Shimizu Engineering Report

Project	General Electric Company ESBWR Project	Shimizu Document No.	SER-ESB-038
Title	Modified RBFB Truncated FE Model Analysis Data	Rev.	1
		Issued Date	9/22/06
		Revised Date	9/28/06

NOTE:

This document provides the data for the truncated Reactor/Fuel Buildings Finite Element (FE) model analysis in response to NRC's request in the DCD audit for RAI 3.8 held on July, 2006.
The requested data was originally issued by SER-ESB-027. NRC reviewed it and requested some simplification and clarification. This document provides the data modified in accordance with NRC's request.
It should be noted that this revision adds information of the modified model used for the analyses to the previous revision. The last information, i.e. analysis results, will be added in the next revision in accordance with the schedule indicated by GE.

1	9/28/06	Additional of modified truncated model	Y.O.	T.T.	T.T.
0	9/22/06	Initial Issue	Y.O.	T.T.	T.T.
Rev.	Date	Note	Approve	Review	Prepare

Shimizu Corporation

Prepared by	T. Toyota	9/22/06
Reviewed by	T. Takahashi	9/22/06
Approved by	Y. Orito	9/22/06

Table of Contents

Lists of Tables

Lists of Figures

1. Scope

At NRC's audit on the ESBWR DCD RAI 3.8, NRC requested GE to provide the data needed to perform their verification analyses using a truncated Reactor Building and Fuel Building (RB/FB) Finite Element (FE) model. Per NRC's request, the data of the original truncated model analysis were provided by Reference 1. However, after reviewing of the original data, NRC requested to simplify and clarify the analysis data.

This report provides the load conditions and analysis model modified in accordance with NRC's request. NASTRAN analysis results for the modified load conditions are also included in this report.

Major modifications on the analysis data are as follows.

a. Load conditions: Loads applied to the model are simplified.

b. Analysis model: The model is modified for the following portions.

- Increase of Spent Fuel Pool slab (Basemat) thickness
- Increase of cylindrical wall thickness at the half north side under the Suppression Pool
- Addition of radial walls under the Suppression Pool

2. Reference

1. SER-ESB-027 "Reactor Building/Fuel Buildings Truncated FE Model Analysis Data," Rev. 1

3. Load Condition

Analyses are performed for the following loads.

- Dead Load
- Pressure Load (at 72 hr. after LOCA)
- Seismic Load
- Hydrostatic Load

The load conditions are summarized in Tables 3-1 through 3-5 and Figures 3-1 and 3-2. Figure 3-3 shows the names and locations of the walls in the truncated FE model.

The evaluation methods of the applied loads are described in the following sections.

It should be noted that the applied loads described in this report mean those applied to the top boundary nodes of the truncated model, i.e. boundary loads, unless noted otherwise.

In addition, loads are not applied to the cylindrical walls and radial walls under the Suppression Pool, since these walls are not connected to the RCCV wall nor RPV pedestal wall through normal rigid slabs. The walls are modeled to consider their constraint effects to the basemat.

3.1 Dead Load

Dead loads applied to the model are evaluated based on the weight of the seismic stick model. Weights of the RBFB, RCCV, and RPV pedestal in the seismic model are converted to the uniform line loads as shown in Tables 3-6 through 3-8. For the RBFB walls, the weights are distributed to each wall in proportion to its sectional area.

3.2 Seismic Load

3.2.1 *Shear Force*

Seismic shear forces are evaluated using the design seismic loads at the base of the buildings. As shown in Table 3-9, the loads for the RBFB are applied to the box walls which are parallel to the direction of the applied shear force. For the RCCV and RPV pedestal, loads are applied to the half areas of the walls as described in Tables 3-10 and 3-11.

3.2.2 *Overturning Moment*

Seismic overturning moments are evaluated based on the design seismic loads. Since the design overturning moment is defined at each floor level, the values at the top of the truncated model are calculated by the equation shown in Table 3-12.

Overturning moments are applied as vertical coupling forces to the walls perpendicular to the earthquake direction. Evaluation methods of the applied loads are shown in Tables 3-13 through 3-15.

3.2.3 *Vertical Force*

Applied loads for the vertical earthquake are determined using the maximum axial forces obtained from seismic analyses. The loads are distributed to the wall in the same manner as the dead load. Tables 3-16 through 3-18 summarize the calculation results of the vertical seismic load.

3.3 Pressure Load

Analysis is performed for the pressure load at the LOCA after 72 hr (45 psig = 0.31 MPa). The loads are applied to the inside surface of the RPV pedestal and the top surface of the Basemat as a uniform pressure load as shown Figure 3-1.

As the boundary loads at the top of model, the loads in the radial and vertical directions, which are evaluated from the results of the global FE model analysis, are applied together with pressure loads. The loads are summarized in Table 3-19 and 3-20. The loads in the hoop direction are not considered since they are negligibly small.

3.4 Hydrostatic Load

Hydrostatic load applied to the inside surfaces of Spent Fuel Pool walls and slab are shown in Figure 3-2. The boundary loads are calculated as shown in Table 3-21.

4. Modified Truncated Model

The following modifications were made for the truncated model. They are summarized in Figure 4-1.

- Increase of Spent Fuel Pool slab (Basemat) thickness
- Increase of cylindrical wall thickness at the half north side under the Suppression Pool
- Addition of radial walls under the Suppression Pool

4.1 Spent Fuel Pool slab

The region of the Spent Fuel Pool slab is shown as the dot pattern in Figure 4-1. The thickness of slab elements is increased form 4.0 m to 5.5 m as shown in Figure 4-2.

4.2 Cylindrical Wall

The cylindrical wall at the north side, i.e. from 90º to 270 º, under the Suppression Pool is indicated as the diagonal line pattern in Figure 4-1. Its thickness increased from 0.6 m to 1.4 m as shown in Figure 4-2.

4.3 Radial Wall

The radial walls shown as cross diagonal line pattern in Figure 4-1 are added to the modified truncated model. Their thicknesses are shown in Figure 4-1. The radial walls in the modified truncated model are shown in Figure 4-2.

The configurations of modified truncated model are shown in Appendix A. In the figures, node ID and element ID are indicated.

These elements are modeled as shell elements which have membrane, bending, and transverse shear stiffnesses. The modeling method of the shell element in the NASTRAN analysis is excerpted from the NASTRAN manual and attached in Appendix B for reference.

4.4 NASTRAN Analysis Input Data

Contents of NASTRAN input data provided are summarized in Tables 4-1 through 4-3.

5. Results of Analysis for Truncated model

<Later>

Table 3-1 Summary of Dead Load

Components	Wall Name	Load Value (MN/m)	Direction
Axial	RA	-2.681	Vertical (+:Upward)
	RG	-2.681	
	R1	-2.681	
	R7	-2.681	
	F3-1	-4.825	
	F3-2	-2.681	
	Iw-R1	-1.340	
	Iw-R2	-1.340	
	Iw-R3	-1.340	
	Iw-R4	-1.340	
	Iw-F1	-2.346	
	Iw-F2	-2.010	
	Iw-F3	-2.010	
	Iw-F4	-2.010	
	Iw-F5	-1.340	
	Iw-F6	-0.804	
	Iw-F7	-2.547	
	Iw-F8	-2.681	
	Iw-F9	-1.340	
	Iw-F10	-1.340	
	Iw-F11	-1.340	
	Iw-F12	-1.541	
	Iw-F13	-1.340	
	RCCV	-5.329	
	Pedestal	-4.245	

Note1: These loads are applied to top of the wall shown in the table
Note2: For the locations of walls, see Figure 3-3.

Table 3-2 Summary of Seismic Shear Force and Overturning Moment

Components	Wall Name	Load Value (MN/m)	Direction
Shear (N to S)	RA	6.693	Horizontal (+:X)
	RG	6.693	
	RCCV_ns	4.226	
	Pedestal_ns	4.719	
Shear (W to E)	R1	6.687	Horizontal (+:Y)
	R7	6.687	
	F3-1	12.036	
	F3-2	6.687	
	RCCV_ew	5.096	
	Pedestal_ew	5.688	
Moment (N to S)	R1	10.369	Vertical (+:Upward)
	R7	-1.550	
	F3-1	-12.377	
	F3-2	-6.876	
	RCCV_ew	9.933	
	Pedestal_ew	9.847	
Moment (W to E)	RA	-10.201	Vertical (+:Upward)
	RG	10.201	
	RCCV_ns	13.142	
	Pedestal_ns	12.460	

Note1: These loads are applied to top of the wall shown in the table
Note2: For the locations of walls, see Figure 3-3.

Table 3-3 Summary of Seismic Vertical Force

Components	Wall Name	Load Value (MN/m)	Direction
Vertical (Axial)	RA	1.248	Vertical (+:Upward)
	RG	1.248	
	R1	1.248	
	R7	1.248	
	F3-1	2.247	
	F3-2	1.248	
	Iw-R1	0.624	
	Iw-R2	0.624	
	Iw-R3	0.624	
	Iw-R4	0.624	
	Iw-F1	1.092	
	Iw-F2	0.936	
	Iw-F3	0.936	
	Iw-F4	0.936	
	Iw-F5	0.624	
	Iw-F6	0.375	
	Iw-F7	1.186	
	Iw-F8	1.248	
	Iw-F9	0.624	
	Iw-F10	0.624	
	Iw-F11	0.624	
	Iw-F12	0.718	
	Iw-F13	0.624	
	RCCV	3.102	
	Pedestal	2.428	

Note1: These loads are applied to top of the wall shown in the table
Note2: For the locations of walls, see Figure 3-3.

Table 3-4 Summary of Pressure Load

Components	Wall Name	Load Value (MN/m)	Direction
Radial & Vertical	RCCV	0.309	Radial (Outward: +)
		0.816	Vertical (+:Upward)
	Pedestal	0.909	Radial (Outward: +)
		-1.608	Vertical (+:Upward)

Note1: These loads are applied to top of the wall shown in the table.
Note2: Pressure loads applied to elements directly are shown in Figure 3-1.

Table 3-5 Summary of Hydrostatic Pressure Load

Components	Wall Name	Load Value (MN/m)	Direction
Horizontal	RA	0.835	+Y
	F3-1	0.835	+X
	Iw-F2	-0.835	+Y
	Iw-F3	-0.835	+Y
	Iw-F7	-0.835	+X

Note1: These loads are applied to top of the wall shown in the table.
Note2: Hydrostatic pressure loads applied to elements directly are shown in Figure 3-2.

Table 3-6 Evaluation of Dead Load for the RBFB

Load[*1] (MN)	Portion	Direction	Thickness[*2] (t: m)	Length[*2] (l: m)	Area (A: m^2)	Unit Load 1[*3] (MN/m^2)	Unit Load 2[*4] (MN/m)
-1030.315	RA	X	2.00	68.0	136.000		-2.681
	RG	X	2.00	68.0	136.000		-2.681
	R1	Y	2.00	47.0	94.000		-2.681
	R7	Y	2.00	47.0	94.000		-2.681
	F3-1	Y	3.60	16.6	59.760		-4.825
	F3-2	Y	2.00	30.4	60.800		-2.681
	Iw-R1	X	1.00	12.0	12.000		-1.340
	Iw-R2	X	1.00	12.0	12.000		-1.340
	Iw-R3	Y	1.00	12.0	12.000		-1.340
	Iw-R4	Y	1.00	12.0	12.000		-1.340
	Iw-F1	X	1.75	4.2	7.350		-2.346
	Iw-F2	X	1.50	2.1	3.150		-2.010
	Iw-F3	X	1.50	12.9	19.350		-2.010
	Iw-F4	X	1.50	8.1	12.150		-2.010
	Iw-F5	X	1.00	12.9	12.900		-1.340
	Iw-F6	X	0.60	16.8	10.080		-0.804
	Iw-F7	Y	1.90	16.6	31.540		-2.547
	Iw-F8	Y	2.00	4.1	8.200		-2.681
	Iw-F9	Y	1.00	8.4	8.400		-1.340
	Iw-F10	Y	1.00	5.5	5.500		-1.340
	Iw-F11	Y	1.00	6.8	6.800		-1.340
	Iw-F12	Y	1.15	5.5	6.325		-1.541
	Iw-F13	Y	1.00	8.4	8.400		-1.340
	Total	-	-	-	768.705	-1.340	-

*1: Load is the same value as the stick model weight.
*2: Thickness and length are dimensions in the FE Model
*3: "Unit Load 1" is the load per unit area. Unit Load 1 = Load / Total A
*4: "Unit Load 2" is the load per unit length. Unit Load 2 = Unit Load 1 * t

Table 3-7 Evaluation of Dead Load for the RCCV

Load*1 (MN)	Portion	Direction	Thickness (t: m)	Length*2 (l: m)	Unit Load*3 (MN/m)
-636.12	RCCV	-	2.00	119.4	-5.329

*1: Load is the same value as the stick model weight.
*2: Length = 19.0 (Radius of the modeled RCCV wall) * 2 * π
*3: "Unit Load" is the load per unit length. Unit Load = Load / l

Table 3-8 Evaluation of Dead Load for the RPV Pedestal

Load*1 (MN)	Portion	Direction	Thickness (t: m)	Length*2 (l: m)	Unit Load*3 (MN/m)
-181.358	Pedestal	-	2.40	42.7	-4.245

*1: Load is the same value as the stick model weight.
*2: Length = 6.8 (Radius of the modeled RPV pedestal) * 2 * π
*3: "Unit Load" is the load per unit length. Unit Load = Load / l

Table 3-9 Evaluation of the Seismic Shear Force for the RBFB

Seismic Direction	Load*1 (MN)	Portion	Direction*2	Thickness*3 (t: m)	Length*3 (l: m)	Area (A: m²)	Unit Load 1*4 (MN/m²)	Unit Load 2*5 (MN/m)
N to S	910.26	RA	X	2.00	68.0	136.000		6.693
		RG	X	2.00	68.0	136.000		6.693
		Total	-	-	-	272.000	3.347	-
W to E	1031.66	R1	Y	2.00	47.0	94.000		6.687
		R7	Y	2.00	47.0	94.000		6.687
		F3-1	Y	3.60	16.6	59.760		12.036
		F3-2	Y	2.00	30.4	60.800		6.687
		Total	-	-	-	308.560	3.343	-

*1: Load is the design seismic shear force at the bottom of the RBFB Walls.
*2: Walls in the same direction as seismic direction are considered.
*3: Thickness and length are dimensions on the FE Model
*4: "Unit Load 1" is the load per unit area. Unit Load 1 = Load / Total A
*5: "Unit Load 2" is the load per unit length. Unit Load 2 = Unit Load 1 * t

Table 3-10 Evaluation of the Seismic Shear Force for the RCCV

Seismic Direction	Load*1 (MN)	Portion*2	Direction	Thickness (t: m)	Length*3 (l: m)	Unit Load*4 (MN/m)
N to S	252.230	RCCV_ns	X	2.00	59.7	4.226
W to E	304.200	RCCV_ew	Y	2.00	59.7	5.096

*1: Load is the design seismic shear force at the bottom of RBFB Wall.
*2: For the portion where the load is applied, see Figure 3-3.
*3: Length is evaluated as effective length. Length = 19.0 (Radius on the FE Model) * 2 * π /2
*4: "Unit Load" is the load per unit length. Unit Load = Load / l

Table 3-11 Evaluation of the Seismic Shear Force for the RPV Pedestal

Seismic Direction	Load*1 (MN)	Portion*2	Direction	Thickness (t: m)	Length*3 (l: m)	Unit Load*4 (MN/m)
N to S	100.810	Pedestal_ns	X	2.40	21.4	4.719
W to E	121.510	Pedestal_ew	Y	2.40	21.4	5.688

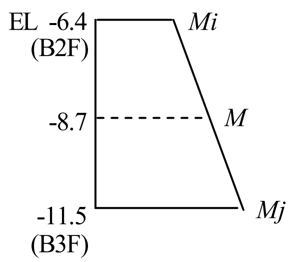
*1: Load is the design seismic shear force at the bottom of RBFB Wall.
*2: For the portion where the load is applied, see Figure 3-3.
*3: Length is evaluated as effective length. Length = 6.8 (Radius on the FE Model) * 2 * π /2
*4: "Unit Load" is the load per unit length. Unit Load = Load / l

Table 3-12 Moment of the Top of Truncated Model

	Level	Stick Model		Moment* (MNm)		
					Direction of Earthquake	
	(m)	EID	NID	#	NS	EW
RBFB	-6.4		101	*Mi*	29730	30230
	-8.7	1101		*M*	31611	32602
	-11.5		2	*Mj*	33900	35490
RCCV	-6.4		201	*Mi*	9560	12720
	-8.7	1201		*M*	10142	13419
	-11.5		2	*Mj*	10850	14270
RPV Pedestal	-6.4		301	*Mi*	1056	1350
	-8.7	1301		*M*	1288	1630
	-11.5		2	*Mj*	1570	1970

