Stresses produced by the dynamic load portion are combined by SRSS with primary stresses produced by SSE.

For the static load portion, snubbers are not activated and stresses are combined with SSE stresses by absolute sum.

Figure 3J-1 Simplified Piping Models

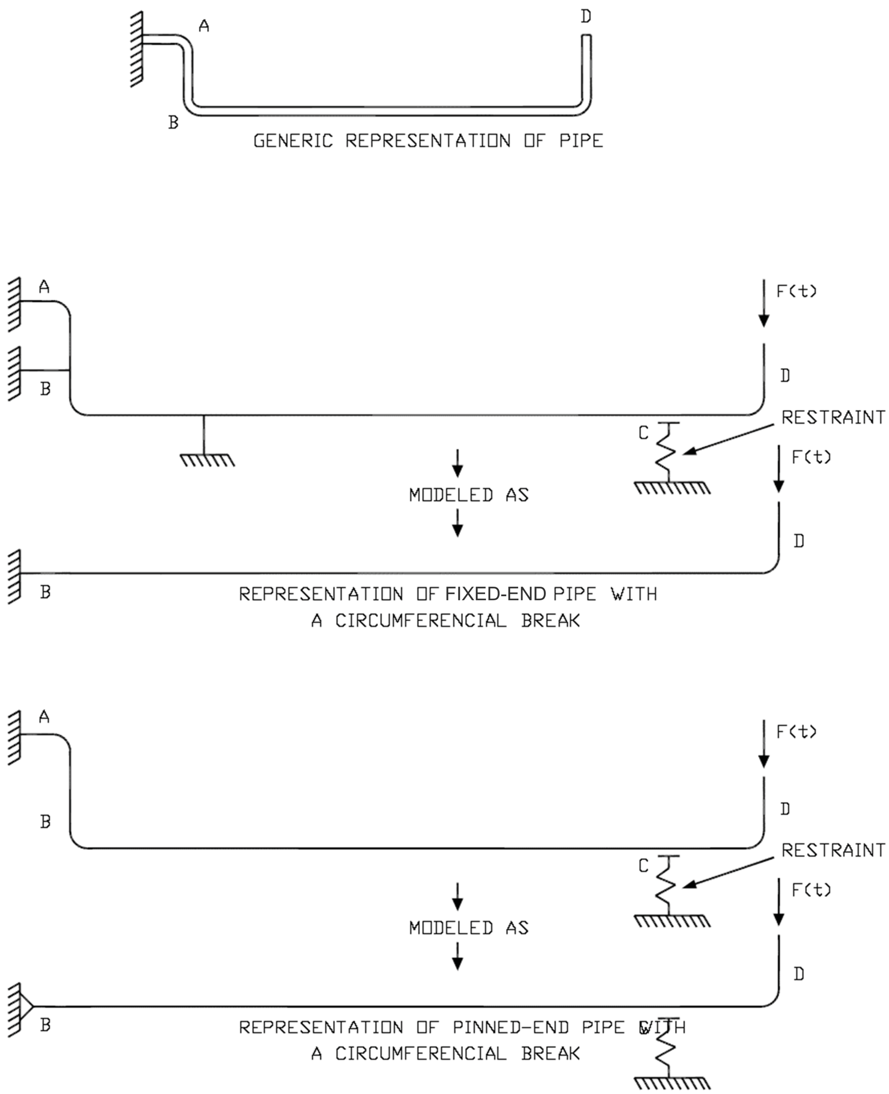
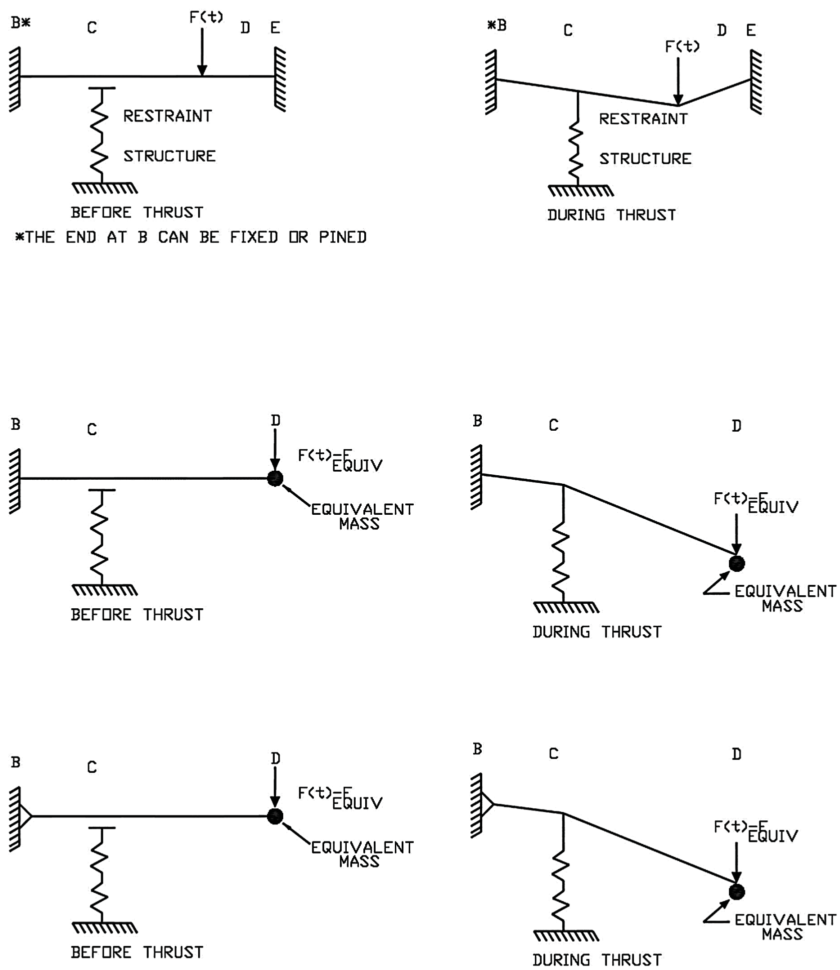


Figure 3J-2 Representation of Pipe With Both Ends Supported With a Longitudinal Break



Appendix 3K RESOLUTION OF INTERSYSTEM LOSS-OF-COOLANT-ACCIDENT

3K.1 INTRODUCTION

An Intersystem Loss-of-Coolant-Accident (ISLOCA) is postulated to occur when a series of failures or inadvertent actions occur that allow the high pressure from one system to be applied to the low design pressure of another system, which could potentially rupture the pipe and release coolant from the reactor system pressure boundary. This may also occur within the high and low pressure portions of a single system. Future advanced light water reactor (ALWR) designs like the ESBWR are expected to reduce the possibility of a loss-of-coolant-accident (LOCA) outside the containment by designing to the extent practicable all piping systems, major system components (pumps and valves), and subsystems connected to the reactor coolant pressure boundary (RCPB) to an ultimate rupture strength (URS) at least equal to the full RCPB pressure. The general URS criteria was recommended by Reference 3K-1 and the NRC Staff recommended specific URS design characteristics by Reference 3K-2.

3K.2 REGULATORY POSITIONS

In SECY-90-016 and SECY-93-087 (References 3K-3 and 3K-4), the NRC staff resolved the ISLOCA issue for ALWR plants by requiring that low-pressure piping systems that interface with the RCPB be designed to withstand reactor pressure to the extent practicable. However, the staff believes that for those systems that have not been designed to withstand full reactor pressure, evolutionary ALWRs should provide (1) the capability for leak testing the pressure isolation valves, (2) valve position indication that is available in the control room when isolation valve operators are de-energized and (3) high-pressure alarms to warn main control room operators when rising reactor pressure approaches the design pressure of attached low-pressure systems or when both isolation valves are not closed. The staff noted that for some low-pressure systems attached to the RCPB, it may not be practical or necessary to provide a higher system ultimate pressure capability for the entire low-pressure connected system. The staff will evaluate such exceptions on a case-by-case basis during specific design certification reviews.

GE provided a proposed implementation of the issue resolution for the Advanced Boiling Water Reactor (ABWR) in Reference 3K-5 and again in Reference 3K-6. The staff in the Civil Engineering and Geosciences Branch of the Division of Engineering completed its evaluation of the Reference 3K-5 proposal. Specifically, as reported by Reference 3K-2 and summarized below, the staff has evaluated the minimum pressure for which low-pressure systems should be designed to ensure reasonable protection against burst failure should the low-pressure system be subjected to full RCPB pressure.

The design pressure for the low-pressure piping systems that interface with the RCPB should be equal to 0.4 times the normal operating RCPB pressure, the minimum wall thickness of low-pressure piping should be no less than that of a standard weight pipe, and that Class 300 valves are adequate. The design is to be in accordance with the ASME Boiler and Pressure Vessel

Code, Section III, Subarticle NC/ND-3600. Furthermore, the staff will continue to require periodic surveillance and leak rate testing of the pressure isolation valves via Technical Specifications, as a part of the in-service inspection program.

3K.3 BOUNDARY LIMITS OF ULTIMATE RUPTURE STRENGTH

Guidance given by Reference 3K-3 provides provision for applying practical considerations for the extent to which systems are designed to the URS design pressure. The following items form the basis of what constitutes practicality and set forth the test of practicality used to establish the boundary limits of URS for the ESBWR:

- It is impractical to consider a disruptive open flow path from reactor pressure to a low pressure sink. A key assumption to understanding the establishment of the boundary limits from this practicality basis is that only static pressure conditions are considered. Static conditions are assumed when the valve adjacent to a low pressure sink remains closed. Thus, the dynamic pressurization effects accompanied by violent high flow transients and temperature escalations which would occur if the full RCPB pressure was connected directly to the low pressure sink, are precluded. As a consequence, the furthest downstream valve in such a path is assumed closed, so that essentially all of the static reactor coolant system pressure is contained by the piping in the URS-designed region.
- It is impractical to design or construct large tank structures to the URS design pressure that are vented to atmosphere and have a low design pressure.
- It is impractical to design piping systems that are connected to low pressure sink features to the URS design pressure when the piping is always locked open to a low pressure sink by locked open valves. These piping sections are extensions of the low pressure sink and need no greater design pressure than the low pressure sink to which they are connected.

3K.4 EVALUATION PROCEDURE

The pressures of each system piping boundary in the ESBWR design are reviewed to ensure URS protection is provided. Where low pressure piping interfaces with higher pressure piping at reactor pressure, design pressures are at least equal to the URS design pressure. The low pressure piping boundaries are designed to URS pressures and extend to the last closed valve connected to piping interfacing a low pressure sink.

3K.5 SYSTEMS EVALUATED

The following systems, interfacing directly with the RCPB, are evaluated.

- Control Rod Drive system Section 4.6
- Standby Liquid Control (SLC) system Section 9.3
- Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) system Section 5.4
- Fuel and Auxiliary Pools Cooling System (FAPCS) Section 9.1

- Nuclear Boiler System (NBS) Section 5.1
- Condensate and Feedwater System (C&FS) Section 10.4

Attachment 3KA contains a system-by-system evaluation of potential reactor pressure application to piping and components, discusses the URS boundary and lists the URS-designed components. For some systems, certain regions of piping and components not designed to URS design pressure are also listed.

3K.6 PIPING DESIGN PRESSURE FOR ULTIMATE RUPTURE STRENGTH COMPLIANCE

Guidelines for URS compliance were established by Reference 3K-2, which concluded that for the ESBWR:

- The design pressure for the low-pressure piping systems that interface with the RCPB pressure boundary should be equal to 0.4 times the normal operating RCPB pressure.
- The minimum wall thickness of the low-pressure piping should be no less than that of a standard weight pipe.

3K.7 APPLICABILITY OF ULTIMATE RUPTURE STRENGTH FOR NON-PIPING COMPONENTS

Reference 3K-2 also provides the NRC Staff's position that:

1. *The remaining components in the low-pressure systems should also be designed to a design pressure of 0.4 times the normal operating reactor pressure. The components include flanges, pump seals, etc.*
2. A Class 300 valve is adequate for ensuring the pressure of the low-pressure piping system under full reactor pressure. The rated working pressure for Class 300 valves varies widely depending on material and temperature (ASME/ANSI B16.34).