Note1: Mi, Mj: design overturning moment

Note2: Moments (M) at EL-8.7m are applied as boundary loads.
The moment (M) is calculated from the following equation.



$$M = \frac{(-6.4-(-8.7))\cdot(Mj-Mi)}{(-6.4-(-11.5))} + Mi$$

$$= \frac{2.3\cdot(Mj-Mi)}{5.1} + Mi$$

Table 3-13 Evaluation of the Seismic Moment for the RBFB

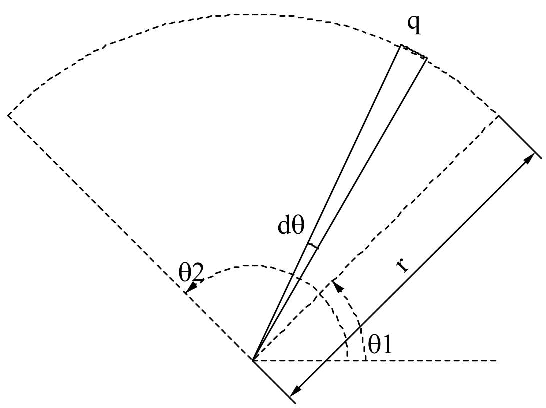
Seismic Dir.	Load[*1] (MN·m)	Portion	Thickness[*3] (t: m)	Length[*3] (l: m)	Area (A: m^2)	Distance (d0: m) R1 ~ ea. Wall C.	C. of Stiff. from R1 (m)[*4]	Distance (d: m) C.ofStiff.~Wall C.	Moment of Inertia (I: m^4)[*5]	Unit Load1[*6] (MN/m^2/m)	Unit Load2[*7] (MN/m)
N to S	31611	R1	2.00	47.0	94.000	0.00		40.887	157144		10.369
		R7	2.00	47.0	94.000	47.00		-6.113	3513		-1.550
		F3-1	3.60	16.6	59.760	68.00		-27.113	43931		-12.377
		F3-2	2.00	30.4	60.800	68.00		-27.113	44695		-6.876
		Total	-	-	308.560		40.887		249282	0.127	
W to E	32602	RA	2.00	68.0	136.000	47.00		-23.500	75106		-10.201
		RG	2.00	68.0	136.000	0.00		23.500	75106		10.201
		Total	-	-	272.000		23.500		150212	0.217	

*1: Refer to Table 3-12.
*2: Orthogonal direction walls to seismic direction are considered.
*3: Thickness and length are dimensions on the FE Model.
*4: Center of Stiffness = Σ(A*d0)/Total A
*5: Moment Inertia = A * d2
*6: Unit Load1 = Load / Total I
*7: Unit Load2 = Unit Load1 * t * d

Table 3-14 Evaluation of the Seismic Moment for the RCCV

Seismic Direction	Load*1 (MN·m)	Portion	Direction	Model Radius (*r*: m)	Unit Load*2 (*q*: MN/m)
N to S	10142	RCCV_ew	Y	19.00	9.933
W to E	13419	RCCV_ns	X	19.00	13.142

*1: Refer to Table 3-12.
*2: Unit Load = Load / (2 * 20.5 * r2) (Refer to following the figure.)



$$M = 2\int_{\theta 1}^{\theta 2} q \cdot r \cdot \sin\theta \cdot r \cdot d\theta$$

$$= 2\sqrt{2} \cdot q \cdot r^2$$

$$\therefore\ q = \frac{M}{2\sqrt{2}r^2}$$

Table 3-15 Evaluation of the Seismic Moment for the RPV Pedestal

Seismic Direction	Load*1 (MN·m)	Portion	Direction	Model Radius (r: m)	Unit Load*2 (*q*: MN/m)
N to S	1288	Pedestal_ew	Y	6.80	9.847
W to E	1630	Pedestal_ns	X	6.80	12.460

*1: Refer to Table 3-12.
*2: Unit Load = Load / (2 * 20.5 * r2) (Refer to the figure in Table 3-14.)

Table 3-16 Evaluation of the Seismic Vertical Force for the RBFB

Load[*1] (MN)	Portion	Direction	Thickness[*2] (t: m)	Length[*2] (l: m)	Area (A: m^2)	Unit Load 1[*3] (MN/m^2)	Unit Load 2[*4] (MN/m)
479.840	RA	X	2.00	68.0	136.000		1.248
	RG	X	2.00	68.0	136.000		1.248
	R1	Y	2.00	47.0	94.000		1.248
	R7	Y	2.00	47.0	94.000		1.248
	F3-1	Y	3.60	16.6	59.760		2.247
	F3-2	Y	2.00	30.4	60.800		1.248
	Iw-R1	X	1.00	12.0	12.000		0.624
	Iw-R2	X	1.00	12.0	12.000		0.624
	Iw-R3	Y	1.00	12.0	12.000		0.624
	Iw-R4	Y	1.00	12.0	12.000		0.624
	Iw-F1	X	1.75	4.2	7.350		1.092
	Iw-F2	X	1.50	2.1	3.150		0.936
	Iw-F3	X	1.50	12.9	19.350		0.936
	Iw-F4	X	1.50	8.1	12.150		0.936
	Iw-F5	X	1.00	12.9	12.900		0.624
	Iw-F6	X	0.60	16.8	10.080		0.375
	Iw-F7	Y	1.90	16.6	31.540		1.186
	Iw-F8	Y	2.00	4.1	8.200		1.248
	Iw-F9	Y	1.00	8.4	8.400		0.624
	Iw-F10	Y	1.00	5.5	5.500		0.624
	Iw-F11	Y	1.00	6.8	6.800		0.624
	Iw-F12	Y	1.15	5.5	6.325		0.718
	Iw-F13	Y	1.00	8.4	8.400		0.624
	Total	-	-	-	768.705	0.624	-

*1: Load is the maximum axial force of dynamic analysis by the stick model.
*2: Thickness and length are dimensions on the FE Model
*3: "Unit Load 1" is the load per unit area. Unit Load 1 = Load / Total A
*4: "Unit Load 2" is the load per unit length. Unit Load 2 = Unit Load 1 * t.

Table 3-17 Evaluation of the Seismic Vertical Force for the RCCV

Load*1 (MN)	Portion	Direction	Thickness (t: m)	Length*2 (l: m)	Unit Load*3 (MN/m)
370.300	RCCV	-	2.00	119.4	3.102

*1: Load is the maximum axial force obtained from the stick model seismic analysis.
*2: Length = 19.0 (Radius on the FE Model) * 2 * π
*3: "Unit Load" is the load per unit length. Unit Load = Load / l

Table 3-18 Evaluation of the Seismic Vertical Force for the RPV Pedestal

Load*1 (MN)	Portion	Direction	Thickness (t: m)	Length*2 (l: m)	Unit Load*3 (MN/m)
103.750	Pedestal	-	2.40	42.7	2.428

*1: Load is the maximum axial force obtained from the stick model seismic analysis.
*2: Length = 6.8 (Radius on the FE Model) * 2 * π
*3: "Unit Load" is the load per unit length. Unit Load = Load / l

Table 3-19 Evaluation of the Pressure Load for the RCCV

Average Force (MN/node)		Nodal Tributary Length (L: m)	Unit Load (MN/m)	
Radial	Vertical		Radial	Vertical
0.768	2.031	2.487	0.309	0.816

Note1: Average Forces are calculated from nodal force at EL -8.7m of the global FE model analysis
Note2: L = 19.0(Radius of the modeled RCCV wall) * 2 * π / 48(nodes)
Note3: Unit Load = [Average Force] / L

Table 3-20 Evaluation of the Pressure Load for the RPV Pedestal

Average Force (MN/node)		Nodal Tributary Length (L: m)	Unit Load (MN/m)	
Radial	Vertical		Radial	Vertical
0.809	-1.432	0.890	0.909	-1.608

Note1: Average Forces are calculated from nodal force at EL -8.7m of the global FE model analysis
Note2: L = 6.8(Radius of the modeled RPV pedestal) * 2 * π / 48(nodes)
Note3: Unit Load = [Average Force] / L

Table 3-21 Evaluation of the Hydrostatic Pressure Load for the Spent Fuel Pool

Spent Fuel Pool			Truncated Model		
Top (EL. m)	Bottom (EL. m)	Depth (m)	Model Top (EL. m)	Depth above Model d (m)	Boundary Load* L (MN/m)
4.35	-10.00	14.35	-8.7	13.05	0.835

*: Boundary Load is calculated following equation. (Refer to Figure 3-2.)

L = 1.0(t/m3) * d / 9.807 * d / 2

Table 4-1 NASTRAN Control Data Files

Load	Control Data File	Note
Dead Load	DL.dat	
Seismic Load	EQNS.dat	Shear (N to S)
	EQEW.dat	Shear (W to E)
	EMNS.dat	Moment (N to S)
	EMEW.dat	Moment (W to E)
	EQZ.dat	Vertical
Pressure Load	PL.dat	
Hydrostatic Load	FL.dat	

Table 4-2 NASTRAN Model Data Files

	Model Data File	Note
Common	cood	Coordinate System Definition
	node_truncated.txt	Grid points (Building)
	soil_node.prn	Grid points (Soil)
	elem_truncated.txt	Shell and bar elements
	rbar_truncated.txt	Rigid bar
	pshell_truncated.txt	Properties of shell elements.
	pbar_truncated.txt	Properties of bar elements.
	mat_truncated.txt	Material properties
Soil Spring	elas_o.prn	Soil spring for vertical loads
	elas_s.prn	Soil spring for horizontal loads

Table 4-3 NASTRAN Load Data Files

Load	Load Data File	Note	Reference Table and Figure
Dead Load	DL.prn	Vertical Force at Top of Model	Table 3-1
Seismic Load	EQNS.prn	Shear Force (NS) at Top of Model	Table 3-2
	EQEW.prn	Shear Force (WE) at Top of Model	Table 3-2
	EMNS.prn	Moment (NS) Top of Model	Table 3-2
	EMEW.prn	Moment (WE) at Top of Model	Table 3-2
	EQZ.prn	Vertical Force at Top of Model	Table 3-3
Pressure Load	PL.prn	Pressure at Top of Model	Table 3-4 Figure 3-1
	pl_truncated.txt	Pressure inside RPV Pedestal	
Hydrostatic Load	FL.prn	Pressure at Top of Model	Table 3-5 Figure 3-2
	fl_truncated.txt	Pressure inside SF Pool	

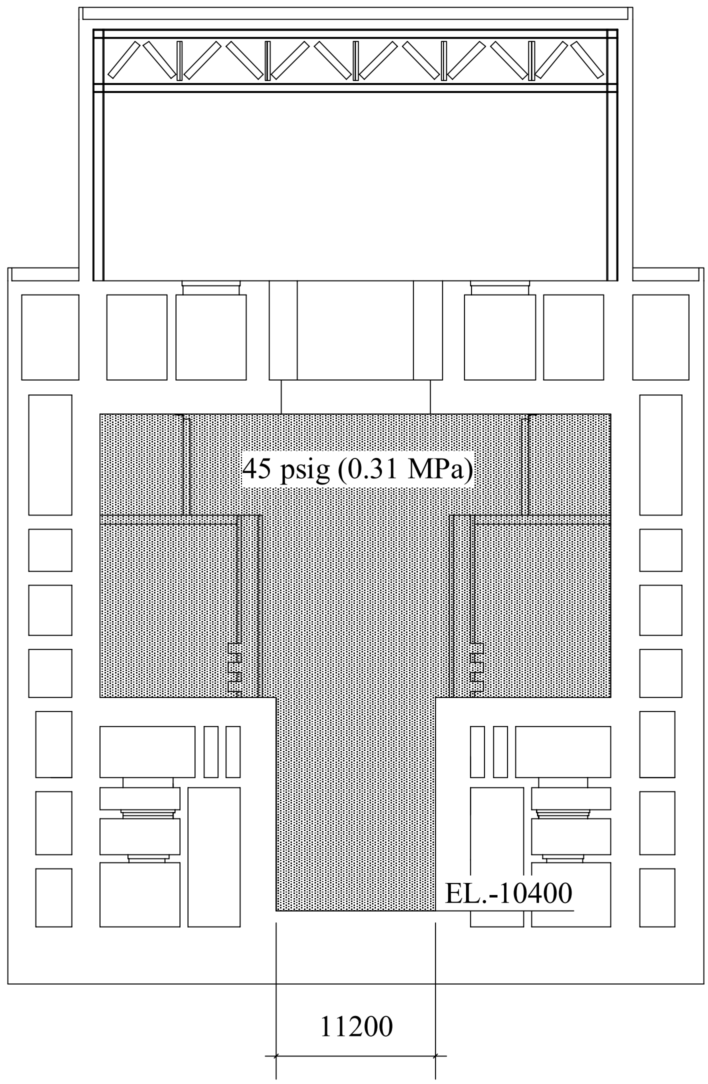


Figure 3-1 Pressure Load Applied to the RCCV Wall and the Basemat at 72 hr. after LOCA

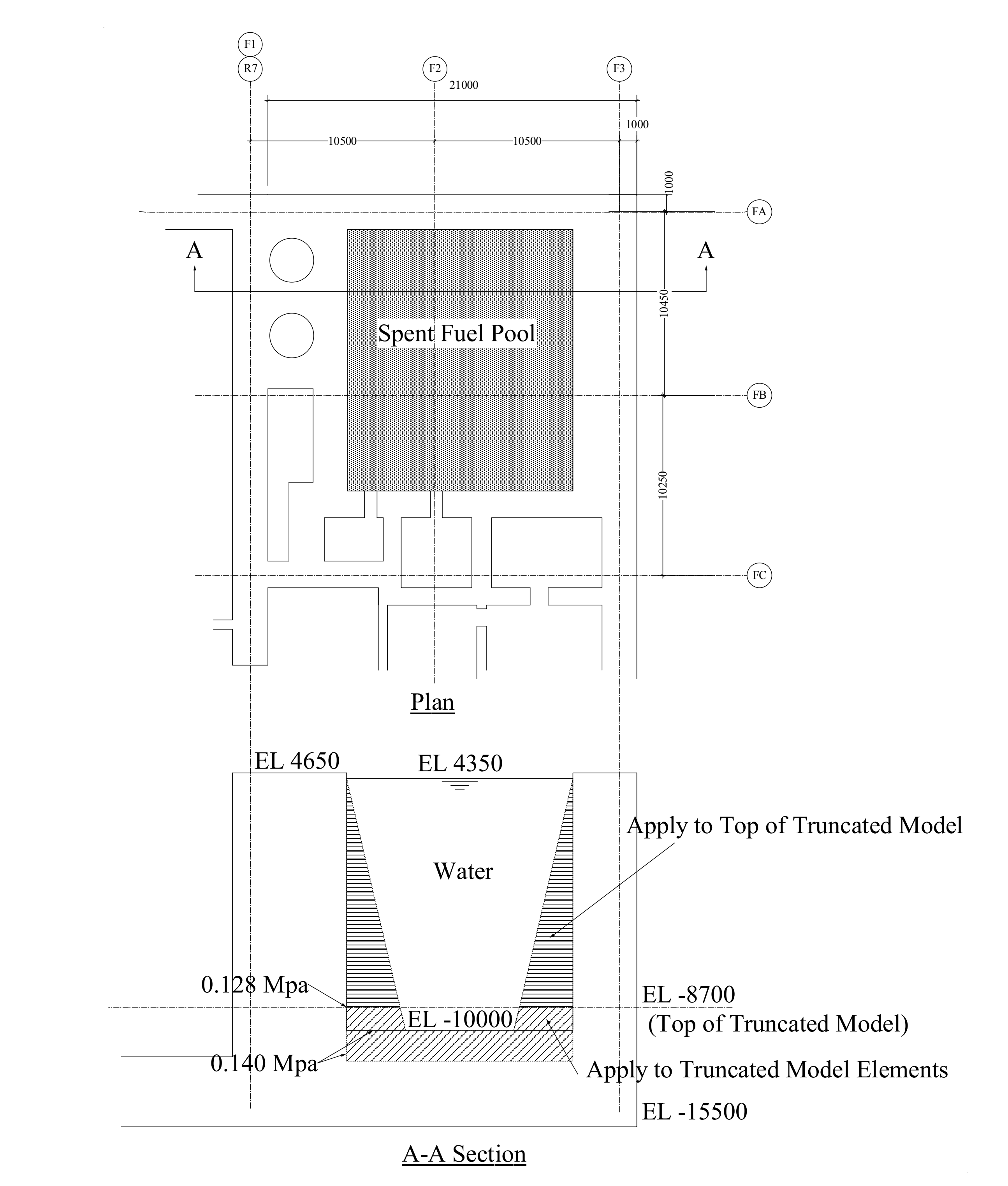


Figure 3-2 Hydrostatic Load Applied to the Spent Fuel Pool Walls and the Basemat

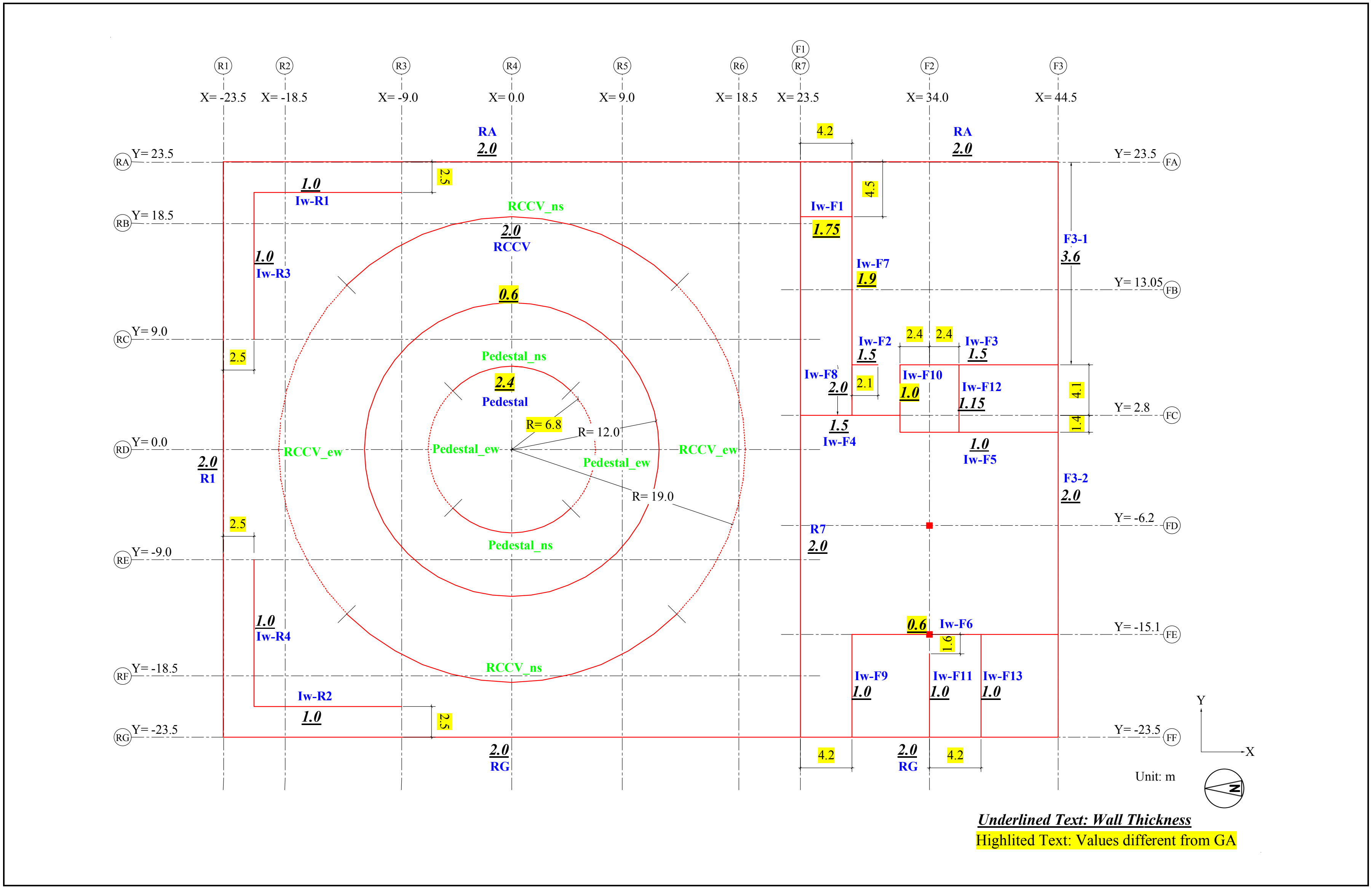


Figure 3-3 Wall Information of Truncated Model

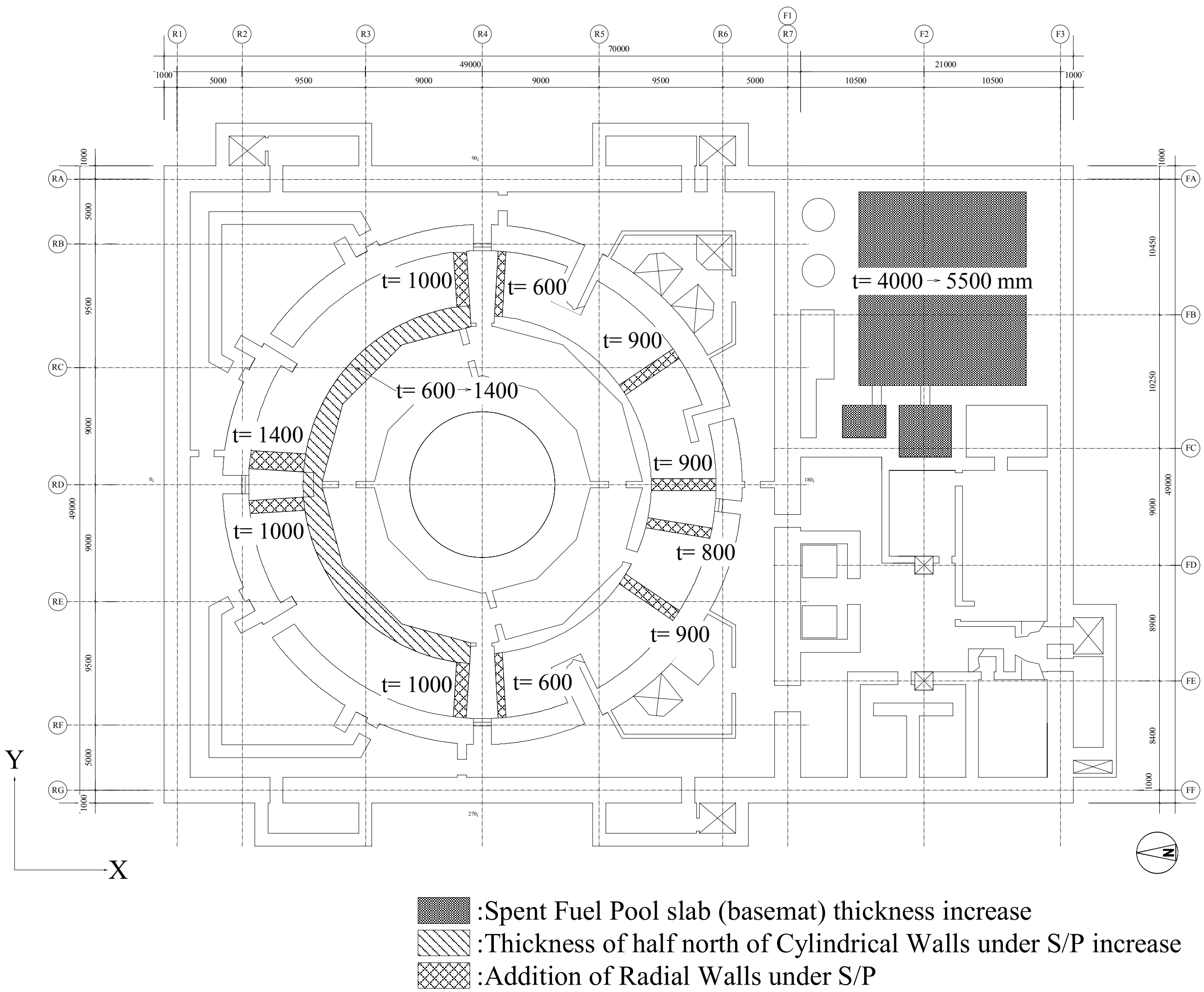


Figure 4-1 Modification in Truncated Model

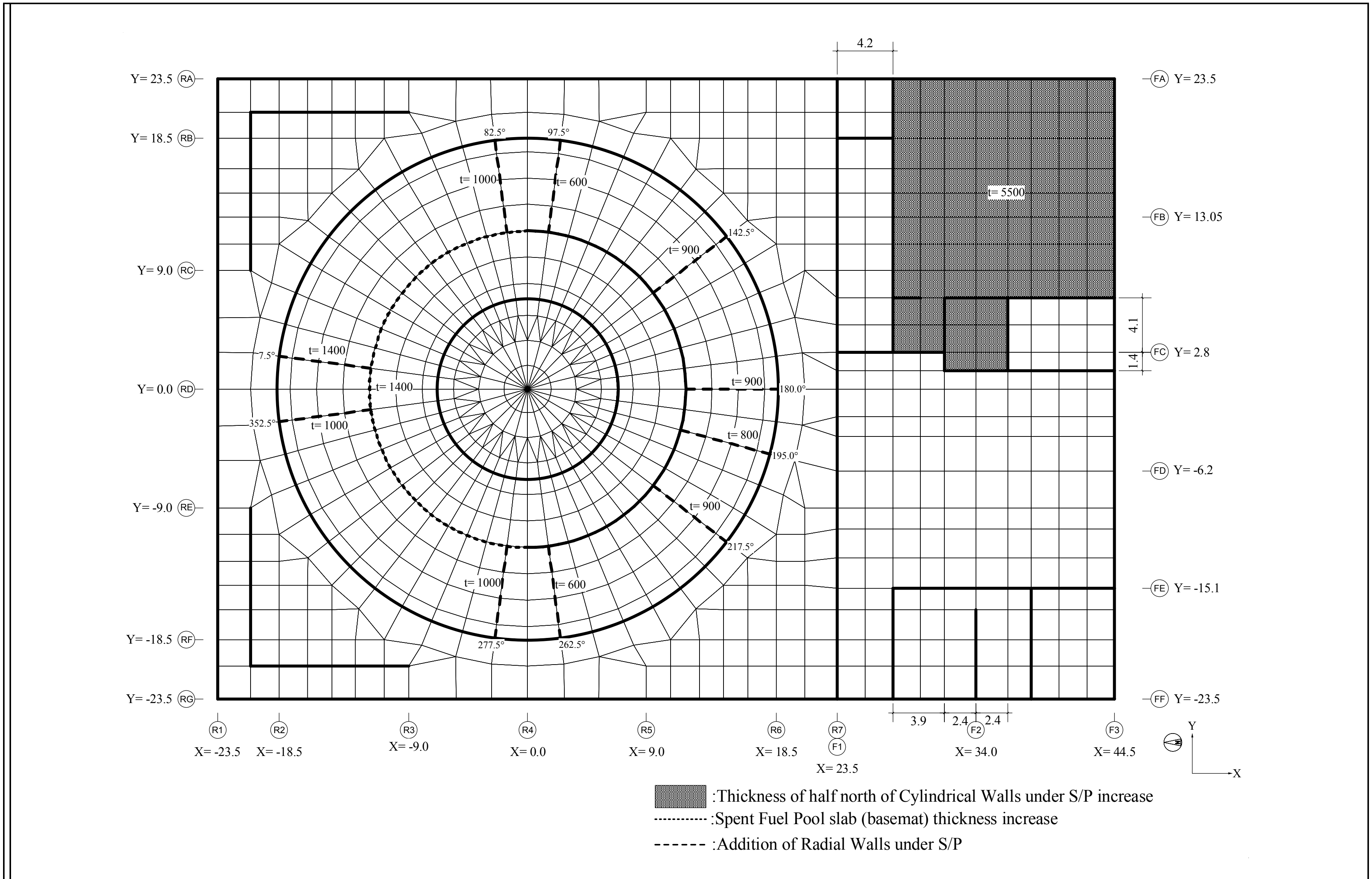
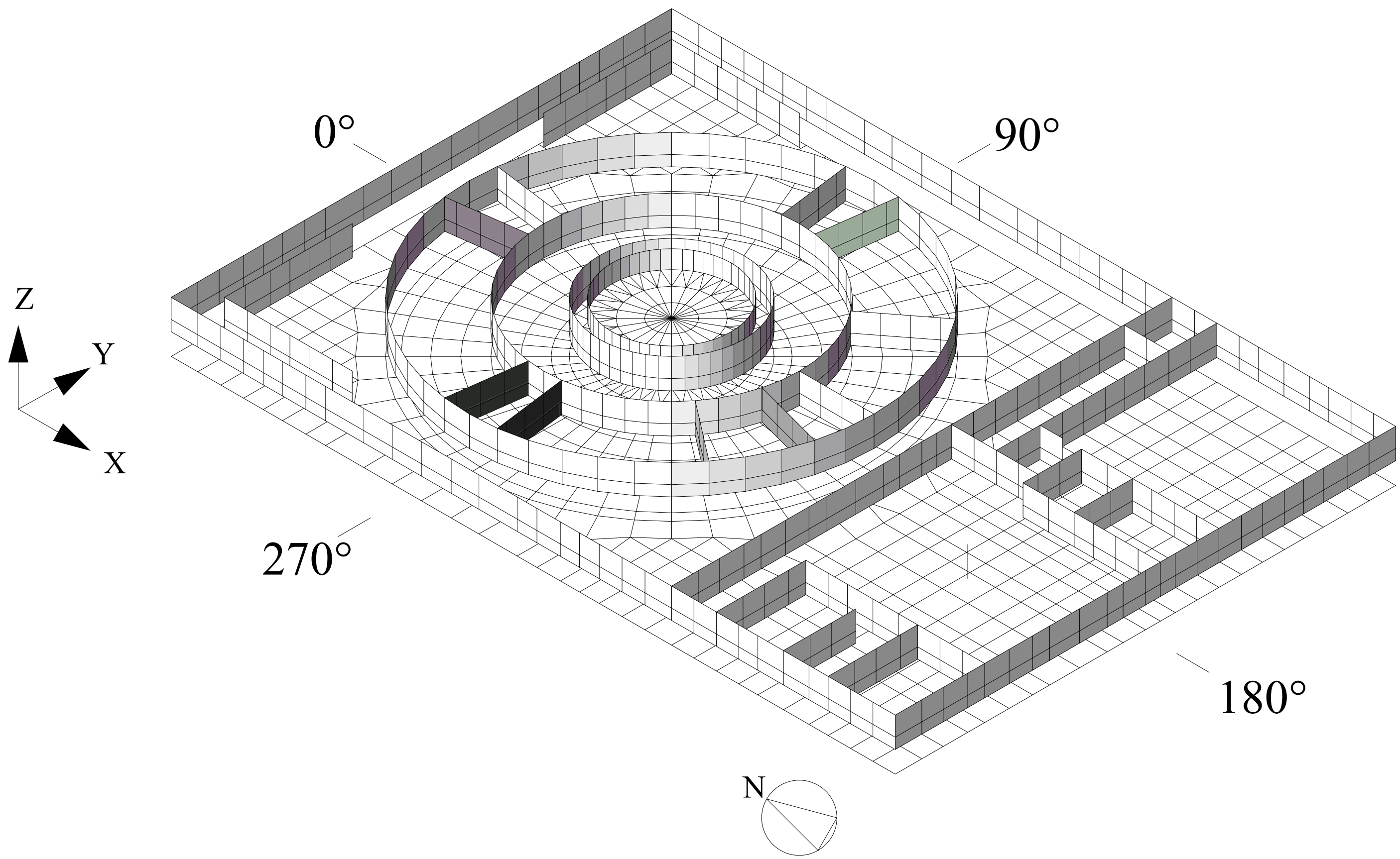
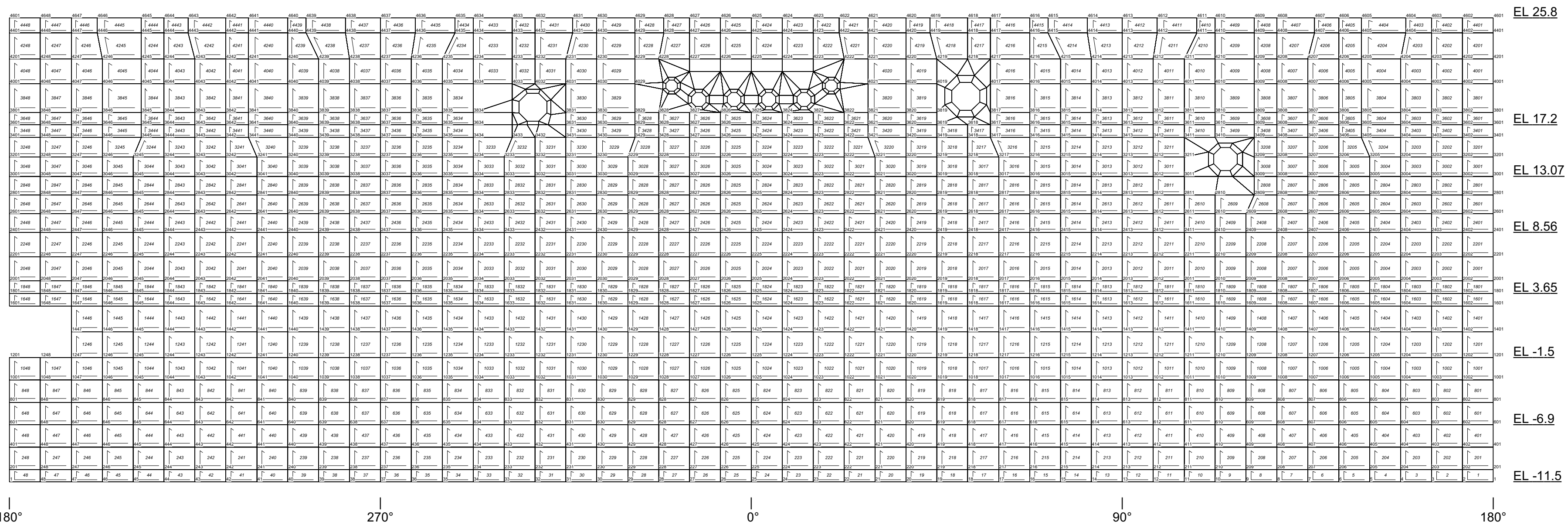