3K.8 RESULTS

The results of this work are incorporated into the ESBWR system design.

3K.9 VALVE MISALIGNMENT DUE TO OPERATOR ERROR

The ESBWR design with the ISLOCA ultimate rupture strength applied for the boundary described by this appendix and its attachment extends the increased design pressure (ultimate rupture strength) over the full extent of regions that could potentially experience reactor pressure, so that operator misaligned valves will not expose piping not designed to the URS pressure to reactor pressure.

3K.10 SUMMARY

Based on the NRC staff's new guidance cited in References 3K-1 through 3K-4, the ESBWR is in full compliance. For ISLOCA considerations, design pressures of at least the URS design pressure and pipe having a minimum wall thickness equal to standard grade provide adequate margin with

respect to the full reactor operating pressure, by applying the guidance recommended by Reference 3K-2. This design pressure is applied to low pressure piping at the applicable boundaries, therefore imposing the requirement on the associated piping, valves, pumps, tanks, instrumentation and other equipment within the boundaries. Piping has a minimum wall thickness equal to standard grade and valves with a design pressure of at least the URS design pressure are required to be a minimum of Class 300.

3K.11 REFERENCES

3K-1 Dino Scaletti, NRC, to Patrick Marriott, GE, "Identification of New Issues for the General Electric Company Advanced Boiling Water Reactor Review," September 6, 1991.

3K-2 Chester Poslusny, NRC, to Patrick Marriott, GE, "Preliminary Evaluation of the Resolution of the Intersystem Loss-of-Coolant Accident (ISLOCA) Issue for the Advanced Boiling Water Reactor (ABWR) - Design Pressure for Low-Pressure Systems," December 2, 1992, Docket No. 52-001.

3K-3 James M. Taylor, NRC, to The Commissioners, SECY-90-016, "Evolutionary Light Water Reactor (LWR) Certification Issues and Their Relationship to Current Regulatory Requirements," January 12, 1990.

3K-4 James M. Taylor, NRC, to The Commissioners, SECY-93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," April 2, I993.

3K-5 Jack Fox, GE, to Chet Poslusny, NRC, "Proposed Resolution of ISLOCA Issue for ABWR," October 8, 1992.

3K-6 Jack Fox, GE, to Chet Poslusny, NRC, "Resolution of Intersystem Loss of Coolant Accident for ABWR," April 30, 1993.

Attachment 3KA ULTIMATE RUPTURE STRENGTH SYSTEM BOUNDARY EVALUATION

3KA.1 CONTROL ROD DRIVE SYSTEM

3KA.1.1 System URS Boundary Description

The Control Rod Drive (CRD) system interfaces with the reactor in a manner that makes low pressure piping over pressurization very unlikely. The minimum failure path from the reactor to the low pressure piping has three check valves in series. This path is from the purge flow channels of the CRD, out through the first check valve in the CRD housing, through the purge supply line that has the second check valve, and to the pump discharge check valve. An alternate path through the accumulator charging line has additionally the normally closed scram valve, and this path is less likely for failure and therefore not considered. The path from the pump discharge, back through the pump to its suction, and back through the suction lines to the condensate storage tank (CST) or the condensate feedwater source is an open path. The pump suction is through the pump suction filters in the normal mode of operation and through the suction filter bypass lines during the reactor high pressure makeup mode of operation. The CRD pumps run continuously while the reactor is at operating pressure, which prevents reactor pressure from reaching the low pressure piping except for the unlikely case when both CRD pumps have failed. Therefore, an ISLOCA condition could only occur when three check valves in series fail open at the same time both CRD pumps have failed. The ISLOCA guidelines do not provide credit for this rare condition, so the low pressure piping is designed to the URS design pressure over the entire low pressure piping region of the CRD system. The suction path through the Condensate Storage and Transfer System (CS&TS) to the CST from the CRD interface is an open path and is not designed to URS design pressure. The primary suction path to the C&FS has a check valve in the path, and the design pressure up to and including the check valve is the URS design pressure.

The normal key assumption, as stated in the Boundary Limits in Section 3K.3 above, that the valve adjacent to a low pressure sink remains closed, means that the pump discharge check valve remains closed as a given. However, this valve is in the high-pressure piping, which is unique for the CRD system according to this accepted line of reasoning. The low-pressure piping is not required to be designed to URS design pressure because it would not experience the high reactor pressure. However, the low-pressure piping is designed to the URS design pressure based on the guidance that states “for all interfacing systems and components which do not meet the full URS criteria, justification is required, which must include engineering feasibility; not solely a risk benefit analysis.” Designing the low-pressure piping to the URS design pressure is feasible and is done.

3KA.1.2 Downstream Interfaces

Other systems are listed below that interface with the CRD system and could possibly be exposed to reactor pressure. A description of the interface location and a statement of its applicability to ISLOCA are given.

- RWCU/SDC system at the output of the CRD pump discharge filter units. The RWCU/SDC design pressure exceeds the URS design pressure.
- NBS at the output of the CRD pump discharge filter units. The NBS design pressure exceeds the URS design pressure.
- CS&TS provides an alternate source of water for the CRD system if the C&FS is not available. Its interfaces with the CRD system are located at pump suction from and system return to the CST. This line cannot be pressurized because of the open communication to the CST, and the CST is vented to atmosphere. There is no source to pressurize the CS&TS line because of closed pump discharge check valves in the CRD URS region.
- C&FS provides a source of water for the CRD pump suction from the turbine building condensate supply. This system is expected to be an open path to a large source similar to CS&TS. Because of the open path, the piping is not considered practical for designing to the URS design pressure.
- Process Sampling System (PSS) at the output of the CRD pump discharge filter units. The PSS design pressure exceeds the URS design pressure.

3KA.1.3 Low-Pressure Piping Systems and Components Designed to URS Pressure

The following is a listing of low-pressure piping systems and components within CRD that are designed to the minimum URS design pressure of 2.82 MPaG (409 psig) based on the ISLOCA considerations outlined in Appendix 3K.

Pipeline/Component Description (see Figure 4.6-8):

CRD Pump Suction Piping and Associated Components

3KA.2 SANDBY LIQUID CONTROL SYSTEM

3KA.2.1 System URS Boundary Description

The SLC system is a high pressure system which injects enriched sodium pentaborate solution inside the reactor through normally closed squib valves. The leakage path includes two check valves in series in addition to a redundant set of normally closed pyrotechnic-type squib valves. The entire SLC system is designed for pressure higher than reactor pressure except the low pressure section from piston pump suction to open mixing drum used for preparation of sodium pentaborate solution. Instrumentation, pressure relief, drain piping and valving are designed to higher than URS design criteria to reduce the level of pressure challenge to these components.

3KA.2.2 Downstream interfaces

The SLC system has no further downstream system interfaces that could possibly be exposed to reactor pressure.

3KA.2.3 Low Pressure Piping Systems and Components Designed to URS Pressure

None.

3KA.3 REACTOR WATER CLEANUP/SHUTDOWN COOLING SYSTEM

3KA.3.1 System URS Boundary Description

The RWCU/SDC system is a high pressure system that is designed above the URS pressure. Low pressure piping connected to the condenser and the liquid waste management system at the downstream of the overboarding line isolation valves is designed to URS design pressure. On the upstream side of the isolation valves, there is a pressure reducing control valve that reduces the pressure before the flow enters the low pressure piping.

3KA.3.2 Downstream Interfaces

Other systems are listed below that interface with RWCU/SDC system and could possibly be exposed to reactor pressure. A description of the interface location and a statement of its applicability to ISLOCA are given.

- FAPCS interfacing piping from the reactor well at the upstream of the Train B of RWCU/SDC system non-regenerative heat exchanger has two locked closed isolation valves in series and the piping provides an open free path to reactor well which is an atmospheric pressure pool.
- FAPCS Low Pressure Coolant Injection (LPCI) interfacing piping with Train B of RWCU/SDC system return piping to Feedwater Line A is designed to a pressure that is above the URS pressure.
- CRD system interfacing piping with Train A of RWCU/SDC system return piping to Feedwater Line B is designed to a pressure that is above the URS pressure.

3KA.3.3 Low-Pressure Piping Systems and Components Designed to URS Pressure

The RWCU/SDC system low pressure piping connected at the downstream side of the overboarding line isolation valves is designed to URS pressure so that the stresses do not exceed the allowable stresses if the piping is subjected to full reactor pressure.

3KA.4 FUEL AND AUXILIARY POOLS COOLING SYSTEM

3KA.4.1 System URS Boundary Description

FAPCS is a low pressure piping system. The FAPCS connects to the RWCU/SDC system at three locations.

LPCI Connections

Its LPCI line is connected to RWCU/SDC system Loop B discharge line, which has an interface with the RCPB via the Feedwater Loop A discharge line (Figure 9.1-1). During reactor power operation, an unisolated break outside the RCPB could lead to an ISLOCA with the release of reactor coolant

from the reactor system pressure boundary. In the FAPCS case, it would require multiple failures before a LOCA could occur, i.e., a break in the FAPCS piping plus failures of the two check valves, which maintain the RCPB.

Containment Cooling Supply Header Connection

The FAPCS has a containment cooling supply header that provides GDCS pool return, suppression pool return, and drywell spray. This header is connected to the RWCU/SDC Loop A discharge line, which has an interface with the RCPB via the Feedwater Loop B discharge line (Figures 9.1-1 and 5.1-4). This connection supports post-LOCA shutdown cooling. When aligned to the reactor pressure vessel (RPV) during operational modes, the RWCU/SDC system operates at pressures higher than the FAPCS design pressure.

Suppression Pool Suction Line Connection

The suppression pool suction line is connected to the RWCU/SDC mid-vessel suction line, which interfaces directly with the RPV (Figures 9.1-1 and 5.1-4). This connection supports post-LOCA shutdown cooling. When aligned to the RPV during operational modes, the RWCU/SDC system operates at pressures higher than the FAPCS design pressure.

3KA.4.2 Downstream Interfaces

LPCI Line Interface

The following design features are provided to the interface between the high and low pressure interfaces to prevent an intersystem LOCA from occurring in FAPCS piping:

- Normally closed isolation valves are provided on the LPCI line to separate the low pressure FAPCS piping from the high pressure condition in the RWCU/SDC pipe during reactor power operation.
- Valve position lights are provided to the operator in the main control room to confirm these isolation valves in the closed positions.
- The isolation valves are provided with a reactor pressure interlock that closes these valves and prevents them from opening whenever a high reactor pressure signal from the NBS is present. Reactor pressure signals ensure high reliability that the isolation valves remain closed.
- The FAPCS LPCI pipe and components between its interface with RWCU/SDC system and the second isolation valve, including the isolation valve, are Quality Group B components designed to above URS pressure.

Containment Cooling Supply Header and FAPCS Suppression Pool Suction Line Interfaces

Each of the connection lines associated with these interfaces contains a normally closed manual isolation valve and a blind spectacle flange to eliminate the possibility for overpressurization from

the RWCU/SDC system Train A during all normal plant modes. This connection is only manually opened in the unlikely event of a LOCA with fuel damage.

3KA.4.3 Low-Pressure Piping Systems and Components Designed to URS Pressure

The low pressure side of LPCI line and the rest of FAPCS piping are not required to be designed to the URS pressure because they are properly protected by the interlock closed isolation valves described above and by a relief valve installed on the LPCI line that protects the line from the overpressure condition, in case of leakage from the RWCU/SDC system side through the isolation valves.

3KA.5 NUCLEAR BOILER SYSTEM

3KA.5.1 System URS Boundary Description

The Main Steam (MS) and Feedwater (FW) piping and instrumentation are designed for reactor pressure.

3KA.5.2 Downstream Interfaces

Other systems are listed below that interface with the Nuclear Boiler System (NBS) and could possibly be exposed to reactor pressure. A description of the interface location and a statement of its applicability to ISLOCA are given.

- The outlet of the CRD pump discharge filter units provide flow to the NBS. The CRD design pressure exceeds the URS design pressure.
- RWCU/SDC provides high pressure return flow to the FW lines. The RWCU/SDC design pressure exceeds the URS design pressure.
- The Isolation Condenser system connects to a piping stub that connects the Depressurization Valves to the RPV, and also there are isolation condenser vent lines that connect to the main steamlines. The isolation condenser design pressure exceeds the URS design pressure.

3KA.5.3 Low-Pressure Piping Systems and Components Designed to URS Pressure

None.

3KA.6 CONDENSATE AND FEEDWATER SYSTEM

3KA.6.1 System URS Boundary Description

The feedwater subsystem of the C&FS provides high pressure feedwater to the reactor. The feedwater subsystem is designed for high pressure except for the feedwater pump suction and the outlet of the feedwater cleanup valve.

In the feedwater pump, the transition to low pressure occurs from the feedwater pump suction into the direct contact feedwater heater (feedwater tank). The feedwater tank is a low pressure sink. The last closed valve in the path from the reactor is the feedwater pump discharge check valve. The

piping to the feedwater pump suction can remain below the URS design pressure because it connects to the low pressure sink feedwater tank. The maintenance block valves in the feedwater pump suction lines are locked open.

In the feedwater cleanup control valve, the transition to low pressure occurs from the feedwater cleanup control valve outlet connection into the condenser shell (hotwell). The hotwell is a low pressure sink. The last closed valve in the path from the reactor in the feedwater cleanup control valve is the normally closed block valve. The piping from the feedwater cleanup control valve to the condenser can remain below the URS design pressure because it connects to the low pressure sink hotwell.

The Condensate subsystem of the C&FS provides condensate to the feedwater tank, and the condensate subsystem is designed for a pressure higher than the feedwater tank, except for the condensate pump suction. The high pressure design includes the condensate polishing (filters and demineralizers) units and the feedwater bypass valve. The transition to low pressure occurs from the condensate suction into the High Pressure condenser shell (hotwell, which is a low pressure sink). The last closed valve in the path from the feedwater tank is the condensate pump discharge check valve. The piping to the condensate pump suction can remain below the feedwater tank design pressure because it connects the low pressure sink hotwell. The maintenance block valves in the condensate pump suction lines are locked open.

3KA.6.2 Downstream Interfaces

None.

3KA.6.3 Low-Pressure Piping Systems and Components Designed to URS Pressure

The maintenance block valves in the condensate pump suction lines are locked open.

Appendix 3L REACTOR INTERNALS FLOW INDUCED VIBRATION PROGRAM

3L.1 INTRODUCTION

A flow-induced vibration (FIV) analysis and testing program of the reactor internal components of the ESBWR initial plant demonstrates that the ESBWR internals design can safely withstand expected FIV forces for reactor operating conditions up to and including 100% power and core flow. The ESBWR FIV program is considered to be a prototype per Reference 3L-1. This will require analysis, measurement and full inspection of reactor internals of the first plant. The ESBWR internals are similar to the Advanced Boiling Water Reactor (ABWR) internals; therefore, analyses and measurements from the ABWR FIV program are used to the extent possible. The ESBWR FIV program includes an initial evaluation phase that has the objective of demonstrating that the reactor internals are not subject to FIV issues that can lead to failures due to material fatigue. Throughout this part of the program, the emphasis is placed on demonstrating that the reactor components will safely operate for the design life of the plant. The results of this evaluation are shown in Reference 3L-1. This evaluation does not include the steam dryer since it is separately evaluated in References 3L-5, 3L-6, and 3L-8; however, an overview of the steam dryer evaluation program is explained in Section 3L.4. The second phase of the program is focused on preparing and performing the startup test program that demonstrates through instrumentation and inspection that no FIV problems exist. This part of the program meets the requirements of Regulatory Guide 1.20 with the exception of those requirements related to preoperational testing that are not applicable to a natural circulation plant.

3L.2 REACTOR INTERNAL COMPONENTS FIV EVALUATION

The ESBWR reactor internals are part of an evolutionary Boiling Water Reactor (BWR) design, but fundamentally the components and function of the reactor vessel and internals are very similar to past BWRs. To a large extent, the ESBWR design of the components relies heavily on the prior design of internals in operating plants to assure that new vibration issues are not introduced. Also, to assure that the flow of steam or water in the reactor vessel is comparable to prior reactors, efforts were made to maintain traditional spacing and dimensional relationships of components. A unique feature of the ESBWR, with respect to FIV, is the fact that ESBWR is a natural circulation plant where no recirculation pumps exist that would create pressure pulses from the pump vanes that would travel into the reactor vessel. The recirculation pump’s excitation has caused failures in components inside previous BWR reactor vessels. For the ESBWR this source of flow excitation does not exist. The ESBWR reactor internals are shown in Figure 5.3-3.

3L.2.1 Evaluation Process – Part 1

The first step in the evaluation process was to establish selection criteria for reactor internal components related to susceptibility to vibration. All reactor internal components were considered

as potential candidates for further evaluation. Each component is evaluated against the following selection criteria:

- Is the component safety-related?
- Is the component of a significantly different or new design compared to earlier BWRs?
- Does the component have a history of FIV-related problems?
- Is the component subjected to significantly different or new flow conditions?

Based on these criteria, the following internal component structures are considered to be candidates for additional evaluation and potential to be instrumented in the startup FIV test program:

- Steam Dryer Bank Hoods and End Plates based on history of past FIV-related problems (e.g., fatigue cracking between hood and endplate).
- Steam Dryer Skirt based on history of past FIV-related problems (e.g., fatigue cracking between skirt and drain channels).
- Steam Dryer Drain Channels based on history of FIV-related problems (e.g., fatigue cracking between skirt and drain channels).
- Steam Dryer Support Ring based on history of FIV-related problems (e.g., steam dryer rocking).
- Chimney Assembly based on new design features (i.e., elongated Chimney Shell, Partition Assembly, Chimney Restraint), potential new flow conditions and limited ability to change the design due to dimensional and performance constraints.
- Chimney Head/Steam Separator assembly based on new design (i.e., shallow dished head or flat head with beam reinforcement, elongated standpipes and thinner stack materials).
- Shroud/Chimney Assembly based on new design features (see Figure 3.9-8), and potential new flow conditions.
- Standby Liquid Control (SLC) internal piping based on new design routed through the shroud and is safety-related.

Components that were evaluated and concluded to require no further evaluation:

- Control Rod Drive Housings
- Control Rod Guide Tubes
- In-Core Monitor Guide Tubes
- In-Core Monitor Housings

For each of these components, the length of the component has decreased from prior BWR product lines due to the plant having shorter fuel. This increases the natural frequencies for these components and moves the natural frequencies beyond the predominant frequencies measured at the prototype ABWR plant. Also, the flow velocities in the reactor pressure vessel (RPV) bottom

head region have decreased and the calculated vortex shedding frequencies are well below the natural frequencies of the components in this region.

Other components such as the top guide and core plate that are not specifically identified as candidates for the instrumentation program are basically proven by trouble-free BWR experience, and have designs and flow conditions that are similar to prior operating BWR plants. Because most of the reactor internal components are large durable components where there has been no history of FIV issues, no FIV issues are anticipated. Also, because it is still early in the program, there is still the opportunity to make adjustments as necessary in the component designs to make them more resistant to FIV.

The results of the Part 1 evaluation are contained in Reference 3L-1.

The chimney assembly was a new component where only limited operating experience was available. Also, the chimney assembly is a structure where the geometry of the partitions places limitations on the plate thicknesses, has a long extended length, and is subject to high velocity two-phase steam flow. From this initial selection, a test and analysis program was established and the results are discussed in Subsection 3L.3.3. For this case, testing was required since no prior relevant test data was available for this component.

A steam dryer initial assessment was performed to study the acoustic and flow effects of the ESBWR configuration in comparison to the ABWR steam dryer design. The initial assessment determined that the increase in the size of the steam dryer support ring and skirt design and the increase in steam velocity did not have any adverse effects on the steam dryer structural integrity. However, at the time of the initial assessment, it was also recognized that the evaluation of BWR operating plant steam dryer loads was an ongoing program that would need to be ultimately factored into the ESBWR steam dryer design and evaluation effort. The progress of the replacement steam dryer program is now at a stage that a meaningful effort can now be planned for the ESBWR steam dryer. The detailed program that is planned is described in Section 3L.4. As a result of the advances in the understanding of steam dryer vibration, differential pressure loads and steam dryer design improvements (see Subsection 3L.2.3), the ESBWR uses a steam dryer design patterned after the ABWR and replacement steam dryer designs developed for BWR plants.

The SLC internal piping is based on a new design and is safety-related. The SLC line is in the downcomer flow field and is subject to vortex shedding flow induced vibration. The vibration characteristics of the SLC internal piping is evaluated as described in Subsection 3L.5.5.1.4. The SLC line is instrumented as part of the startup test program as shown in Table 3L-4.

3L.2.2 Evaluation Process – Part 2

The next phase of the evaluation program performed additional work to demonstrate the adequacy of the components where Part 1 determined additional evaluations were required. The objective of this phase completes a more quantitative evaluation and documents the existing facts regarding the individual components. This part of the evaluation focuses on the following:

1. Similarities and differences of the ESBWR component design configurations as compared to prior designs. In most cases the comparison design is ABWR components.
2. A review of prior calculations for the components being evaluated, to establish the mode shapes and natural frequencies. Calculation of the ESBWR component natural frequencies is determined based on this data.
3. Prior plant startup instrumentation data from the prototype ABWR plant is reviewed to establish the magnitude and frequency of the measured vibration data, and to review the resulting calculated stress for the components that were instrumented.
4. A comparison of the flow paths and characteristics of the ESBWR design to prior BWR designs where a startup vibration test program was conducted.

Using the results of the above items, an assessment as to the likelihood of FIV issues is completed and documented in Reference 3L-1. This report does not include the steam dryer since it was evaluated in separate reports (see References 3L-5, 3L-6, and 3L-8). The evaluations for the chimney components and SLC lines are included in this report, but alternate methods to those described above have been used to evaluate FIV since these are new BWR components. This report concludes that FIV evaluations have been completed and that none of the reactor internal components are susceptible to FIV.

During the evaluation phase, the process as identified in Subsection 3.9.2.3 was followed to prepare finite element analysis (FEA) models per the details shown in Subsection 3L.5.5.1. This information will then be used as the basis for the instrumentation in the ESBWR startup test program. It should be noted that the SLC internal piping, steam dryer and chimney have already been identified in Section 3L.2.1 for inclusion in the startup test program.

3L.2.3 Design and Materials Evaluation

FIV-related fatigue cracking and intergranular stress corrosion cracking are major causes of reactor internal component degradation observed in operating BWRs. The ESBWR reactor internals are designed to resist fatigue loading. Design evaluations are conducted to evaluate load paths and streamline structural discontinuities thus reducing stress risers that contribute to fatigue failure. Welds are reduced by integrating components through machining or castings. Some components are specifically designed for intersections between larger components so groove welds can be used in lieu of fillet welds. Design evaluations are also conducted to stiffen the component structure moving component fundamental frequencies above the frequency range associated with hydrodynamic and acoustic loads.

The reactor internal materials, as specified in Subsection 4.5.2, are resistant to corrosion and stress corrosion cracking in the BWR steam/water environment.

3L.3 CHIMNEY ASSEMBLY AND STANDBY LIQUID CONTROL INTERNAL PIPING EVALUATION

3L.3.1 Design and Materials

The chimney assembly design consists of a chimney shell and partition assembly. The chimney shell has a bottom ring that rests on the top guide (Figure 3.9-8). The chimney partitions rest on the top surface of the top guide. The top of the partition assembly is supported against the inside of the chimney shell. The partition assembly is a grid of square structures, each of which encompasses and lines up with four top guide fuel cells (i.e.,16 fuel assemblies). The chimney shell and partitions are fabricated using austenitic stainless steel plate (Table 4.5-1). The partitions are full length welded near the junctions of the partitions. The chimney shell that houses the partition structure is cylindrical, similar to the core shroud. A sketch of the chimney assembly is shown in Figure 3L-1. Because the chimney shell has structural characteristics similar to the shroud, this component is considered under the generic reactor internals vibration program, and the partition assembly is considered to be the unique component that requires special vibration consideration.