Figure 4-2 Modified Truncated Model

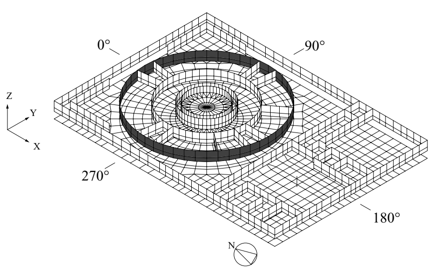
Appendix A　Figures of Analysis Model



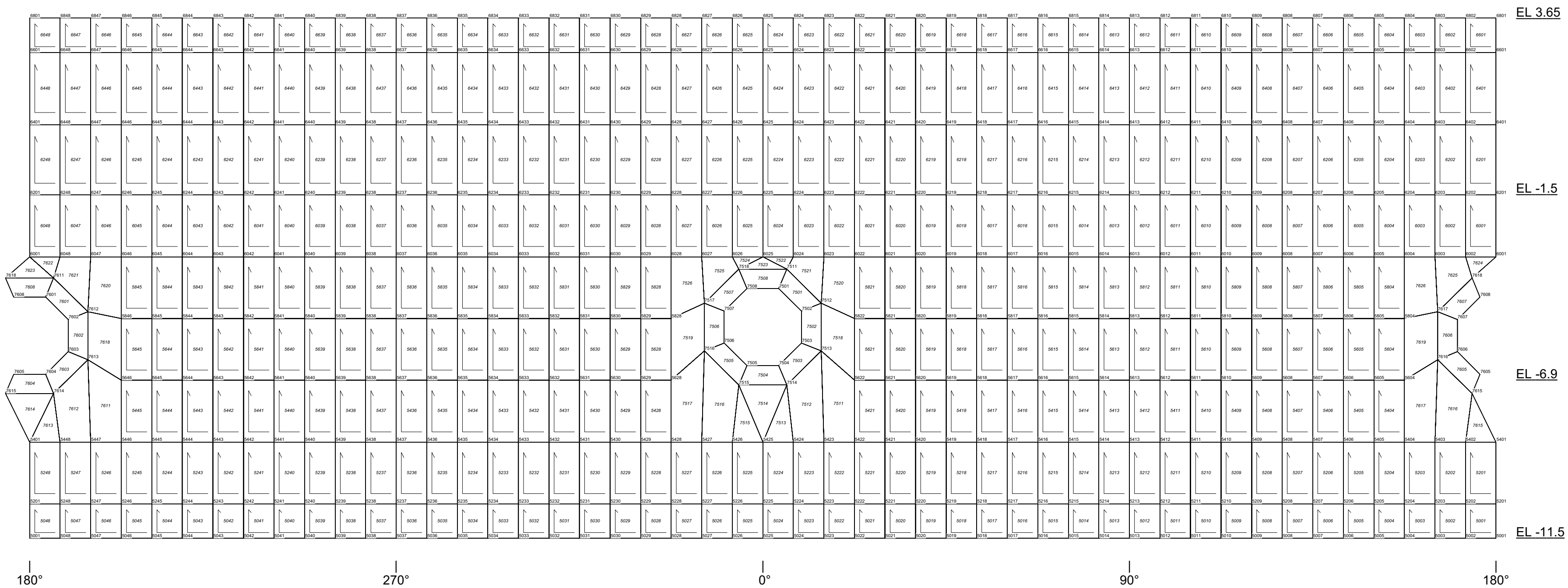
Modified Truncated Model



View: from Inside to Outside

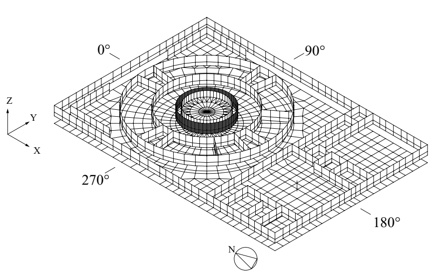


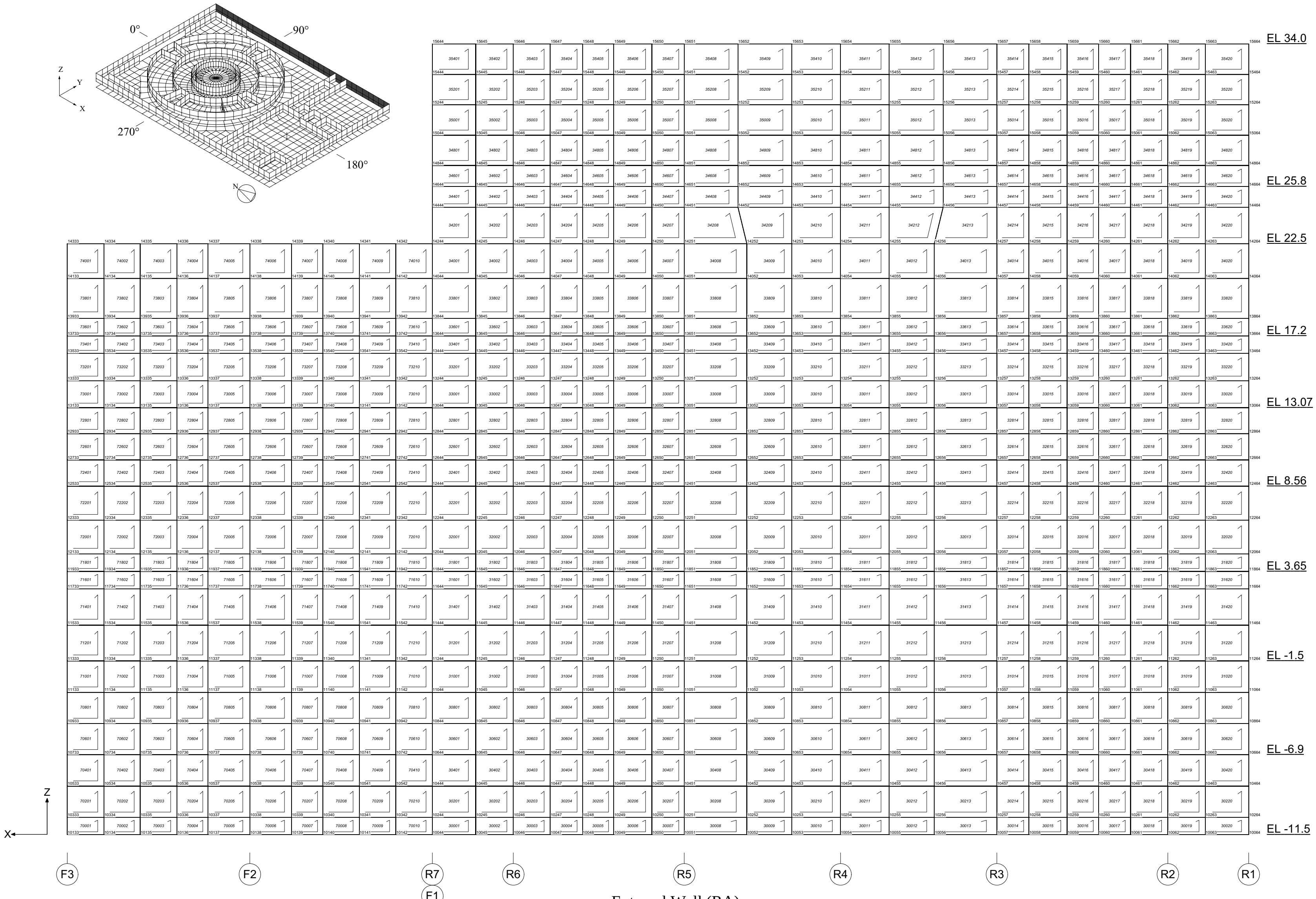
RCCV & Cylinder Wall below RCCV



View: from Inside to Outside

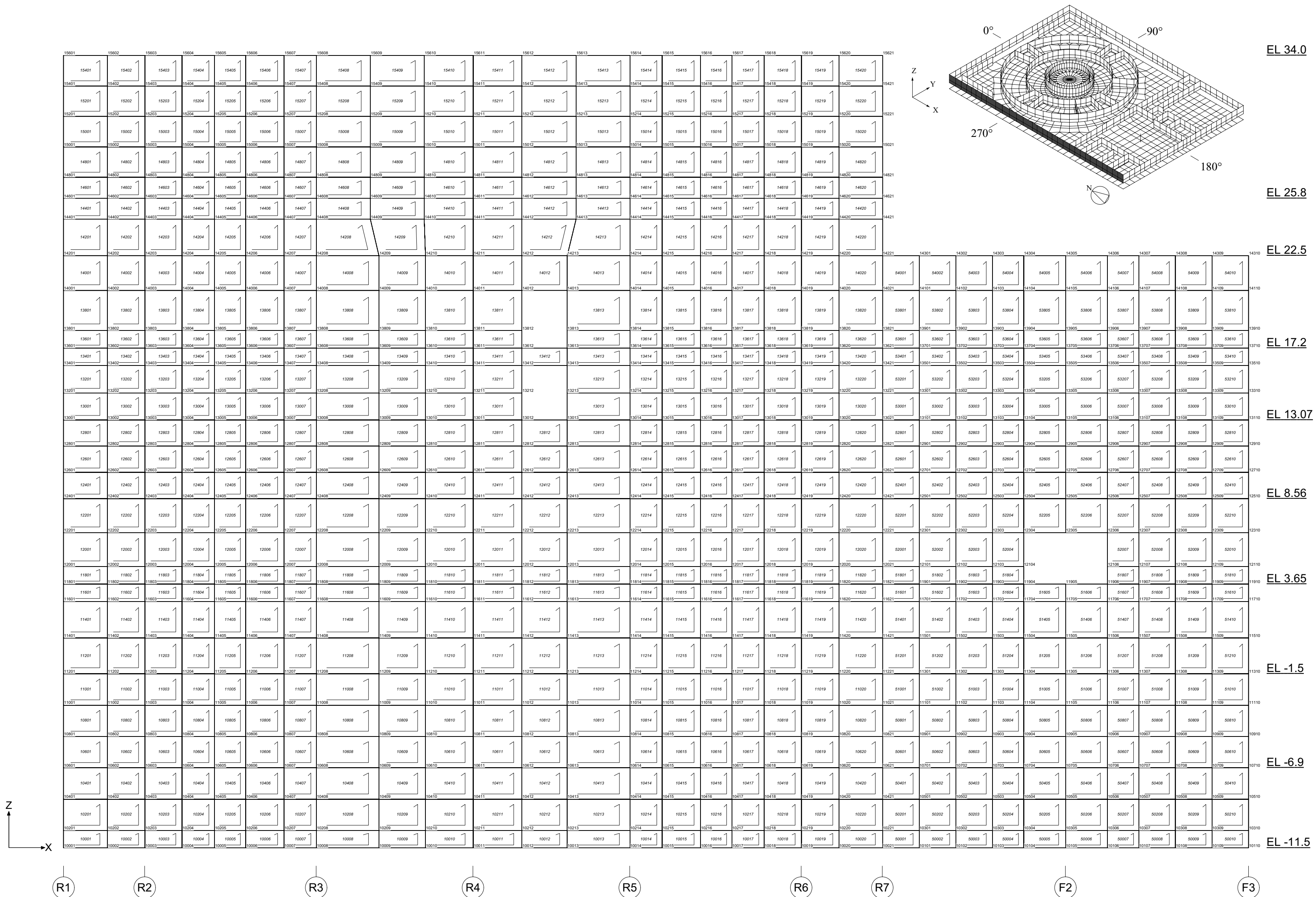
RPV Pedestal





External Wall (RA)

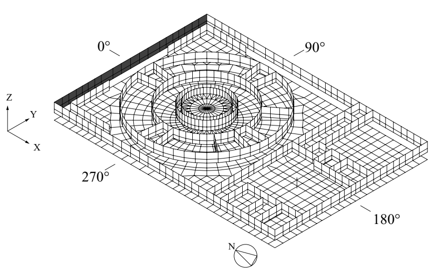
View: from Outside (East) to Inside (West)

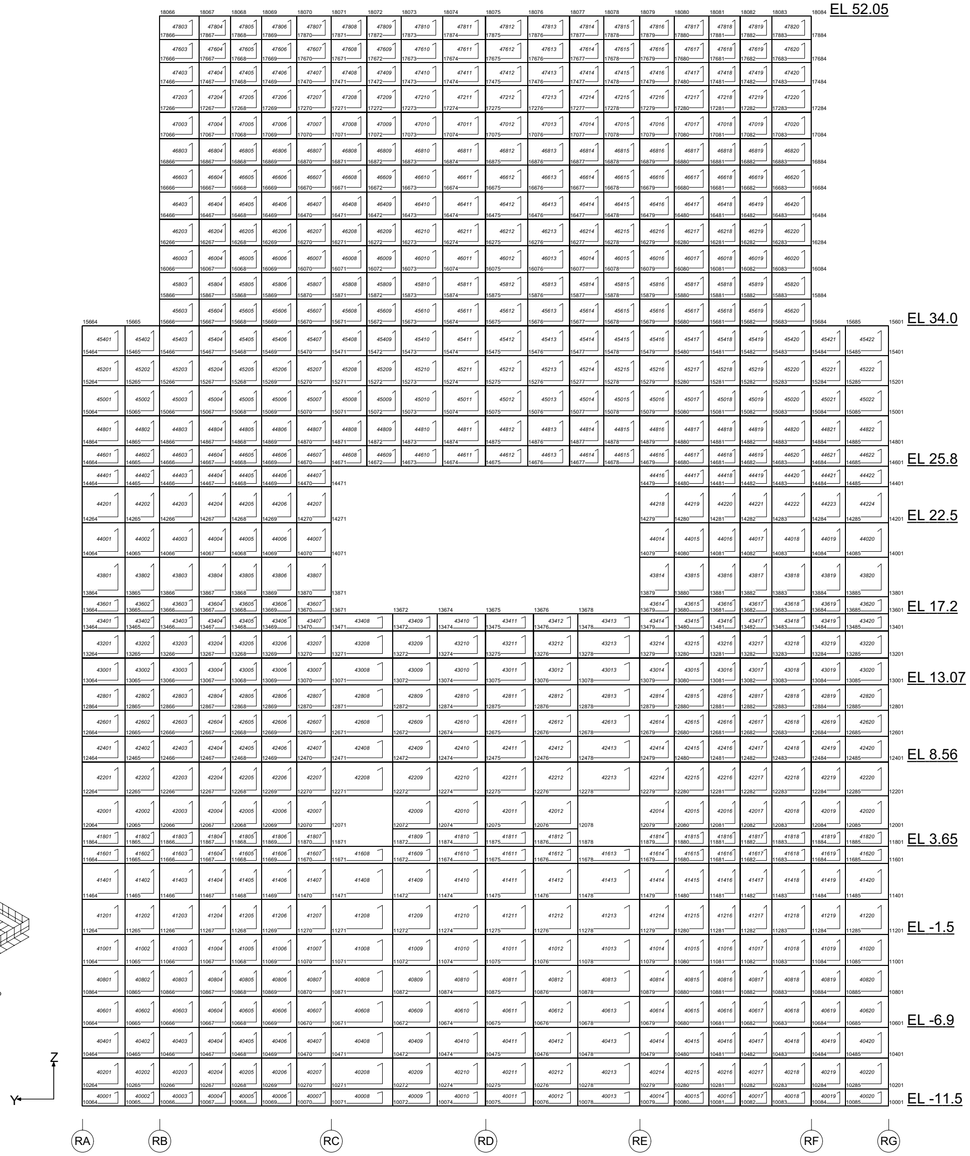


External Wall (RG)