3L.3.2 Prior Operating Experience

Prior to the ESBWR design, the BWR-1 Dodewaard plant had operating experience with this chimney design, although it did not have a vibration instrumentation program. For this plant, the partition size was a square configuration that encompassed four fuel assemblies within the cell, which is ¼ the dimension of the ESBWR partitions. Also, the height was approximately ½ the length of the ESBWR design. The partition thickness was 3 mm (0.12 in) as compared to 9 mm (0.35 in) for ESBWR, and the partitions were welded together using intermittent fillet welds as compared to full-length groove welds in joints that are positioned away from the partition intersections for ESBWR. Although the partitions were not instrumented, the plant operated for almost 30 years without any issues related to the chimney structure. Since the design of the ESBWR chimney partitions is more fatigue-resistant, this Dodewaard operational history provides additional assurance that the ESBWR will not have FIV issues.

3L.3.3 Testing and Two-phase Flow Analysis

For the ESBWR, the chimney partition assembly constitutes a structure that has a unique vibration evaluation program as part of the ESBWR reactor internals. In order to assess its capability to maintain structural integrity under plant operating conditions, a flow induced vibration evaluation is performed in which the fluctuating fluid force acting on the partition plates is evaluated by a combination of scale tests and two-phase flow analysis.

The test scope comprised a 1/6-scale (100 mm x 100 mm [4 in x 4 in]), a 1/12-scale (50 mm × 50 mm [2 in x 2 in]) and one almost full scale (500 mm × 500 mm [20 in x 20 in]) chimney. Tests use a mixture of air and water to simulate two-phase flow testing inside the chimney. The velocities of the gas and liquid components of the two-phase flow were adjusted to be consistent with ESBWR values to simulate the actual two-phase flow pattern. Different inlet flow conditions in the smaller

scale models were used to investigate the influence of inlet mixing within the partition to simulate different power conditions. Pressure fluctuation was measured on the inner surface of the partition wall with pressure transducers. The 1/6-scale model was later divided into four cells for investigating the pressure fluctuations between cells (Reference 3L-1).

The scale model tests were used to investigate the effect of model size on the magnitude of pressure fluctuations acting on the partition wall in steam-water conditions.

A structural analysis of the chimney and partition design was then conducted using finite element methods. First, an eigenvalue analysis determined that the lowest natural frequency of the chimney structure is approximately 54 Hz. This was sufficiently greater than the predominant frequency of pressure fluctuation determined by testing (2 Hz) that a static analysis of the structure was concluded to be proper. Based on the results of that static analysis, a maximum stress of 32.8 MPa (4,760 psi), with a fatigue strength reduction factor of 2, was calculated near the edge of the partition plate joint. This stress value is bounded by the allowable vibration highest stress amplitude of 68.9 MPa (10,000 psi) specified in Subsection 3.9.2.3.

3L.3.4 SLC Internal Piping Evaluation

The SLC line is a new ESBWR component that enters the downcomer flow region at two locations, 180 degrees apart, in the annulus between the RPV and the chimney. The SLC piping continues down to the shroud where the piping divides and penetrates the shroud at two locations each. Since the configuration of the SLC line has a new geometry and location within the RPV, this component is analyzed and tested during initial startup.

A finite element beam model of SLC line was constructed and analyzed for FIV induced stresses (see Subsection 3L.5.5.1.4). The fundamental frequency of the SLC line was determined to be 31.2 Hz, which is well separated from the vortex shedding frequency of 5.5 Hz and, therefore, of no concern.

The SLC piping in the annulus is instrumented during startup of the first ESBWR. A summary description of these sensors is shown in Table 3L-4.

3L.4 STEAM DRYER EVALUATION PROGRAM

3L.4.1 Steam Dryer Design and Performance

The ESBWR steam dryer consists of a center support ring with dryer banks on top and a skirt below. A typical steam dryer is shown in Figure 3L-2. The dryer units, made up of steam drying vanes and perforated plates, are arranged in six parallel rows called dryer banks. The ESBWR steam flow rate is approximately 15% higher than ABWR. The ESBWR RPV has a larger inner diameter at the vessel flange than ABWR, which allows dryer banks to be extended, thereby accommodating the higher steam flow. The additional dryer unit face area results in approximately the same flow velocity through the drying vanes as ABWR and helps maintain moisture removal performance requirements. The support ring is supported by RPV support brackets. The steam dryer assembly does not physically connect to the chimney head and steam separator assembly. The cylindrical skirt attaches to the support ring and projects downward to form a water seal around the array of steam separators. Normal operating water level is approximately mid-height on the steam dryer skirt.

Wet steam from the core flows upward from the steam separators into an inlet header, then horizontally through the inner perforated plate, the dryer vanes and the outlet perforated plates, then vertically in the outlet header and out into the RPV dome. Dry steam then exits the RPV through the steam outlet nozzles. Moisture (liquid) is separated from the steam by the vane surface and the hooks attached to the vanes. The captured moisture flows downward, under the force of gravity, to a collection trough that carries the liquid flow to vertical drain channels. The liquid flows by gravity through the vertical drain channels to the lower end of the skirt where the flow exists below the normal water level.

The prototype for the ESBWR steam dryer builds on the successful operating experience of the ABWR steam dryer. Although the ESBWR steam dryer will have a larger diameter and wider vane banks to accommodate close to 15% higher steam flow, the vane height, skirt length, outer hood setback from the main steam nozzle, and water submergence will be similar to the ABWR steam dryer. The ESBWR steam dryer also draws experience from operating plant replacement steam dryer program fabrication, testing and performance. Steam dryers recently tested and installed in BWR/3 plants had experienced high pressure loads under extended power uprate operating conditions. These loads were characterized by an abnormally high pressure tone at approximately 155 Hz that emanated from an acoustic resonance in one or more of the safety relief valve (SRV) standpipes. The replacement steam dryers were specifically designed to withstand the FIV and acoustic resonance loading that led to fatigue failures in the steam dryers for these plants. In addition, the SRV/SV standpipes and main steamline branch lines in ESBWR are specifically designed to preclude first and second shear layer wave acoustic resonances that could be a significant contributor to steam dryer loading at normal operating conditions. Table 3L-1 provides a comparison between major configuration parameters of the ESBWR, the ABWR prototype and a BWR/3 replacement steam dryer.

3L.4.2 Materials and Fabrication

Current industry and replacement steam dryer practices are applied to the materials and fabrication of the ESBWR steam dryer. The steam dryer materials are selected to be resistant to corrosion and stress corrosion cracking in the BWR steam/water environment, see Table 4.5-1.

3L.4.3 Load Combinations

Design loads for the steam dryer are based on evaluation of the ASME B&PV Code load combinations provided in Table 3.9-2 except that the load definitions that pertain to the steam dryer are modified as shown in Table 3L-2. These load combinations consist of deadweight loads, static and fluctuating differential pressure loads (including turbulent and acoustic sources), seismic, thermal, and transient acoustic and fluid impact loads.

3L.4.4 Fluid Loads on the Steam Dryer

During normal operation, the steam dryer experiences a static differential pressure loading across the steam dryer plates resulting from the pressure drop of the steam flow across the vane banks. The steam dryer also experiences fluctuating pressure loads resulting from turbulent flow across the steam dryer and acoustic sources in the vessel and main steamlines. During transient and accident events, the steam dryer also experiences acoustic and flow impact loads that result from system actions (e.g., turbine stop valve closure) or from the system response (e.g., the two-phase level swell following a main steamline break).

Of particular interest are the fluctuating acoustic pressure loads that act on the steam dryer during normal operation that have led to fatigue damage in previous steam dryer designs. In the low frequency range, these pressure loads have been correlated with acoustic sources driven by the steam flow in the outer hood and vessel steam nozzle region. In the high frequency range, acoustic resonances in the stagnant steamline side branches (e.g., relief valve standpipes) are coupled to the vessel, thus imparting a pressure load on the steam dryer. Vessel acoustic modes may also be excited by sources inside and outside the vessel, resulting in additional acoustic pressure loads in the middle frequency range.

A detailed description of the pressure load definition for the ESBWR steam dryer is provided in Reference 3L-5. The load definition is based on the Plant Based Load Evaluation Methodology described in Reference 3L-8. Reference 3L-8 provides the theoretical basis of the methodology, describes the analytical model and provides benchmark and sensitivity comparisons of the methodology predictions with measured pressure data taken from instrumented steam dryers. The fluctuating load definition is based on the load definitions based on in-plant measurements that were developed for the steam dryer structural analyses in several extended power uprates. These load definitions provide a fine-mesh array of pressure time histories that are consistent with the structural finite element model nodalization. Multiple load definitions are used in the ESBWR steam dryer analysis in order to evaluate the steam dryer response over a wide frequency range. These load definitions include the limiting low and high frequency loads observed in plants with

instrumented steam dryers. Based on the unique plant configurations (e.g., dead legs in the main steamlines that may amplify the low frequency acoustic response) and operating conditions (e.g., high steam line flow velocities) in these instrumented plants, the load definitions from these plants are expected to provide a robust load definition for the ESBWR. The load definitions developed for the ESBWR are also benchmarked against the instrumented steam dryer measurements taken during startup testing for the lead ABWR. The ESBWR and ABWR have the same vessel diameter and vessel steam nozzle design (with flow restricting venturi), and similar main steamline layouts; therefore, it is expected that the frequency content of the ESBWR steam dryer pressure loads will be similar to those measured on the ABWR.

3L.4.5 Structural Evaluation

A FEA is performed to confirm that the ESBWR steam dryer is structurally acceptable for operation. The FEA uses the load definitions described in Subsection 3L.4.4. The FEA is performed using a whole steam dryer analysis model to determine the most highly stressed locations, also see Subsection 3L.5.5.1.3. The FEA consists of dynamic analyses for the load combinations identified in Subsection 3L.4.3. If required, locations of high stress identified in the whole steam dryer analysis are further evaluated using solid finite element models to more accurately predict stresses at these locations. Additional analysis confirms that the RPV steam dryer support lugs accommodate the predicted loads under normal operation and transient and accident conditions. (Also see Subsection 3L.5.5.1.3.)

The structural evaluation of the ESBWR steam dryer design is presented in Reference 3L-6.

3L.4.6 Instrumentation and Startup Testing

The ESBWR steam dryer is instrumented with temporary vibration sensors to obtain flow induced vibration data during power operation. The primary function of this vibration measurement program is to confirm FIV load definition used in the structural evaluation is conservative with respect to the actual loading measured on the steam dryer during power operation, and to verify that the steam dryer can adequately withstand stresses from flow induced vibration forces for the design life of the steam dryer. The instrumentation and startup testing program for the ESBWR steam dryer follows NRC regulatory guidance in Reference 3L-10, as described below. The detailed objectives are as follows:

- Determine the as-built frequency response parameters: This is achieved by frequency response testing the steam dryer components. The results yield natural frequencies, mode shapes and damping of the components for the as-built steam dryer. These results are used to verify portions of the steam dryer analytical model.
- Confirm FIV loading: In order to confirm loading due to turbulence, acoustics and other sources, dynamic pressure sensors are installed on the steam dryer. These measurements will provide the actual pressure loading on the steam dryer under various operating conditions.

- Verify the design: Based on past knowledge gained from different steam dryers, as well as information gleaned from analysis, selected areas are instrumented with strain gages and accelerometers to measure vibratory stresses and displacements during power operation. The measured strain values are compared with the allowable values (acceptance criteria) obtained from the analytical model to confirm that the steam dryer alternating stresses are within allowable limits.

The objective of the steam dryer frequency response test is to identify the as-built frequencies and mode shapes of several key components of the steam dryer at ambient conditions. Different components of the steam dryer have different frequencies and mode shapes associated with them. The areas of interest are the drain channel, the outer hood panel, the inner hood panel, the side panel, and the skirt. These results are used to verify portions of the finite element model of the steam dryer.