A-5

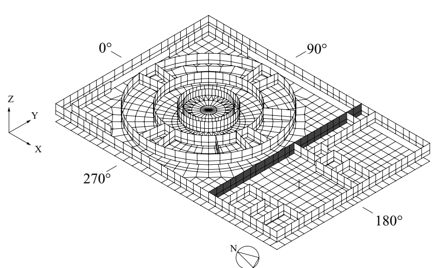
View: from Outside (West) to Inside (East)

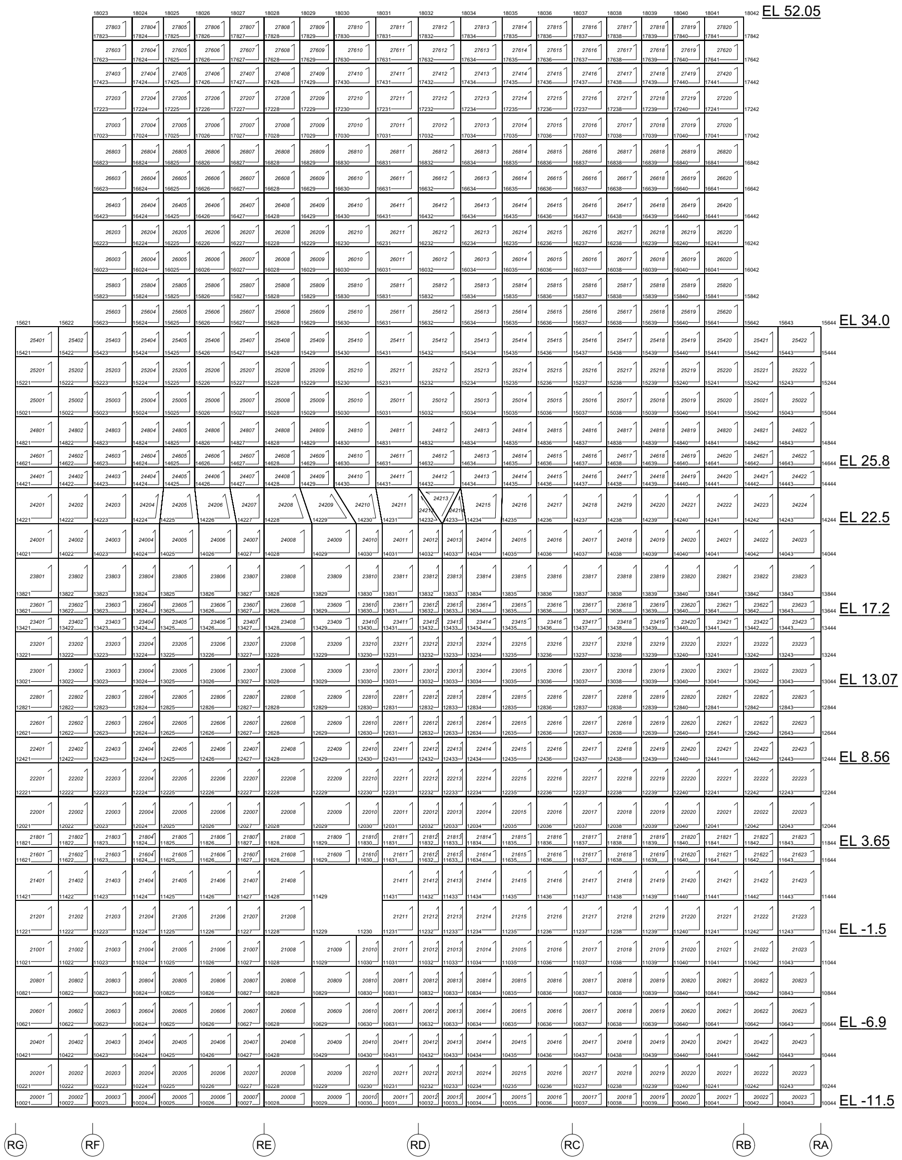




View: from Outside (North) to Inside (South)

External Wall (R1)
A-6

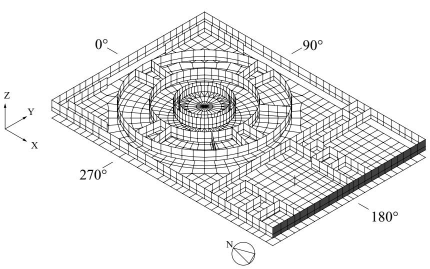


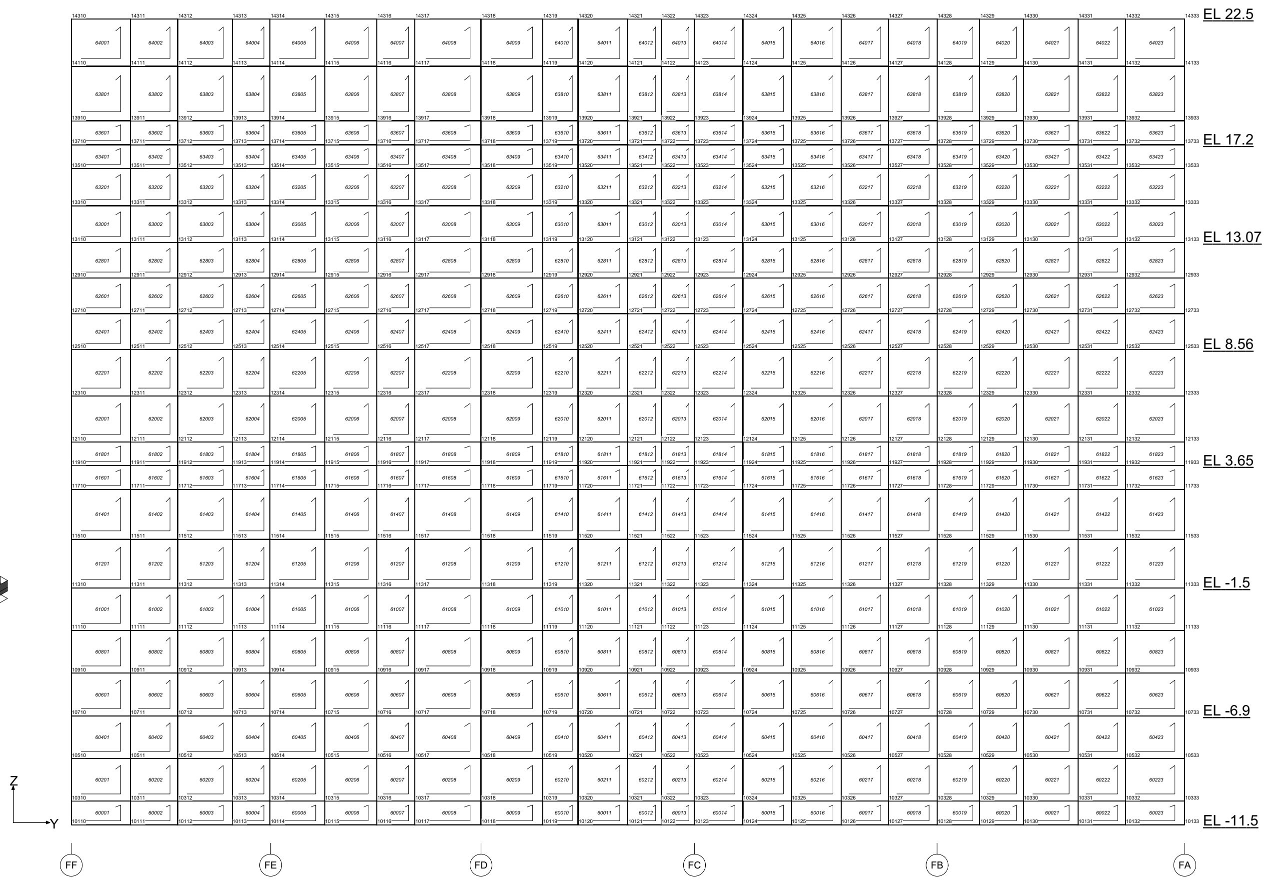


View: from FB (South) to RB (North)

External Wall (R7)

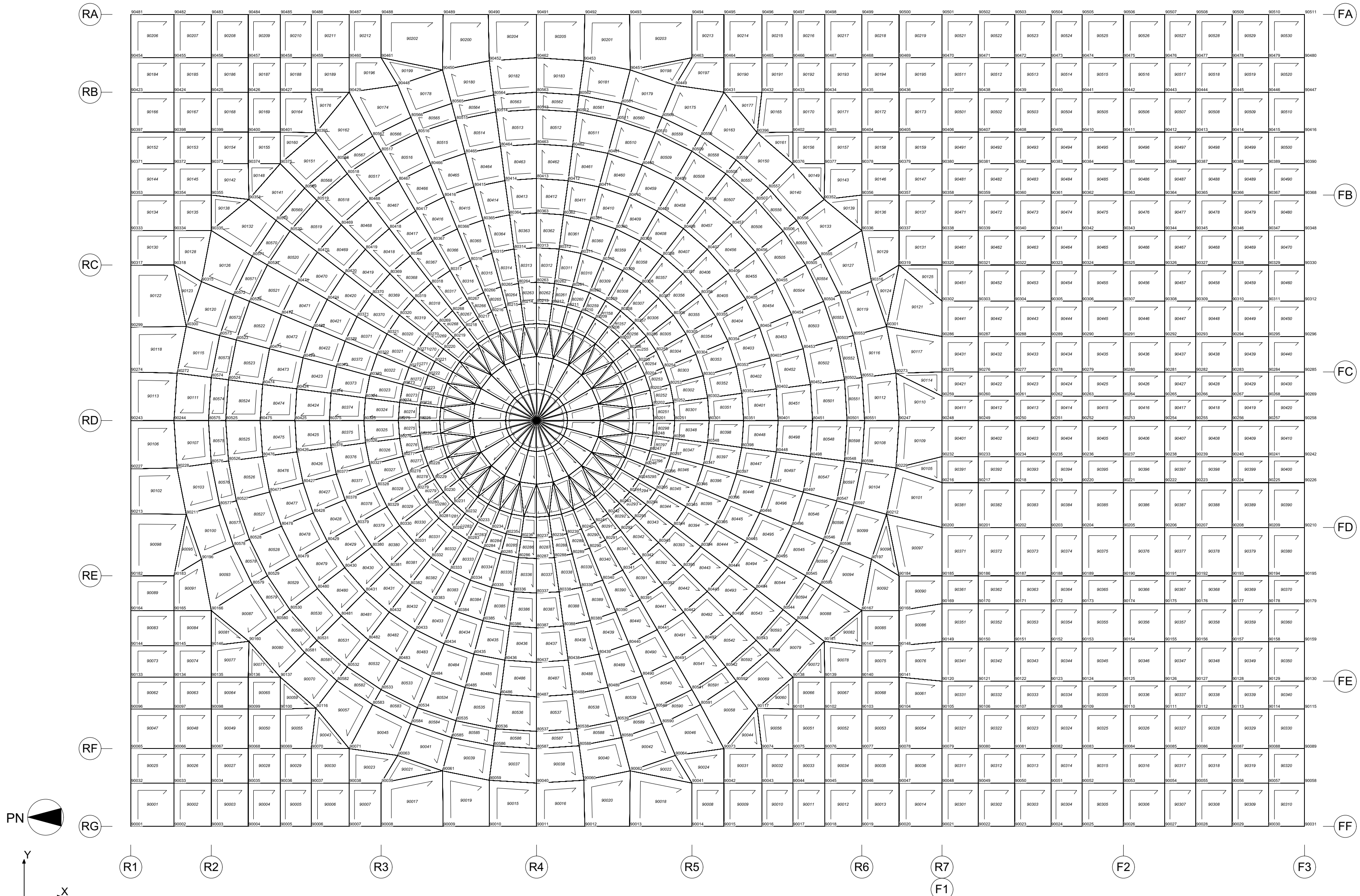
A-7





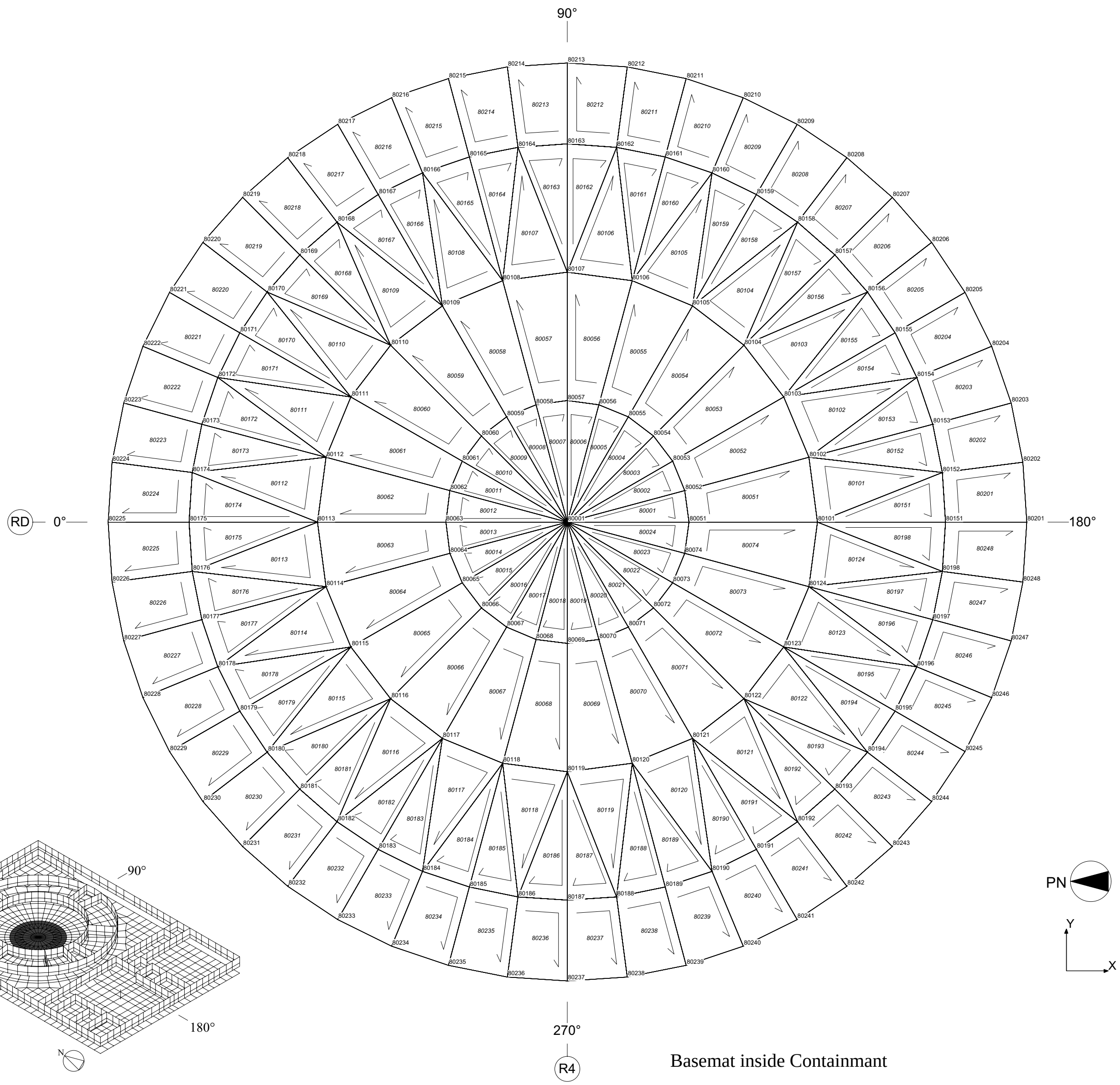
View: from Outside (South) to Inside (North)

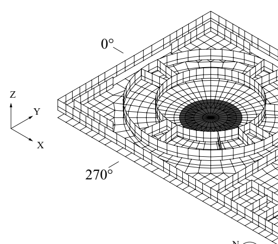
External Wall (F3)



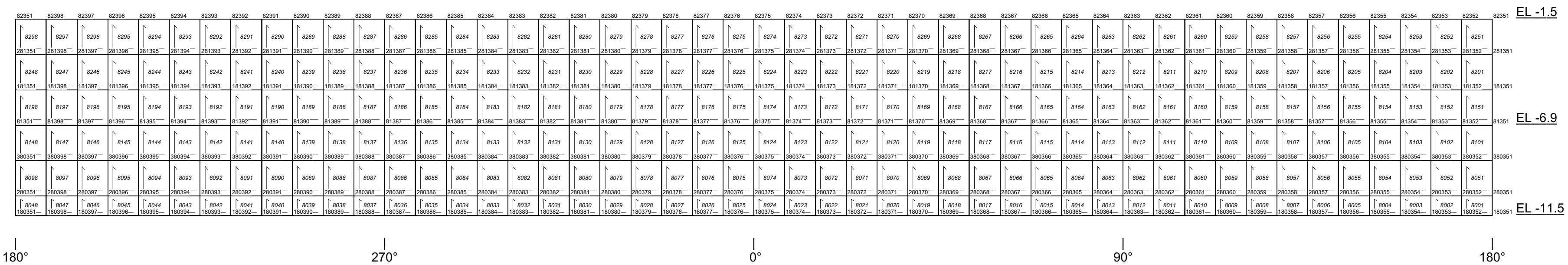
Basemat

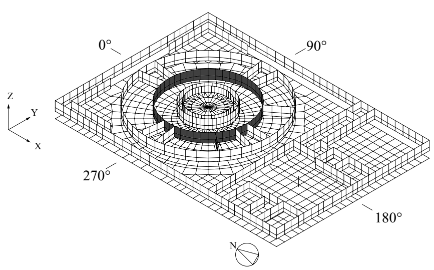
A-9





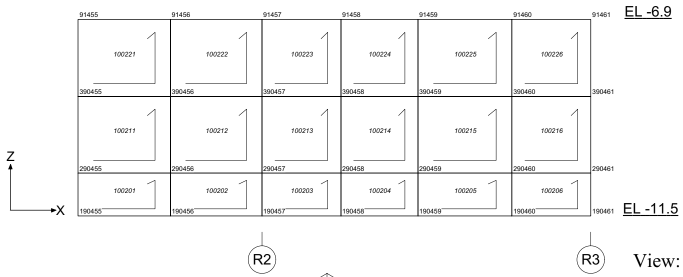
Basemat inside Containmant



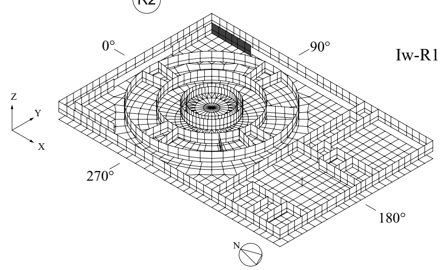


View: from Inside to Outside

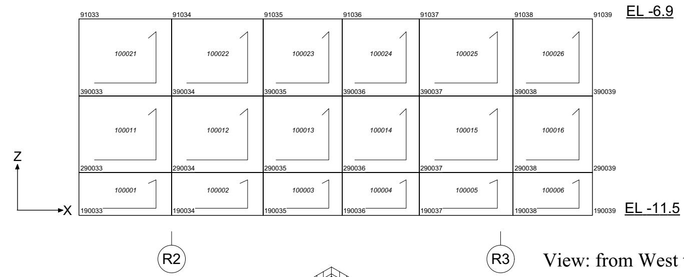
Cylindrical Inner Wall



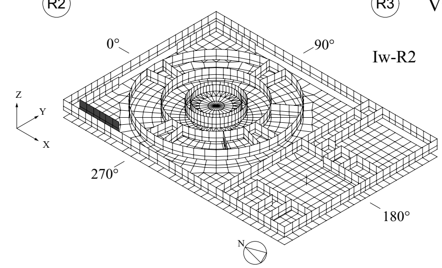
View: from West to East



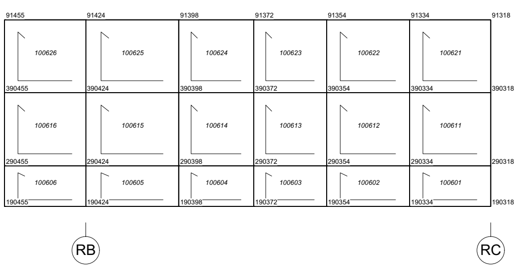
Iw-R1



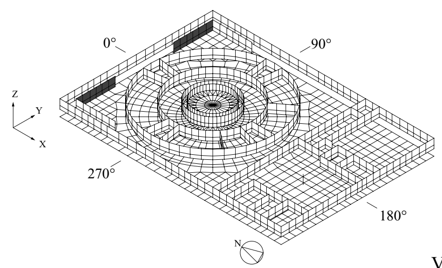
View: from West to East

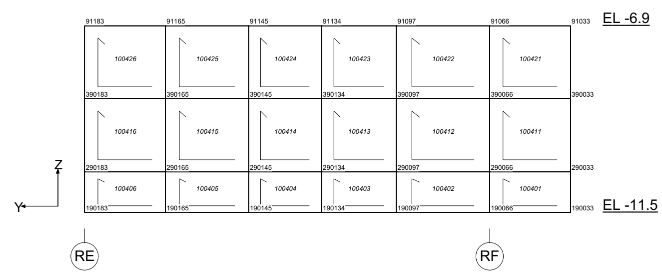


Iw-R2



Iw-R3

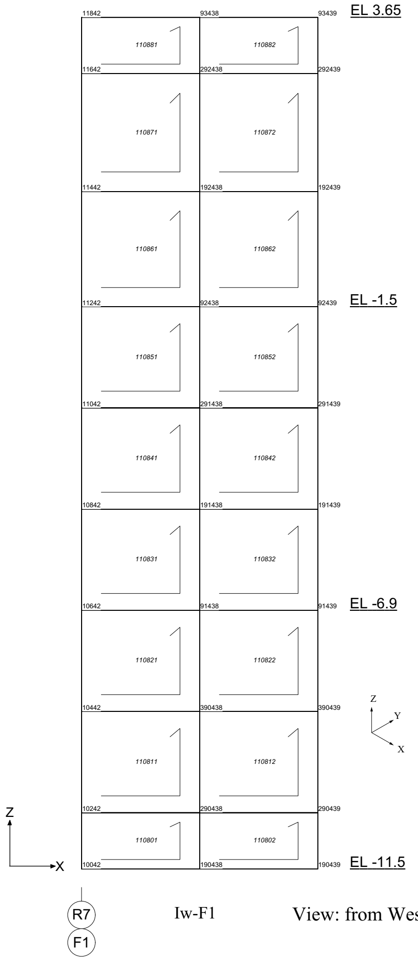




Iw-R4

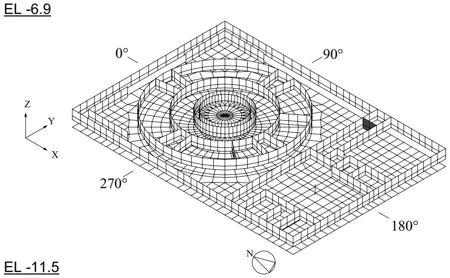
View: from North to South

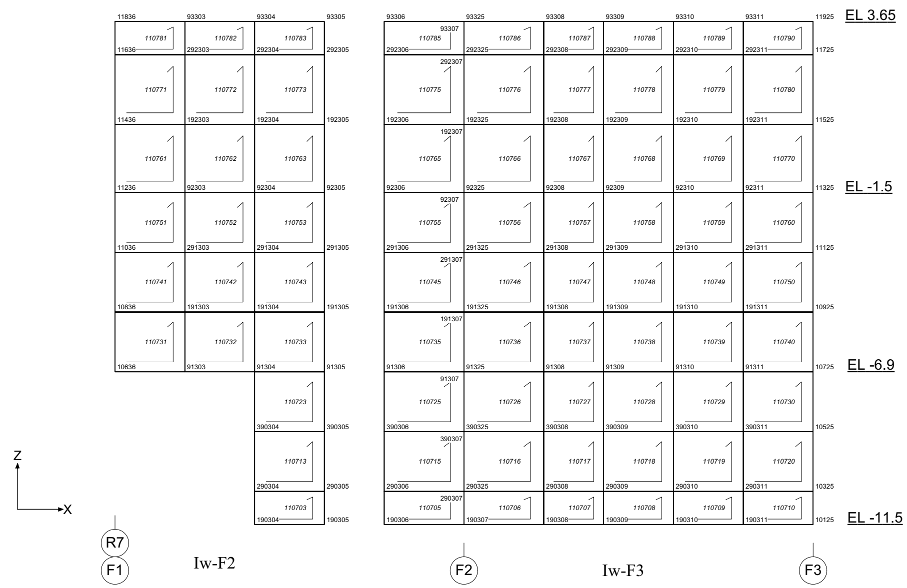
Inner Wall (in Reactor Building)



Iw-F1

View: from West to East

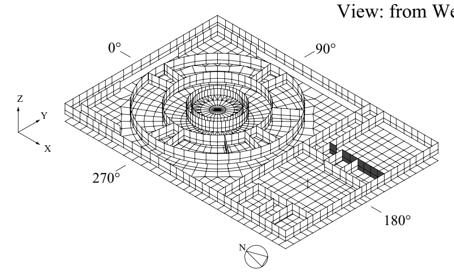




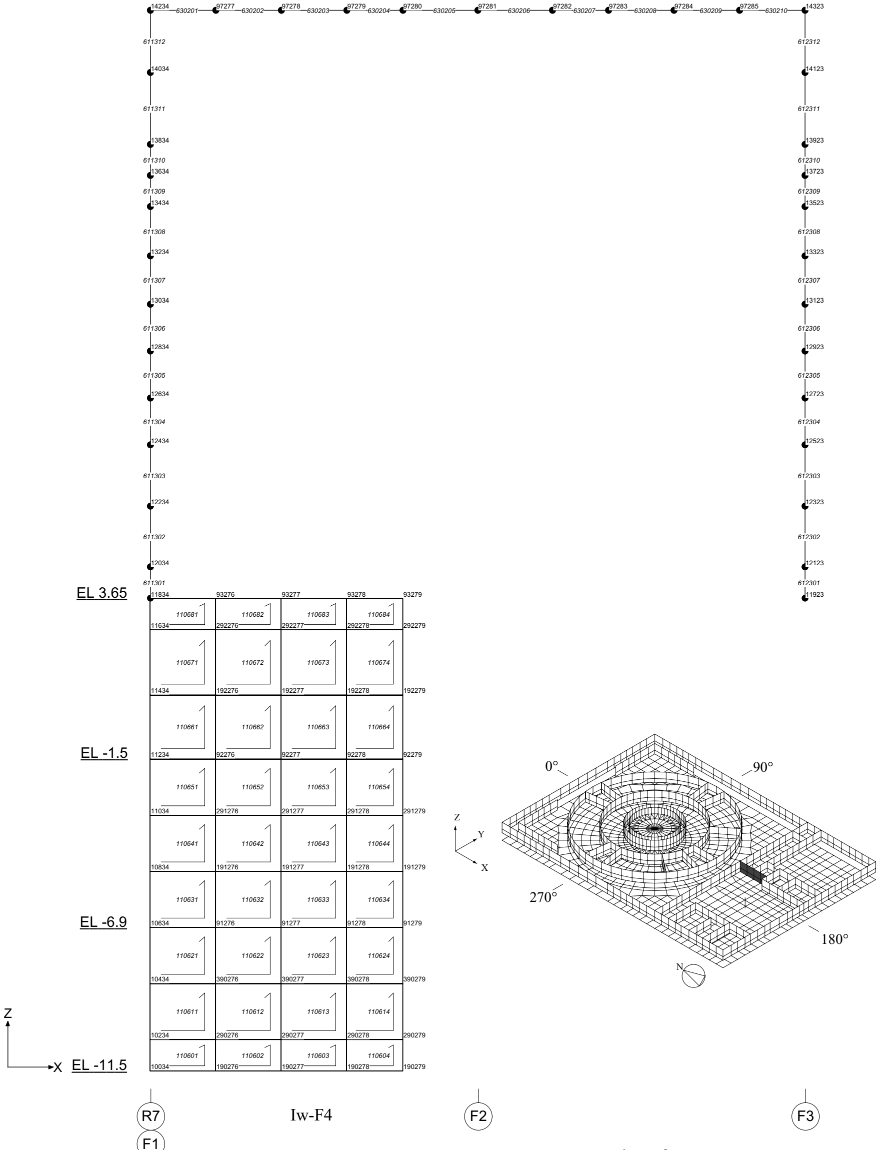
Iw-F2

Iw-F3

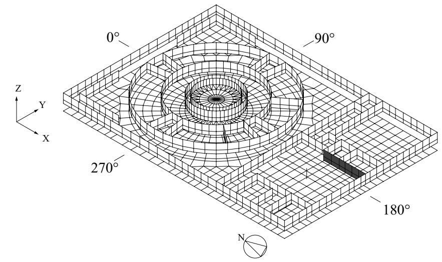
View: from West to East

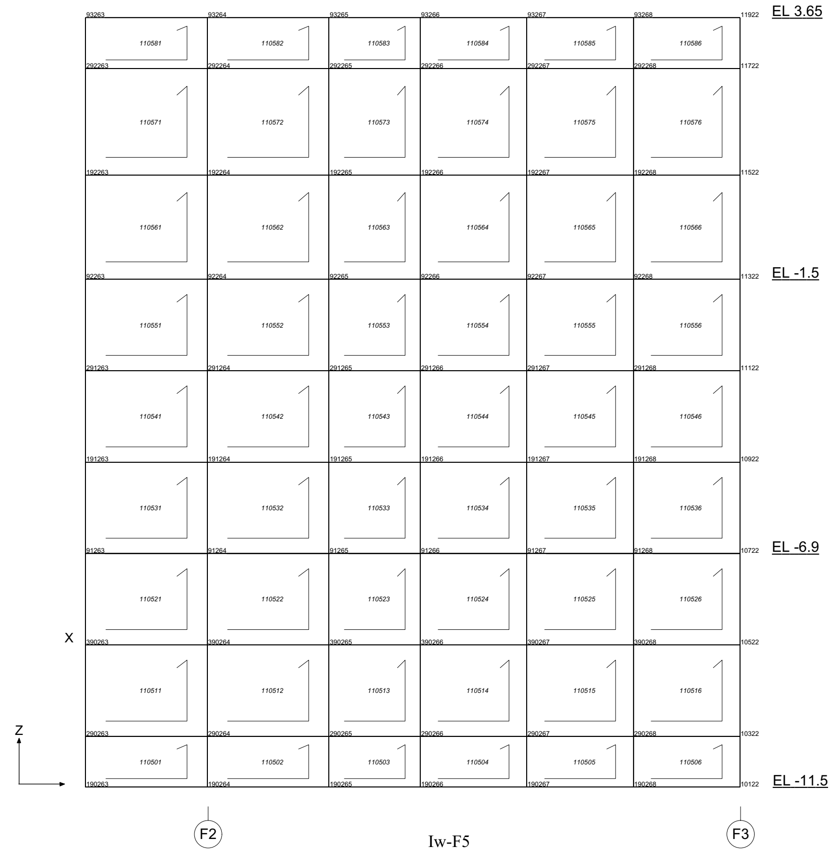


Inner Wall (X Direction 1; in Fuel Building)