The concern is that local natural frequencies may coincide with existing forcing functions to cause resonance conditions. The resonance could cause high stresses to occur in localized areas of the steam dryer. A finite element frequency response analysis can calculate the frequency and mode shape of a component, but they are only ideal approximations to the real values due to variations such as plate thickness, weld geometries, configuration tolerances and residual stresses that affect the assumed boundary conditions in the finite element model. The mode shapes and frequencies determined by the frequency response test are used to validate the finite element frequency response analysis and determine the uncertainty in the finite element model predictions of the frequency response. The FE model and experimental transfer functions are then used to derive frequency dependent amplitude bias and uncertainty of the FE model for key areas of the dryer. This is described further in Reference 3L-6.

The frequency response test is performed following final assembly of the steam dryer. The tests are performed with the steam dryer resting on simulated support blocks similar to the way the steam dryer is seated inside the reactor vessel.

Two types of frequency response tests are performed on the steam dryer: (1) Dry frequency response test, and (2) Wet frequency response test with the steam dryer skirt and drain channels partially submerged in different water levels (to approximate in-reactor water level). Both tests are conducted in ambient conditions. Temporary bondable accelerometers are installed at predetermined locations for these tests. An instrumented input force is used to excite the steam dryer at several pre-determined locations and the input force and the structural responses from the accelerometers are recorded on a computer. The data is then used to compute experimental transfer functions mode shape, frequency and damping of the instrumented steam dryer components using appropriate software. The temporary sensors are then removed and the steam dryer is cleaned prior to installation in to the reactor vessel.

The steam dryer vibration sensors consist of strain gages, accelerometers and dynamic pressure sensors, appropriate for the application and environment. A typical list of vibration sensors with their model numbers is provided in Table 3L-3. The selection and total number of sensors is based on past experience of similar tests conducted on other BWR steam dryers. These sensors are specifically designed to withstand the reactor environment. The pressure instrument locations are selected to provide a good measure of the acoustic loading through the frequency range of interest. A proper distribution of the steam dryer pressure instruments facilitates accurate assessments of FIV loads. The layout of the steam dryer pressure instrument locations is evaluated using the RPV acoustic FEA Model. The approach used to determine the number and locations of pressure instruments is described in Subsections 2.3.2 and 4.4.2 of Reference 3L-8.

The steam dryer startup test and monitoring power ascension limits are developed on a similar basis as the monitoring limits used for recent extended power uprate replacement steam dryers. The power ascension limits are based on the final FIV analysis performed for the as-built steam dryer. Strain gages and accelerometers are used to monitor the structural response during power ascension. Accelerometers are also used to identify potential rocking and to measure the accelerations resulting from support and vessel movements. The approach used to determine the number and locations of the strain gages and accelerometers is described in Section 9.0 of Reference 3L-6. Specific information utilized to verify the FIV load definition during startup testing is described further in References 3L-5 and 3L-6.

Each of the sensors is pressure tested in an autoclave prior to assembly and installation on the steam dryer. An uncertainty analysis is performed to calculate the expected uncertainty in the measurements.

Prior to initial plant start-up, strain gages are resistance spot-welded directly to the steam dryer surface. Accelerometers are tack welded to pads that are permanently welded to the steam dryer surface. Surface mounted pressure sensors are welded underneath a specially designed dome cover plate to minimize flow disturbances that may affect the measurement. The dome cover plate with the pressure transducer is welded to an annular pad that is welded permanently to the steam dryer surface. The sensor conduits are routed along a mast on the top of the steam dryer and fed through the RPV instrument nozzle flange to bring the sensor leads out of the pressure boundary. Sensor leads are routed through the drywell to the data acquisition area outside the primary containment.

Pressure transducers and accelerometers are typically piezoelectric devices, requiring remote charge converters that are located in junction boxes inside the drywell. The data acquisition system consists of strain gages, pressure transducers and accelerometer signal conditioning electronics, a multi-channel data analyzer and a data recorder. The vibration data from all sensors is recorded on magnetic or optical media for post processing and data archival. The strain gages, accelerometer and pressure transducers are field calibrated prior to data collection and analysis. This calibration includes the addition of natural strain gauge factors based on the specific vendor supplied

calibration sheets and their effects on the final stress tables. The locations of the gauges are more distributed than BWR EPU gauge locations. The locations are selected to avoid pressure nodes in the acoustic harmonic response for frequencies that contribute most heavily to loading in the dryer components with the highest stress. The final pressure transmitter locations are evaluated using the PBLE model with multiple combinations of Frequency Response Function (FRF) sets corresponding to different transmitter locations. The resulting data are used to find locations that provide redundancy and minimize singularities over the frequency ranges of interest, with special consideration at frequencies critical to high stress locations in the dryer. The sensitivity of locations to dimensional tolerances is also considered. Strain gauge manufacturer installation procedures are followed to duplicate previous installations. Care is taken to assure surface preparation (attachment surface area polish), spotweld welding energy, and weld strength recommendations are followed for each gauge. Applicable lessons learned from manufacturer’s recommendation were also incorporated into the GEH welding procedure specification. Furthermore, knowledge is passed to the welders by holding pre-job briefs and discussing the proper technique for applying the gauges, emphasizing the uniform placement of spot welds at approximately 0.7 – 0.8 mm intervals. Afterwards, the welders will practice on shims until peel tests are successfully completed. Quality Control personnel are present to accept the weld process. The temporary vibration sensors are removed after the first outage.

The steam dryer pressure measurements are used as input to an acoustic model for determining the pressures acting on the steam dryer in order to provide a pressure load definition for use in performing confirmatory structural evaluations.

In addition to the elements described above, NRC regulatory guidance (Reference 3L-10) describes elements of the comprehensive vibration assessment program that is implemented prior to and through startup testing. The following regulatory positions for prototype steam dryers address the program elements applicable to the ESBWR steam dryers:

- Position 2.1 provides a description of the vibration and stress analysis program, including specific items that should be included in the vibration and stress analysis submittal prior to implementation of the vibration measurement program.
- Position 2.2 provides a description of the vibration and stress measurement program, which is to verify the structural integrity of reactor internals, determine the margin of safety, and confirm results of the vibration analysis.
- Position 2.3 describes the inspection program for inspection both prior to and following plant operation.
- Position 2.4 describes documentation of results of the program.
- Position 2.5 describes the schedule for conducting the vibration assessment program.

COL Information Item 3.9.9-1-A implements the vibration assessment program. For each of the regulatory positions above, the NRC guidance (Reference 3L-10) explains how the program is to be

conducted, how the processes assure structural integrity of the steam dryer, and identifies information and reports that are to be prepared and when the information and reports should be submitted. Steps in the process for the regulatory positions include the following key elements:

Position 2.1: The steam dryer analysis and modeling methodologies for performing a vibration and stress analysis are described in References 3L-5, 3L-6, and 3L-8. NRC guidance specifies that a summary of the vibration analysis program should be submitted to the NRC at least 60 days prior to submission of the description of the vibration measurement and inspection programs (or 120 days if submitted with a description of the vibration measurement and inspection phases description). Thus, a summary of the as-built steam dryer structural analysis with the applied acoustic loads would be developed and submitted to the NRC. In addition, the supporting information will be available for NRC review for assuring acceptance criteria are met in accordance with ESBWR DCD Subsections 3.9 and 14.3. This analysis is used to correlate results obtained through vibration measurements during power ascension.

Position 2.2: Details of the steam dryer monitoring program are described above and in References 3L-5, 3L-6, and 3L-8. According to NRC guidance, a description of the vibration measurement and inspection phases of the comprehensive vibration assessment program should be submitted to the NRC in sufficient time to permit utilization of the staff's related recommendations (allowing 90 days for staff's review and comment period). This submittal would be focused on the as-built steam dryer monitoring and instrumentation to be used for obtaining vibration measurements, with details of the data acquisition and reduction system (e.g., transducer types, transducer position, measures to maximize quality of data, online data evaluation system, procedures, and bias errors associated with the instruments). During power ascension, the steam dryer instrumentation (strain gages, accelerometers and dynamic pressure transducers) is monitored against established limits to assure the structural integrity of the steam dryer is maintained. If resonant frequencies are identified and the vibrations increase above the pre-determined criteria, power ascension is stopped. The acceptability of the steam dryer for continued operation is evaluated by revising the load definition based on the measured loading, repeating the structural analysis using the revised load definition, and determining revised operating limits based on the results of the structural analysis.

Position 2.3: Specific steam dryer inspection recommendations for the ESBWR steam dryer design are developed based on the final as-built design and structural analysis results. The steam dryer inspection recommendations are consistent with Reference 3L-2, and consistent with Boiling Water Reactor Vessel Internals Program guidance issued by the BWR owners group specific to reactor internals vibration. According to NRC guidance, a description of the inspection phase would be included in the submittal with a description of the vibration measurement program. This description would identify any inspections that are to be performed prior to and following operation during power ascension, and describe procedures and method of inspections, if any, of the steam dryer.

Position 2.4: According to NRC guidance, results of the comprehensive vibration assessment program should be reviewed and correlated to determine the extent to which test acceptance

criteria are satisfied. The preliminary report following startup testing should compare preliminary comparison of data to test acceptance criteria and identify anomalous data that could bear on the steam dryer structural integrity. If results are acceptable, the final report should include a description of any deviations, comparison between measured and analytically determined modes of structural response and hydraulic response for verifying analytical technique, determination of margins of safety, and evaluation of unanticipated observations or measurements that exceeded acceptable limits not specified as test acceptance criteria (as well as disposition of such deviations). If testing or inspections reveal defects or unacceptable results, the final report should also include an evaluation and description of the modifications or actions planned to justify the structural adequacy of the steam dryer.

Position 2.5: A schedule for conducting the elements of the comprehensive vibration assessment program is inherent in COL Information Item 3.9.9-1-A. NRC guidance specifies that the steam dryer be classified as prototype or non-prototype; that a commitment be made in the DCD or COL application regarding the scope of the comprehensive vibration assessment program; and that certain submittals be made describing the program and results with suggested schedules for the submittals.

With the detailed description above and implementation of COL Information Item 3.9.9-1-A, the instrumentation and startup testing program elements are consistent with NRC regulatory guidance and adequately ensure steam dryer structural integrity.

3L.5 STARTUP TEST PROGRAM

This section summarizes the program for preparing and performing the startup FIV testing including the methods and analysis that are performed when the startup test data is available. This section assumes that the initial selection of components identified in Subsection 3L.2.1 will be part of the analysis and instrumentation associated with the startup testing program.

Testing requirements of this program are incorporated into the Initial Test Program detailed in Section 14.2 through the Reactor Internals Vibration Test described in Subsection 14.2.8.2.11. The test procedure acceptance criteria, derived from the evaluations described in this appendix, are classified by definitions in the Startup Administrative Manual outlined in Subsection 14.2.2. Direction on the quality process to be used to control the resolution of test acceptance criteria failures is incorporated in the Startup Administrative Manual and specific guidance may be included in the test procedure.

3L.5.1 Component Selections

The components that are selected for instrumentation are determined from the initial evaluation phase as discussed in Subsection 3L.2.1. Many different sensors of four different types are utilized to measure vibration related data on several different reactor internal component structures.

3L.5.2 Sensor Locations

Having determined the components to instrument during the test, sensor locations on those structures are determined based upon the analytically predicted mode shapes for each structure, or calculated maximum stress locations or, sensor locations based on computational fluid dynamics modeling, and in some cases, based upon the location of past FIV-related failures. Strain gages and accelerometers are used for monitoring vibration levels. Strain gages measure local strain from which local stress can be calculated. Based on knowledge of the natural mode shapes of the structure or calculated stress distribution, highest stresses at other locations on the structure are determined from these data. Accelerometers (with double integration of the output signal) provide measurements of local structural displacement. This information, together with knowledge of the natural mode shapes of the structure or calculated stress distribution, allows the highest stresses to be calculated at other locations. Pressure sensors are also utilized at various locations in the vessel. These are not used to measure structural vibration directly, but rather to measure the pressure variation that is often a forcing function that causes the structural vibration. These pressure sensor data are very useful for determining the source of any excessive vibration amplitudes, if they are to occur during testing. Sensor types and locations are listed in Table 3L-4.