Iw-F4



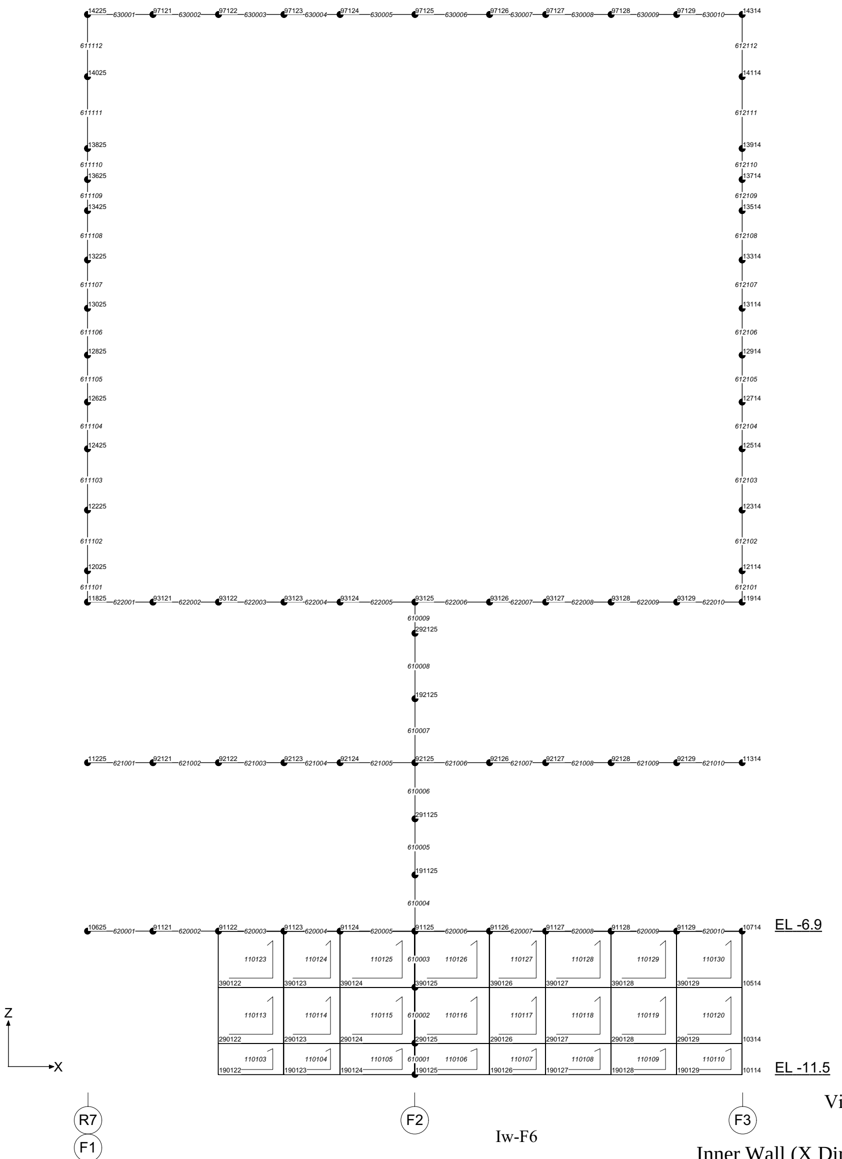


Iw-F5

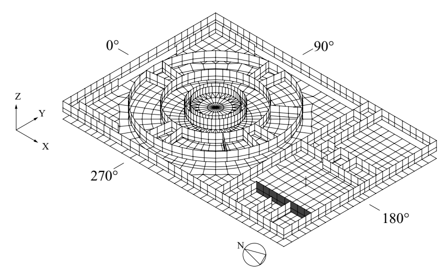
View: from West to East

View: from West to East

Inner Wall (X Direction 2; in Fuel Building)

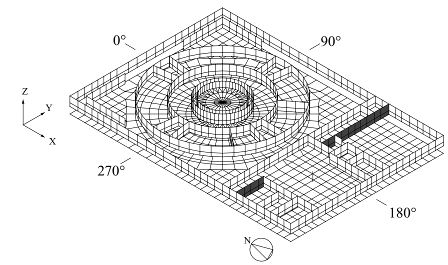


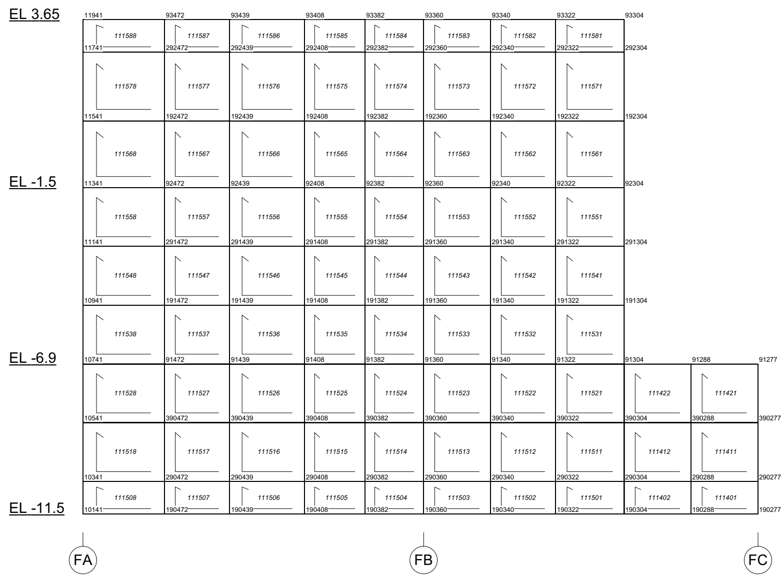
Iw-F6



View: from West to East

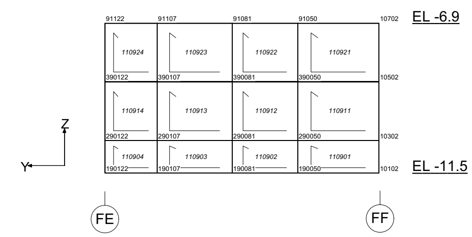
Inner Wall (X Direction 3; in Fuel Building)





Iw-F7

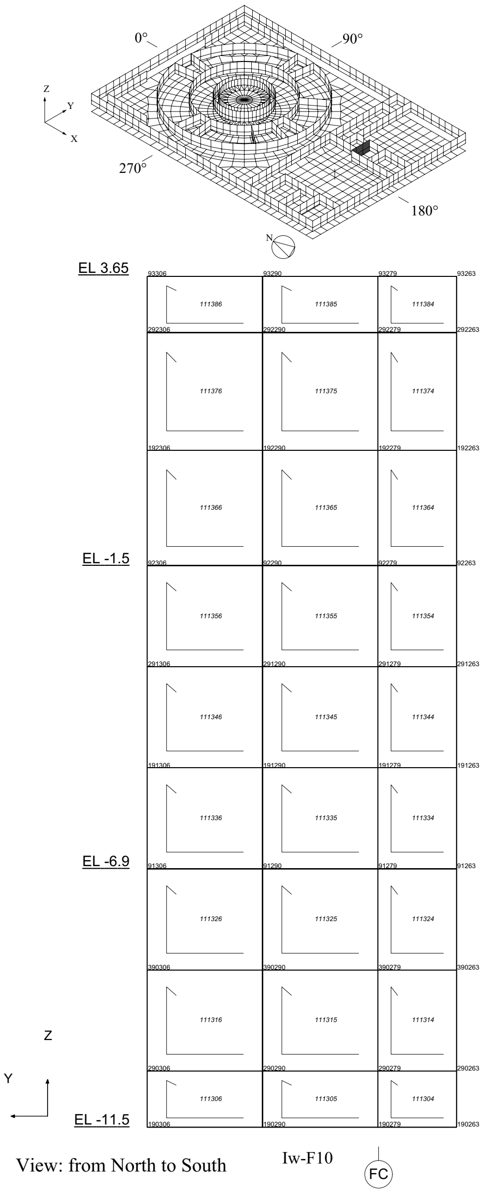
Iw-F8



Iw-F9

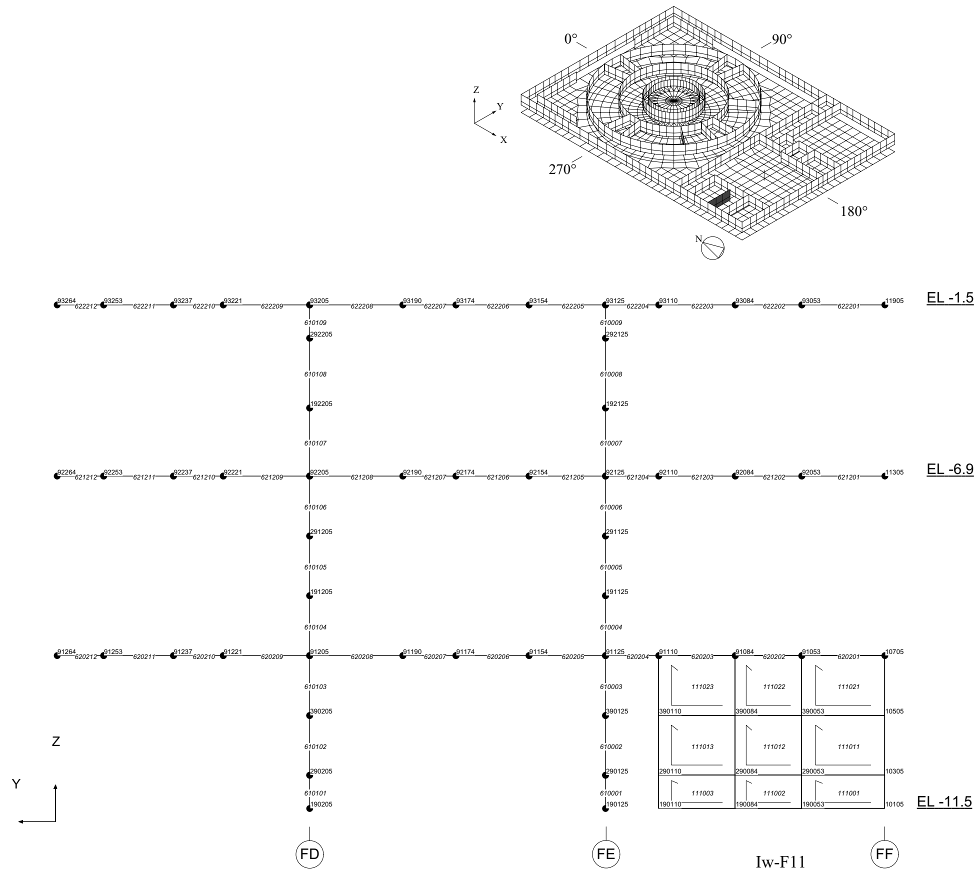
View: from North to South

Inner Wall (Y Direction 1; in Fuel Building)



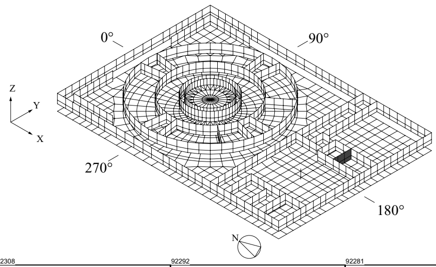
View: from North to South

Iw-F10



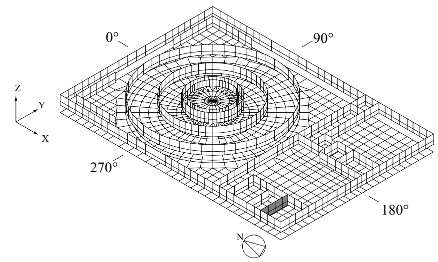
Inner Wall (Y Direction 2; in Fuel Building)

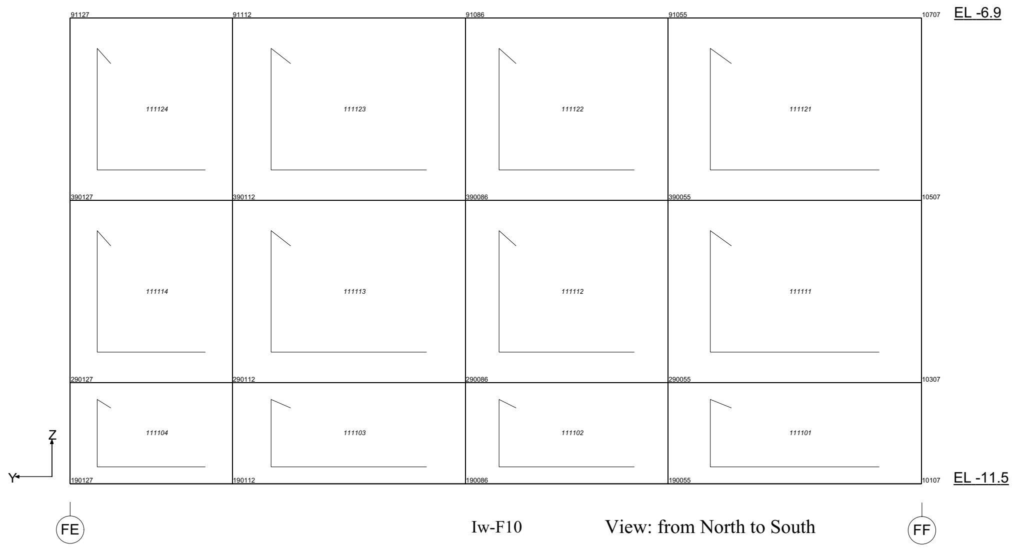
View: from North to South



View: from North to South

Iw-F12

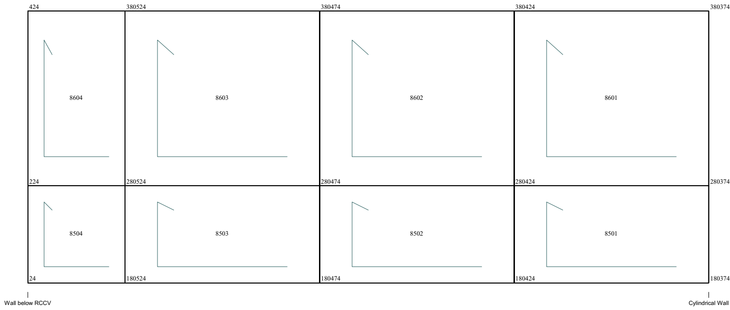




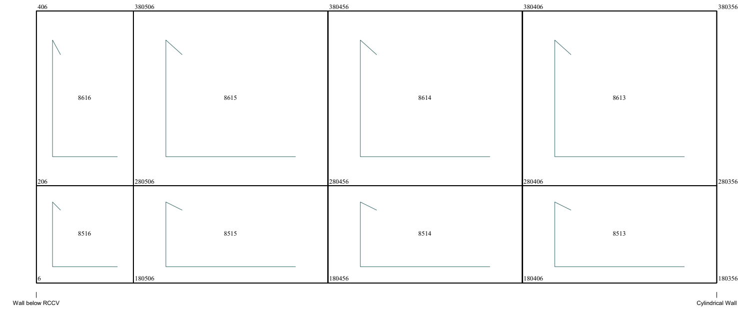
Iw-F10

View: from North to South

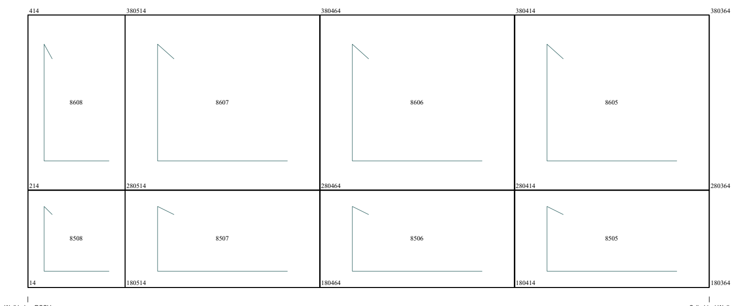
Inner Wall (Y Direction 3; in Fuel Building)



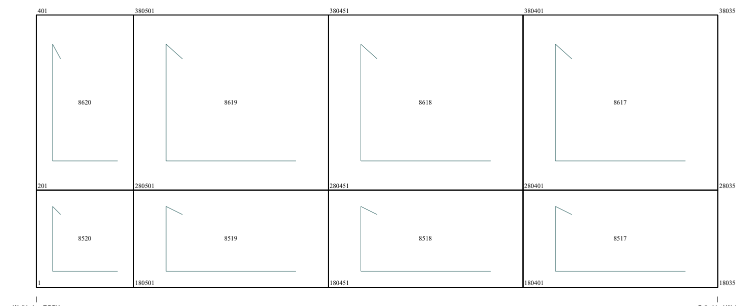
Radial Inner Wall (No.1: 7.5°)



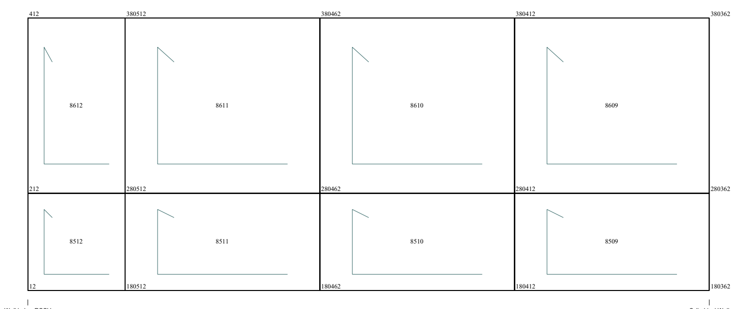
Radial Inner Wall (No.4: 142.5°)



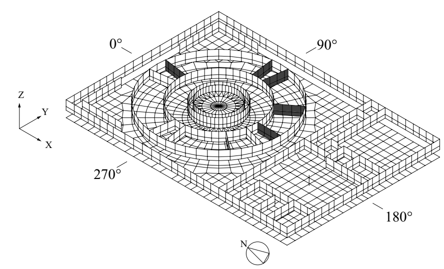
Radial Inner Wall (No.2: 82.5°)