3L.5.3 Test Conditions

Test conditions are selected early in the FIV test program to consider a variety of steady-state and transient operating conditions that could be expected to occur during the life of the plant. Tests are identified in the Initial Test Program (ITP) schedule during heat up and power operation testing phases, when at steady-state conditions and with transient test sequences, as necessary. Specific conditions for testing are integrated into the initial startup by inclusion in the ITP schedule outlined in Subsections 14.2.2.4 and 14.2.7. Hold points and milestones are included to allow for test result review and approval, overall phase testing approval and authorization to proceed with the next testing phase documented in the Startup Administrative Manual, which includes time for COL Holder and NRC staff interactions.

RPV internals vibration at steady-state conditions is more important than transient conditions for evaluating the structural integrity of components. This is because steady-state normal operating conditions can exist for long periods of time, allowing a very large number of vibration cycles to accumulate. The FIV caused by transient operating conditions is far less influential because of the relatively low number of vibration cycles that occur over the lifetime of the plant. The purpose in including transient test conditions is to confirm that extremely high stresses do not occur during transients. This check is accomplished during the actual startup transient tests by the vibration engineers monitoring the test equipment. Transient stress levels near the allowable limit would be easily and immediately detected by the vibration engineers. No such high stress levels are expected to occur during the ESBWR initial plant FIV transient tests. Therefore, for the purposes of confirming the structural capability of the internals, steady-state test conditions are the most important conditions to evaluate.

Total volumetric core flow rate is also an important parameter that affects the vibration magnitude of the internals. Vibration amplitude generally increases as the volumetric flow rate increases.

3L.5.4 Data Reduction Methods

Basically, two types of data reduction are performed: (1) time history analyses and (2) spectrum analyses. In either data reduction method, the measured peak-to-peak (p-p) value of each sensor signal is compared to the allowable p-p value. Even though time history, spectrum analyses or both are performed for each selected sensor and test condition, the results from only one data reduction method are used for comparison to the allowable values. The selection of the method is dependent on the analysis method used for data evaluation. Table 3L-5 describes the method of data reduction that is applicable to each component.

3L.5.4.1 Time History Analysis

The time history method uses the analyzer's time capture mode of operation. Time capture is performed for a period of several minutes for all the selected sensors and test conditions. The frequency bandwidth for the time capture is chosen to accommodate 0-200 Hz as a minimum for most channels.

For comparison to the allowable vibration amplitude, the measured p-p value over specified bandwidths needs to be obtained for sensors in specific components. The bandwidths used for p-p measurements for various components are shown in Table 3L-5. There are six bandwidths for time history p-p measurement: 0-80 Hz, 0-200 Hz, 0-100 Hz, 80-200 Hz, 100-200 Hz and 0-1600 Hz. The 0-1600 Hz is used only for the accelerometer for the purpose of detecting impacts. The other three bandwidths are used for normal vibrations.

For the 0-200 Hz bandwidth, the maximum p-p values over several minutes of data for selected sensors and test conditions are obtained directly from the time capture. Specification of the bandwidth for time capture (0-200 Hz) automatically results in a low-pass filtered signal.

In order to obtain the maximum p-p in the 0-100 Hz range, the histogram operation is employed on the time capture traces. When the bandwidth (0-100 Hz) is specified in the histogram operation, the signal is automatically low-pass filtered in the specified frequency range. The histogram measurement shows how the amplitude of the input signal is distributed between its maximum and minimum values. The horizontal axis is the amplitude axis and usually the center of the horizontal axis is the zero point with positive and negative amplitudes on either side of the zero. The vertical axis is the number of counts or the number of times a particular amplitude value occurs in a time-history. From the histogram, the maximum positive and maximum negative values in a time history can be obtained, from which the maximum p-p of the time history can be obtained.

For the 100-200 Hz bandwidth range, the time captured traces are filtered in the 100-200 Hz range and the p-p is obtained over a period of several minutes. The filtered time history between 100 and 200 Hz is scanned to obtain maximum and minimum values to get p-p values.

For the 0-1600 Hz range for accelerometers, the time history signal is examined for the presence of any impacts.

3L.5.4.2 Frequency Analysis

The spectrum shows the signal in the frequency domain. There are several different types of spectra. The linear spectrum is the Fourier transform of the time history signal. The auto power spectrum is the magnitude squared of the linear spectrum, which is computed by multiplying the Fourier transform of the signal by its complex conjugate. This spectrum contains magnitude information only. The spectra generated for ESBWR data reduction are auto power spectra. The spectra for selected sensors and test conditions are obtained from the captured time history described previously.

Signal averaging is used to obtain better statistical properties. It is possible to select the number of averages and the type of averaging. There are three types of averaging:

- Stable (normal)
- Exponential
- Peak Hold

The averaging method used for ESBWR is "Peak Hold", which compares the current spectral value of each individual frequency during the analysis interval to the last spectral value and holds the larger of the two. The resultant spectrum is a composite spectrum which envelopes the spectrums of all analysis intervals. The parameters used in the spectrum generation are described in Table 3L-6**.**

In order to obtain greater accuracy on amplitude of the frequency spectrum, a flat top window is selected.

From the spectrum, the dominant frequencies of vibration and their root mean square (RMS) magnitudes can be identified. The frequency is in the horizontal axis and the RMS magnitude is in the vertical axis. The p-p value of vibration at each dominant frequency is obtained by multiplying the RMS value (from the peak hold spectrum) by a factor of 6. This factor is obtained from many years of reactor experience and is a conservative estimate of the p-p value. This p-p value is then used to compute the stress at the sensor location and the maximum stress in the structure.

3L.5.5 Data Evaluation Methods

This section describes the methods used to evaluate the reduced test data for the purpose of determining whether maximum stress levels are below the maximum allowable fatigue stress limits for the materials. A significant portion of this evaluation lies in the determination of the natural vibration modes of the instrumented components as determined using finite element models. Subsection 3L.5.5.1 describes the finite element models used in this process. Subsection 3L.5.5.2 describes the steps involved in determining the maximum stress amplitudes from the reduced data.

3L.5.5.1 Finite Element Models

Dynamic analytical finite-element models are developed for the following ESBWR plant reactor internal components:

- Chimney Head and Steam Separators
- Shroud and Chimney
- Steam Dryer
- SLC Line

The dynamic analytical finite-element models are used to predict the natural vibration frequency, modal displacement, and modal strain and stress for each of the dominant vibration response modes. Descriptions of the finite-element models are given in the following subsections.

3L.5.5.1.1 Chimney Head and Steam Separators

In order to determine the chimney head and steam separator vibration frequencies and mode shapes, a 3-dimensional model is developed using the ANSYS computer code (Reference 3L-3). The detailed model consists of the components that provide structural members within the assembly. Since the separator assembly units are the standard product used on prior BWR product lines, and that operates within the range of the design steam flow rates, detailed modeling is not required. In this model, each nodal point has four degrees of freedom, namely:

- radial displacement
- tangential displacement
- vertical displacement
- meridian rotation

3L.5.5.1.2 Shroud and Chimney

In order to determine the shroud vibration frequencies and mode shapes, an axisymmetric shell model is developed using the ANSYS computer code (Reference 3L-3). The detailed shell model consists of both the RPV, chimney, chimney support, and shroud such that the hydrodynamic interaction effects between the components are accounted for. In this model, each nodal point has four degrees of freedom, namely:

- radial displacement
- tangential displacement
- vertical displacement
- meridian rotation

The following assumptions are made in generating the axisymmetric shell model:

1. *Discrete components move in unison for steam separators, standpipes, and CRDHs and guide tubes.*
2. Masses are lumped at the nodal points. Rotational inertias of the masses are neglected.
3. Stiffnesses of control rods, control rod drives, steam dryers, and in-core housings are neglected.
4. Top guide and core plate masses are lumped to the shroud.
5. Masses of CRDHs below the vessel are lumped to the bottom head.

Equivalent shells are used to model the mass and stiffness characteristics of the guide tubes, steam separators, and standpipes such that they match the frequencies obtained from a horizontal beam model.

Diagonal hydrodynamic mass terms are selected such that the beam mode frequencies of the shell model agree with those from the beam model.

The RPV, chimney and shroud are modeled as thin shell elements. The shell element data are defined in terms of thickness, mass density, modulus of elasticity, and Poisson’s ratio for the appropriate material and temperature.

The natural frequencies and mode shapes of the shroud shell model are given in terms of two parameters, termed “n” and “m”. The “n” parameter refers to the number of circumferential waves, while the “m” parameter refers to the number of axial half-waves. Thus, for beam types of vibration, n=1.

3L.5.5.1.3 Steam Dryer

The design of the steam dryer assembly for the ESBWR plant is similar to ABWR.

However, the total steam flow rate of the ESBWR plant is different from past designs. These differences warrant a detailed vibration analysis and test monitoring to assure the adequacy of the new design to withstand the FIV.

In the ABWR initial plant FIV test program of the steam dryer assembly, accelerometers were located on the cover plate and several locations on the skirt, and strain gages were located directly on the skirt, drain channels and hoods (Reference 3L-5). In addition, pressure sensors were used to measure the pressure differentials between the inside and outside of the upper skirt adjacent to the front hood and the lower skirt. The differential pressure fluctuation across the hoods and skirt is the primary forcing function causing vibration of the steam dryer structure.

A dynamic finite element model of the steam dryer assembly is developed using the ANSYS computer code (References 3L-3 and 3L-6). Due to the complicated geometry and the large size of the analytical model, major components may be modeled with coarse meshes such that their dynamic contributions are accounted for in the whole steam dryer assembly vibration responses.

Separate refined dynamic finite element models of the major components are then developed to provide a high resolution of the component's response calculation.

The structural material properties and density for the steam dryer components at temperature are used in the model. The effect of the water on the dynamic responses is accounted for by explicitly modeling the dynamic properties of the fluid in the submerged portions of the skirt, drain channels, and the base ring.

Prior analytical models have predicted that the vibration modes are closely spaced. The final as-built structural predictive vibration analysis is performed prior to startup testing for correlation to final measurement results of acoustic loads measured on the steam dryer during startup testing, as elements of a comprehensive vibration assessment program described in Subsection 3L.4.6.

3L.5.5.1.4 Standby Liquid Control Lines

There are two SLC pipes that enter the reactor vessel and are routed to the shroud. To accurately predict the vibration characteristic of the SLC line, a dynamic finite element model of the entire line is developed. In the model, the ends of the line are fixed anchor points since the lines are welded at the vessel nozzle and the shroud attachment points. The SLC line is supported at six places. The top vertical segment is supported at the RPV at two places along its length; the horizontal circular segment is supported by two symmetrically placed supports at the shroud; and the two vertical segments in the bottom length are supported at the shroud by one support in each segment.

3L.5.5.2 Stress Evaluation

Table 3L-7 lists the methods that are used for each instrumented component for the FIV test program. Evaluation of all internals except the steam dryer is contained in this subsection; steam dryer structural evaluation is contained in Reference 3L-6. For this section, Method I is used for components that have many closely spaced natural vibration modes and utilizes the strain energy weighting method applied to all modes over the frequency range of interest. This method has previously been applied to the ABWR prototype plant startup tests of In-core Monitor housings, and shroud. Method II is similar to Method I, except that it is applied to two frequency bands, 0-100 Hz and 100-200 Hz. Method III is used for components that have relatively few, distinct dominant natural modes that are matched to the analytical modes. This method has previously been applied to the in-core guide tubes.

Maximum stress amplitude values for evaluation against allowable limits are determined from the test data and finite element models using one of three different evaluation methods. The method used for a particular component depends on the complexity of that component's vibration characteristics. Each of these methods yield conservatively high predictions of the maximum stress anywhere on the structure. These conservatively high stress predictions are compared against conservatively low acceptance criteria to assure that none of the components is experiencing high stress vibrations that might cause fatigue failures. The acceptable fatigue limit stress amplitude for

the reactor internals component material is 68.9 MPa (10,000 psi), with the exception of the steam dryer.

Method I is used for components that have many closely spaced vibration frequencies or closely spaced natural vibration modes distributed over a relatively narrow frequency range. The method utilizes a strain energy weighting method applied to all modes over the entire frequency range. It is applied by determining the maximum p-p amplitude from an unfiltered time history segment. This maximum value is multiplied by a combined shape factor (derived from the strain energy weighting method) and stress concentration factors (SCFs) to yield the maximum stress value that could be expected to be found anywhere on the structure. This value is then compared against the acceptable fatigue limit stress amplitude for the component and material.

Method II is used for components that have many closely spaced vibration frequencies or closely spaced natural vibration modes that are unevenly distributed over several frequency ranges. The method is very similar to Method I, except that it is applied over several separate frequency bands. The maximum stress amplitude values for each frequency band are then added together absolutely to yield a conservatively high value for the overall maximum stress amplitude that could be found anywhere on the structure. This value is then compared against the acceptable fatigue limit stress amplitude for the component and material.

Method III is used for components that have relatively few, distinct dominant natural modes that can be easily identified and matched to the modes predicted by the finite element models. This method utilizes a mode shape factor for each vibration mode that relates the stress at the sensor location to the stress at the maximum stress location for that mode. Appropriate SCFs are also considered in this process. Response spectra are generated from the sensor output, from which the equivalent maximum p-p strain amplitude for each mode can be determined. The mode shape and SCFs are applied mode by mode to determine the maximum stress amplitude associated with each mode. Then the maximum stress amplitudes from each of the modes are added together absolutely to yield a conservatively high maximum overall stress amplitude for the structure. This value is then compared against the acceptable fatigue limit stress amplitude for the component and material.

These methods have identical initial steps to obtain mode shape factors for each natural mode. The steps for these methods are as follows: (Note: The evaluation method described here relates to strain gages. Similar steps are used for accelerometers used in their displacement mode. The example assumes a maximum allowable stress amplitude for the material of 68.9 MPa (10,000 psi) for the purposes of illustration.)

1. *The dynamic finite element model of each instrumented component is used to predict the natural vibration modal displacement, frequency and stress for each vibration response mode. Specifically, the computer model provides the following results for each mode:*

   ω_i=Natural frequency for vibration mode i

   $\{\phi\}_i$=Mass normalized displacement mode shape for vibration mode i.

(Normalized such that the generalized mass, $\{\phi\}_i^T[M]\{\phi\}_i$, is unity, where [M] is the mass matrix.)

$\{\sigma\}_i$=Normalized stress distribution for vibration mode i.
(The stress corresponding to the mass normalized mode shape, $\{\phi\}_i$)

The theory and methods for calculation of these parameters may be found in text books on the subject of basic vibration analysis, such as Reference 3L-4.

2. For each vibration mode, SCFs are applied at weld locations and regions with high stress gradient. From this information, the maximum stress intensity location and value is determined for each vibration mode.

$$\sigma_{i,max} = \text{Max}\{SCF_i \bullet \sigma_i\} \text{ considered over the entire structure}$$

where

SCF_i = Stress concentration factor at some location

σ_i = Normalized stress intensity at the same location

$\sigma_{i,max}$ = Normalized maximum stress intensity for mode i

3. From the stress distribution of Step 1, a mode shape factor is derived relating the stress at the sensor to the stress at the maximum stress location as determined in Step 2:

$$MSF_i = \frac{\sigma_i(\text{at maximum stress intensity location})}{\sigma_{i,\,sensor}}$$

where

MSF_i = Mode shape factor

$\sigma_{i,sensor}$ = Normalized stress at sensor location for vibration mode i

4. The mode shape factor from Step 3 and the maximum allowable stress amplitude for the material [68.9 MPa (10,000 psi)] are used to determine the maximum allowable stress value at the sensor location for each mode.

$$\sigma_{i,sensor,allowed} = \frac{68.9\text{ MPa}}{(MSF_i) \bullet (SCF_i)}$$

where

$\sigma_{i,sensor,allowed}$ = Maximum allowed zero to peak stress amplitude at sensor location for vibration mode i (stress amplitude at sensor when maximum stress amplitude in structure is 68.9 MPa)

5. The allowable strain for mode i ($\varepsilon_{i,allowed}$) is then calculated from this maximum allowed stress amplitude at the sensor location:

$$\varepsilon_{i,\,allowed} = \frac{\sigma_{i,sensor,allowed}}{E}$$

where

E = Young's modulus [e.g., 1.86 x 10^5 MPa (27.0 x 10^6 psi) at 160°C (320°F)]

This equation is for uniaxial stress components.

At this point, Methods I and II diverge from Method III.

3L.5.5.2.1 Methods I and II

The next two steps are identical for Methods I and II.

1. A weighting factor is determined by the strain energy method, which begins by obtaining the solution to the following equation based on the expected forcing function:

$$\{U\} = q_1\{\phi\}_1 + q_2\{\phi\}_2 + \ldots = \sum_{i=1}^{N} q_i\{\phi\}_i$$

where

{U} = A vector representing the displacement response of the structure when subjected to the expected forcing function shape. This displacement response to an input forcing function is calculated from the finite element model on the computer.

$\{\phi\}_i$ = Mass normalized mode shape for vibration mode i. Mode shapes were determined from modal analysis of the finite element model. The mode shapes are normalized such that the generalized mass, $\{\phi\}_i^T[M]\{\phi\}_i$, is unity (where [M] is the mass matrix).

q_i = Mode i response, dependent on load distribution. These coefficients are calculated from the previously calculated {U} and $\{\phi\}_i$ using formulas derived from the generalized Fourier Theorem.

This is an application of the generalized Fourier Theorem, which establishes that a displacement function such as {U} can be represented by a linear sum of the eigenfunctions, $\{\phi\}_i$. The theory and methods for calculation of these coefficients may be found in text books on the subject of basic vibration analysis, such as Reference 3L-4.

2. The strain energy contribution, e_i, for each mode is then calculated:

$$e_i = \frac{1}{2} \bullet q_i^2 \bullet \{\phi\}_i^T \bullet [K] \bullet \{\phi\}_i$$

where

[K] = The structural stiffness matrix (For a more detailed explanation of the theory and calculation methods, see text books on the subject vibration analysis, such as Reference 3L-4.)

3. This step is similar for both Methods I and II, the only difference being that Method I includes the entire frequency range in one group, while Method II uses several groups of frequency ranges. Then the strain energy weighted allowable strain vibration amplitude is calculated over a given frequency range by combining the weighted strain allowable values for each mode as follows:

   For

   $$\omega_i < \omega_1, \omega_2, \ldots, \omega_n \leq \omega_{II}$$

   where

   $$\varepsilon_{II,allowed} = \frac{e_1 \cdot \varepsilon_{I,allowed} + e_2 \cdot \varepsilon_{2,allowed} + \ldots + e_n \cdot \varepsilon_{n,allowed}}{e_1 + e_2 + \ldots + e_n}$$

   $\varepsilon_{II,allowed\ formula}$ = Allowable strain value between ω_I and ω_{II}, which includes the SCF

   It should be noted that this step conservatively assumes that the highest stress of each mode occurs at the same physical location on the structure. In reality, the maximum stress locations for different modes may occur at different locations. Since the purpose of this calculation is just to confirm that the maximum stress is less than an acceptable limit, it is quite acceptable to add this conservatism. However, it should be understood that the value calculated is conservatively high, and it is not an accurate prediction of the actual stress amplitude. If a stress calculated in this manner should exceed the limit in a few situations, then a less conservative calculation can be used in those few cases.

   The strain value in the above equation is the allowable strain used during the actual execution of the test. It represents the strain level at the sensor location when the maximum stress on the structure is 68.9 MPa (10,000 psi).

4. Step 9 is the same for both Methods I and II, except that it is applied to each of the multiple frequency ranges associated with Method II; whereas, Method I is only for one frequency range. The combined shape factor is derived to relate the maximum zero-to-peak strain value measured at the sensor location to the corresponding maximum zero-to-peak stress intensity value on the structure.

   $$\sigma_{II,max} = \frac{\varepsilon_{II,measured,max}}{\varepsilon_{II,allowed}} \bullet (68.9\text{ MPa}) = \varepsilon_{II,measured,max} \bullet \mathrm{CSF}$$

   where

   $\mathrm{CSF} = \frac{(68.9\text{ MPa})}{\varepsilon_{II,allowed}}$ = Combined Shape Factor with the SCF included.

   $\sigma_{II,max}$ = Maximum zero-to-peak stress value anywhere on the structure for modes within the frequency range of ω_I to ω_{II}.

   $\varepsilon_{II,measured,max}$ = Maximum measured zero-to-peak strain (one-half of maximum measured p-p) from time history of sensor band pass filtered over the frequency range ω_I to ω_{II}.

This is the maximum zero-to-peak stress value anywhere on the structure as determined by Method I. For Method I, this value is compared to 68.9 MPa (10,000 psi) for determination of acceptability.

5. One additional step remains for Method II. The maximum stress values for each frequency band are added together using the absolute sum method to determine the overall maximum stress on the structure for comparison to the 68.9 MPa (10,000 psi) limit for the material.

$$\sigma_{MAX} = \sigma_{II,max} + \sigma_{III,max} + ...+\sigma_{N,max}$$

where

σ_{MAX} = Maximum overall zero-to-peak stress anywhere on structure as determined by Method II.

$\sigma_{N,max}$= Maximum zero-to-peak stress anywhere on structure within the frequency range of ω_{N-1} to ω_N (N-1 frequency ranges total).

σ_{MAX} is compared to the 68.9 MPa (10,000 psi) limit in order to determine acceptability under Method II.

It should be noted that this step conservatively assumes that the highest stress of each mode occurs at the same time. In reality, the maximum stress occurs at different times. Since the purpose of this calculation is just to confirm that the maximum stress is less than an acceptable limit, it is quite acceptable to add this conservatism. However, it should be understood that the value calculated is conservatively high, and it is not an accurate prediction of the actual stress amplitude. If a stress calculated in this manner should exceed the limit in a few situations, then a less conservative calculation can be used in those few cases.

3L.5.5.2.2 Method III

Method III uses the mode shape factor from Step 3, the SCF and the measured strain value to determine the maximum stress amplitude anywhere on the structure for each natural mode. Picking up after Step 5 from Subsection 3L.5.5.2:

1. *Maximum stress in the structure is calculated from the measured strain value at the sensor location.*

$$\sigma_{i,MAX} = \varepsilon_{i,measured,max} \cdot E \cdot MSF_i \cdot SCF_i$$

where

$\sigma_{i,MAX}$	=	Maximum zero-to-peak stress anywhere on structure for mode i.
$\varepsilon_{i,measured,max}$	=	Maximum zero-to-peak strain for mode i as determined from power spectrum from sensor signal.
E	=	Young's Modulus
MSF_i	=	Mode Shape Factor for mode i.

SCF_i = Stress Concentration Factor as applicable for maximum stress location for mode i.

2. The maximum stress values for each mode are added together using the absolute sum method to determine the overall maximum stress on the structure for comparison to the 68.9 MPa (10,000 psi) limit for the material.

$$\sigma_{MAX} = \sigma_{1,MAX} + \sigma_{2,MAX} + \ldots + \sigma_{N,MAX}$$

where

σ_{MAX} = Maximum overall zero-to-peak stress anywhere on structure as determined by Method III.

$\sigma_{i,MAX}$ = Maximum zero-to-peak stress anywhere on structure for mode i (n total dominant modes).

σ_{MAX} is compared to the 68.9 MPa (10,000 psi) limit in order to determine acceptability under Method III.

It should be noted that this step conservatively assumes that the highest stress of each mode occurs at the same physical location on the structure and at the same time. In reality, the maximum stress locations for different modes may occur at different locations and at different times. Since the purpose of this calculation is just to confirm that the maximum stress is less than an acceptable limit, it is quite acceptable to add these conservatisms. However, it should be understood that the value calculated is conservatively high, and it is not an accurate prediction of the actual stress amplitude. If a stress calculated in this manner should exceed the limit in a few situations, then a less conservative calculation can be used in those few cases.

In summary, all three methods involve two significant conservatisms:

- The assumption of the maximum stresses occurring at the same location in a component
- The assumption that the maximum stresses for different modes occur at the same time

Inclusion of these two significant conservatisms results in significantly higher calculated stresses.

3L.5.5.3 (Deleted)

3L.6 REFERENCES

3L-1 GE Hitachi Nuclear Energy, “Reactor Internals Flow Induced Vibration Program”, NEDE-33259P-A, Revision 3, Class III (Proprietary), October 2010, and NEDO-33259-A, Revision 3, Class I (Non-proprietary), October 2010.

3L-2 General Electric Company, “BWR Steam Dryer Integrity”, Service Information Letter (SIL) 644 Revision 2, August 30, 2006.

3L-3 ANSYS Engineering Analysis System User’s Manual, see Table 3D.1-1 for the applicable revision.

3L-4 Elements of Vibration Analysis, Leonard Meirovitch, McGraw Hill Book Co., 1975.

3L-5 GE Hitachi Nuclear Energy, "Steam Dryer - Acoustic Load Definition," NEDE-33312P, Revision 5, Class III (Proprietary), December 2013, and NEDO-33312, Revision 5 Class I (Non-Proprietary), December 2013.

3L-6 GE Hitachi Nuclear Energy, "Steam Dryer - Structural Evaluation," NEDE-33313P, Revision 5, Class III (Proprietary), December 2013, and NEDO-33313, Revision 5, Class I (Non-Proprietary), December 2013.

3L-7 (Deleted)

3L-8 GE Hitachi Nuclear Energy, "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology, PBLE01 Model Description," NEDE-33408P, Revision 5, Class III (Proprietary), December 2013, and NEDO-33408, Revision 5 Class I (Non-proprietary), December 2013.

3L-9 (Deleted)

3L-10 Regulatory Guide 1.20, "Comprehensive Vibration Assessment Program For Reactor Internals During Preoperational and Initial Startup Testing," Revision 3, March 2007.

Table 3L-1 Comparison of Typical Major Steam Dryer Configuration Parameters

Steam Dryer Configuration Parameter	ESBWR	ABWR	Replacement BWR/3
Number of Banks	6	6	6
Active height /flow area for vane modules	1918 mm (75.5 in)/ 65.6 m^2 (706 ft^2)	1848 mm (72.8 in)/ 58.8 m^2 (633 ft^2)	1852 mm (72.9 in)/ 54.3 m^2 (585 ft^2)
Approximate weight	55,400 kg (122,100 lb)	50,000 kg (110,000 lb)	45,545 kg (100,410 lb)
Outside diameter of upper support ring	6920 mm (272 in)	6808 mm (268 in)	6096 mm (240 in)
Overall height	5334 mm (210 in)	5226 mm (206 in)	4979 mm (196 in)
Length of skirt	2668 mm (105 in)	2731 mm (108 in)	2432 mm (95.8 in)
Skirt thickness	9.65 mm (0.38 in)	7 mm (0.28 in)	9.65 mm (0.38 in)
Cover plate thickness	12.7 mm (0.50 in)	16 mm (0.63 in)	12.7 mm (0.50 in)
Hood thickness	19 mm (0.75 in) - outer bank 12.7 mm (0.50 in) - inner banks	16 mm (0.63 in) - outer bank 8 mm (0.32 in) - inner banks	25.4 mm (1.0 in) - outer bank 12.7 mm (0.50 in) - inner banks
Average steamline flow velocity	47 m/s (154 ft/sec)	46 m/s (151 ft/sec)	62 m/s (203 ft/sec)

Table 3L-2 Specific Steam Dryer Load Definition Legend

Normal (N)	Normal and abnormal loads associated with the system operating conditions, including thermal loads, depending on acceptance criteria. These include deadweight, static differential pressure, and fluctuating pressure loads.
TSV	Turbine stop valve closure induced loads in the main steam piping and components integral to or mounted thereon. For the steam dryer, these include acoustic and flow impact loads. Separate load cases are evaluated for load components that are separated in time (e.g., acoustic impact and flow impact).
LOCA8	Acoustic impact loads on the steam dryer due to a postulated steamline break. Separate load cases are evaluated for load components that are separated in time (e.g., acoustic impact and level swell impact).
LOCA9	Level swell impact loads on the steam dryer due to a postulated steamline break. Separate load cases are evaluated for load components that are separated in time (e.g., acoustic impact and level swell impact).

Table 3L-3 Typical Vibration Sensors

Vibration sensor type	Typical sensor model
Strain gage	Kyowa Model KHC-10-120-G9
Accelerometer	Vibro-meter Model CA901
Dynamic pressure transducer	Vibro-meter Model CP104 or Model CP211

Table 3L-4 Sensor Locations and Types

Equipment Item	Location on Equipment	Sensor Type	Location Basis
Steam Dryer Support Ring	On top of support	Accelerometer (Acceleration Mode)	Past experience of steam dryer rocking
Steam Dryer Skirt	At bottom of steam dryer	Accelerometer (Displacement Mode)	Modal analysis
Steam Dryer Hood	Dryer bank hood and end plate	Strain Gage Pressure Transducer	Past experience of cracks at weld & to obtain forcing function data
Steam Dryer Drain Channel	At top & bottom, side edge of drain channels	Strain Gage	Modal analysis Past experience of cracks at weld
Steam Dryer Skirt	At top & bottom of skirt	Strain Gage Pressure Transducer	Modal analysis & to obtain forcing function data
Shroud	On the outside diameter near shroud bottom at maximum stress location	Strain Gage	Dynamic analysis
Separator Top	On the guide ring	Accelerometer	Past experience to measure separator motion
Vessel Dome Region	On steam dryer FIV instrument post.	Pressure Transducer	To obtain forcing function data
Chimney	On the middle of chimney at 4 different azimuths	Accelerometer	To obtain data on new design chimney vibration
Standby Liquid Control Line	Strain gages on the shroud penetration piping at the bottom along the principal stress directions Accelerometer near the end of the circular header to measure radial and tangential accelerations	Strain Gage and accelerometers	New design and dynamic analysis

(1) Vibration data for all equipment listed in Table 3L-4 will be acquired during initial startup and power ascension testing.

Table 3L-5 Applicable Data Reduction Method for Comparison to Criteria[2][3]

Component	Sensor Type	Applicable Data Reduction Method	Frequency Bandwidth (Hz)[1]
Shroud	Strain Gages	Time History	0-100
Steam Dryer Skirt	Strain Gages	Time History	0-200
Steam Dryer Skirt	Accelerometer (Displacement)	Time History	0-100
Steam Dryer Drain Channels	Strain Gages	Time History	0-100, 100-200
Steam Dryer Hoods	Strain Gages	Time History	0-100, 100-200
Steam Dryer Support Ring	Accelerometer	Time History	0-1600 0-80, 80-200
Separator Top	Accelerometer	Time History	0-100
Chimney	Accelerometer	Time History	0-200
Standby Liquid Control Lines	Strain Gages, Accelerometer	Time History	0-100

(1) It should be noted that the 200 Hz frequency range is approximate and is dependent on the SRV standpipe design. The frequency range monitored and evaluated in the FIV test program is adjusted to bound the range of frequencies determined for the final SRV standpipe design.

(2) Pressure sensors data reduction from steam dome, steam dryer skirt, and steam dryer hood are not included in this table. The pressure data from these components are discussed in Subsection 3L.4.6.

(3) For Method III, the spectrum method may be used in place of the Time History Method in cases with sufficient margin.

Table 3L-6 Parameters Used in Spectrum Generation

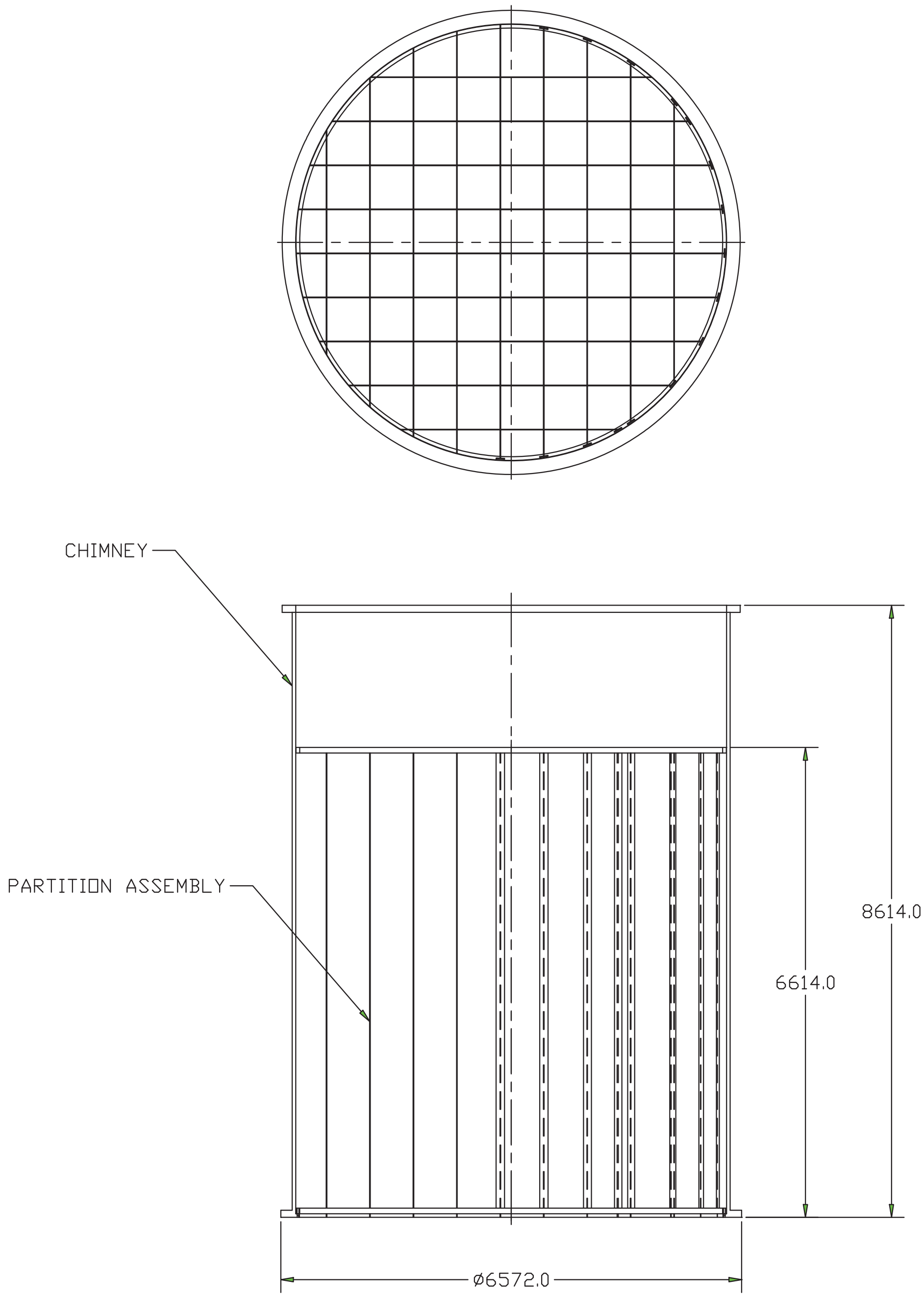
Parameter	Value
Bandwidth	0-200 Hz*
Time length	3 minutes
No. of Fourier Lines	400
Resolution	0.5 Hz
Window	Flat Top
No. of averages	90
Overlap	0%
Noise reduction	None
Average Type	Peak-hold
P-P Value	RMS x 6

* *It should be noted that the 200 Hz frequency range is approximate and is dependent on the SRV standpipe design. The frequency range monitored and evaluated in the FIV test program is adjusted to bound the range of frequencies determined for the final SRV standpipe design.*

Table 3L-7 Data Evaluation Methods to be Used for Each Component

Internal Component	Data Evaluation Method Used
Shroud and Chimney	I
Steam Dryer	See Subsection 3L.5.5.3
Standby Liquid Control Line	III

Figure 3L-1 Typical Chimney Assembly



Note: All units are in mm.

Note: All units are in mm.

Figure 3L-2 Typical Steam Dryer Assembly