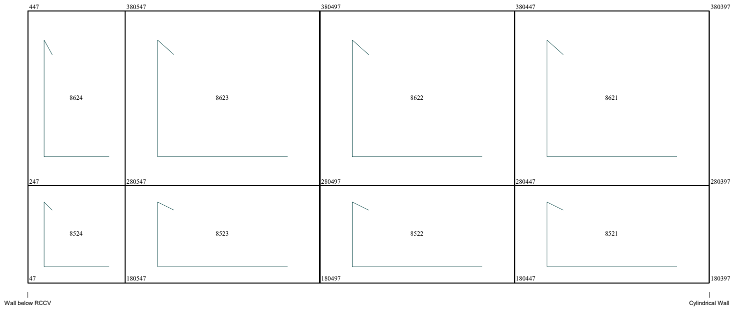


Radial Inner Wall (No.5: 180.0°)

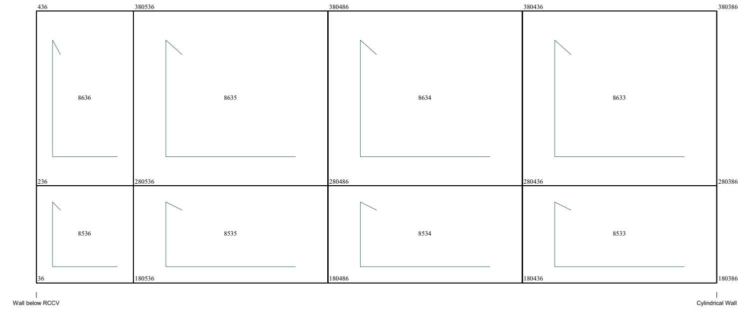


Radial Inner Wall (No.3: 97.5°)

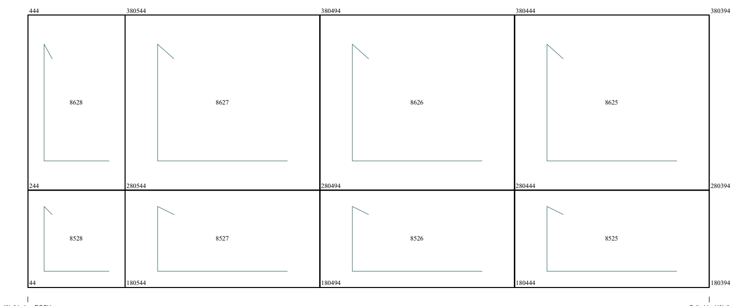




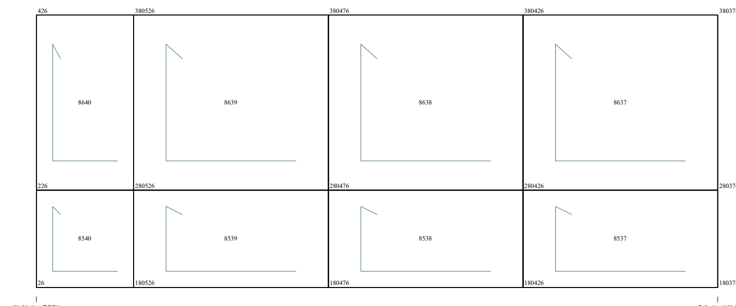
Radial Inner Wall (No.6: 195.0°)



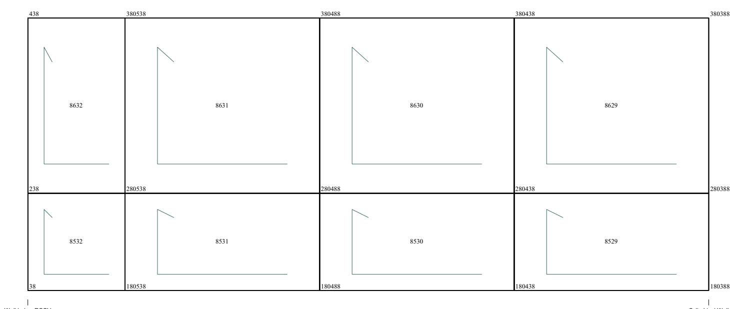
Radial Inner Wall (No.9: 277.5°)



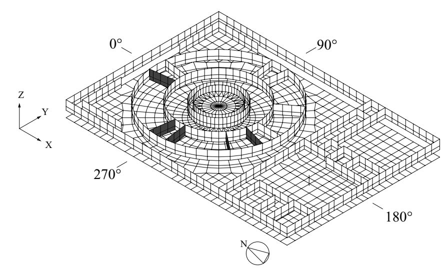
Radial Inner Wall (No.7: 217.5°)

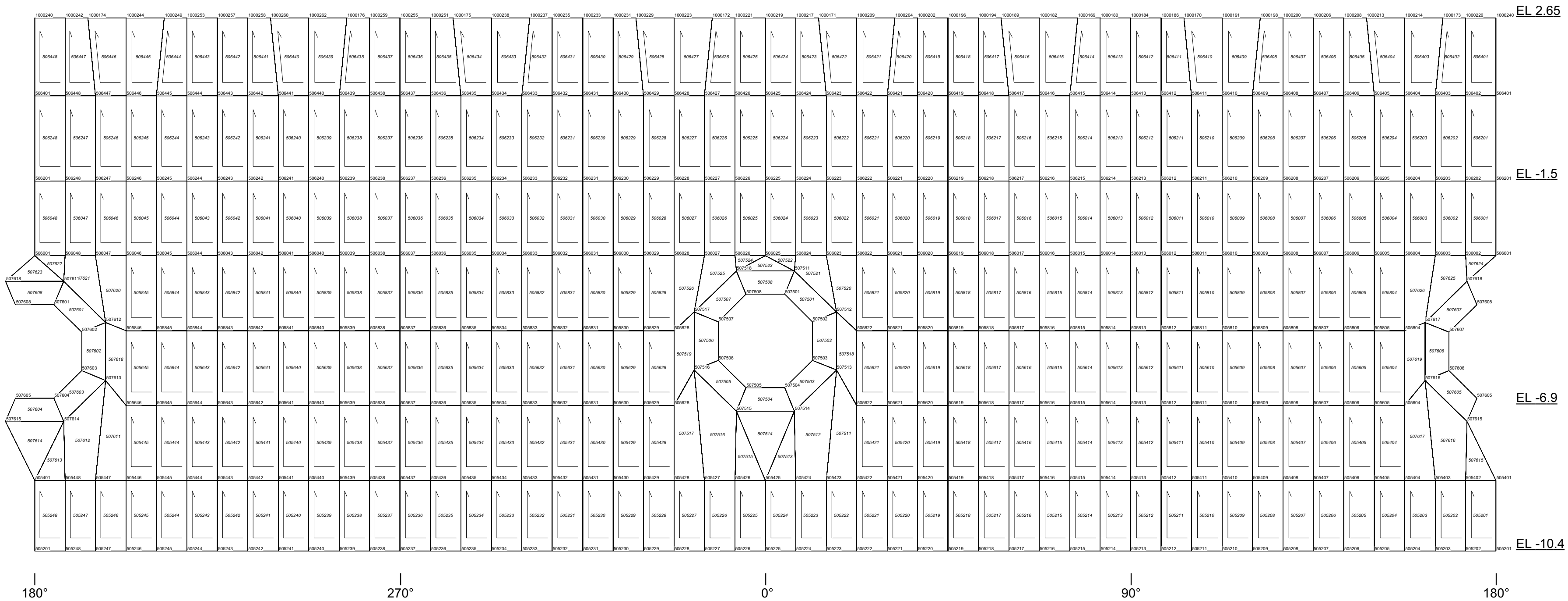


Radial Inner Wall (No.10: 352.5°)

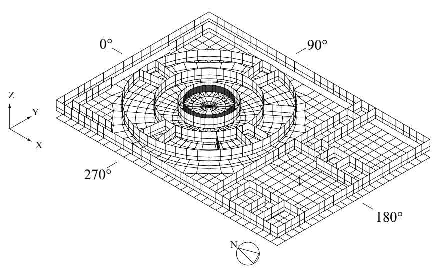


Radial Inner Wall (No.8: 262.5°)

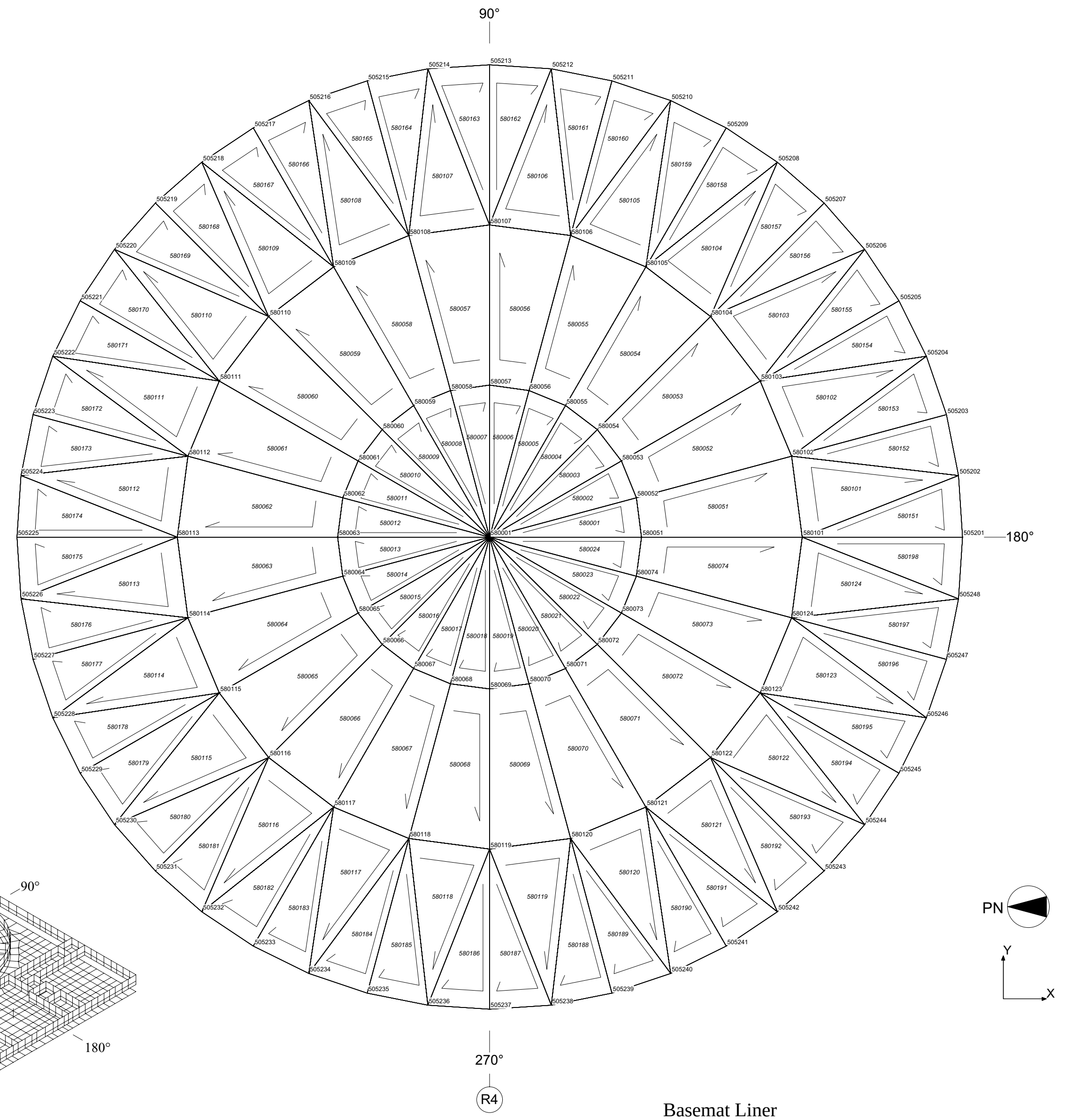


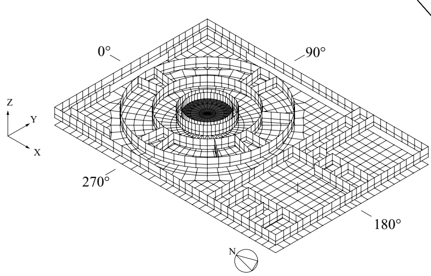


View: from Inside to Outside



RPV Pedestal Liner





Basemat Liner

Appendix B Definition of Shell Element Property in NASTRAN User Manual

PSHELL Shell Element Property

Defines the membrane, bending, transverse shear, and coupling properties of thin shell elements.

Format:

1	2	3	4	5	6	7	8	9	10
PSHELL	PID	MID1	T	MID2	12I/T**3	MID3	TS/T	NSM	
	Z1	Z2	MID4						

Example:

PSHELL	203	204	1.90	205	1.2	206	0.8	6.32	
	+.95	-.95							

Field	Contents
PID	Property identification number. (Integer > 0)
MID1	Material identification number for the membrane. (Integer ≥ 0 or blank)
T	Default membrane thickness for Ti on the connection entry. If T is blank then the thickness must be specified for Ti on the CQUAD4, CTRIA3, CQUAD8, and CTRIA6 entries. (Real or blank)
MID2	Material identification number for bending. (Integer ≥ -1 or blank)
12I/T**3	Bending moment of inertia ratio, $12I/T^3$. Ratio of the actual bending moment inertia of the shell, *I*, to the bending moment of inertia of a homogeneous shell, $T^3/12$. The default value is for a homogeneous shell. (Real > 0.0; Default = 1.0)
MID3	Material identification number for transverse shear. (Integer > 0 or blank; unless MID2 > 0, must be blank.)
TS/T	Transverse shear thickness ratio, T_s/T. Ratio of the shear thickness, (T_s), to the membrane thickness of the shell, *T*. The default value is for a homogeneous shell. (Real > 0.0; Default = .833333)
NSM	Nonstructural mass per unit area. (Real)

Z1, Z2	Fiber distances for stress calculations. The positive direction is determined by the right-hand rule, and the order in which the grid points are listed on the connection entry. See Remark 11. for defaults. (Real or blank)
MID4	Material identification number for membrane-bending coupling. See Remarks 6. and 13. (Integer > 0 or blank, must be blank unless MID1 > 0 and MID2 > 0, may not equal MID1 or MID2.)

Remarks:

1. All PSHELL property entries should have unique identification numbers with respect to all other property entries.
2. The structural mass is calculated from the density using the membrane thickness and membrane material properties. If MID1 is blank, then the density is obtained from the MID2 material.
3. The results of leaving an MID field blank (or MID2 = -1) are:

MID1	No membrane or coupling stiffness
MID2	No bending, coupling, or transverse shear stiffness
MID3	No transverse shear flexibility
MID4	No bending-membrane coupling unless ZOFFS is specified on the connection entry. See Remark 6.
MID2=-1	See Remark 12.

Note: MID1 and MID2 must be specified if the ZOFFS field is also specified on the connection entry.

4. The continuation entry is not required.
5. The structural damping (GE on the MATi entry) is obtained from the MID1 material. If MID1 is blank, then it is obtained from the MID2 material. If PARAM,SHLDAMP,DIFF or DIFF is any other character except SAME, then the structural damping K^4 matrix is computed using the GE entries on the MATi entries according to rules in the following table. If a single PSHELL corresponds to row 8 of the table, then all PSHELLs in the model will follow the rule of row 8. Rows 1-7 is an attempt to maintain upward compatibility, if a user inadvertently places a SHLDAMP,DIFF in the model

8
BULK

Caution: Large values of damping associated with an MID4 entry, when using PARAM,SHLDAMP,DIFF, can cause structural instability in transient dynamics.

Table 8-30 SHELL Structural Damping Rules

SHELL Structural Damping Rules					
Row	MID1	MID2	MID3	MID4	K^4 based on
1*	v	v			MID1 GE value
2	v				MID1 GE value
3	v	-1			MID1 GE value
4	v	v			MID1 GE value
5		v			MID2 GE value
6		v	v		MID2 GE value
7	v1	v2	v3	v4	$n \rightarrow$ total number of non blank vi $m \rightarrow$ total number of non zero ge_i If: n = m and $ge_i = ge_2 = \ldots = ge_m$ Or: $m = 1$ and $ge_1 \neq 0$ Or: $m = 0$ MID1 GE value
8	v1	v2	v3	v4	Otherwise: $ge_1 \cdot$ membrane-stiff $+ ge_2 \cdot$ bending-stiff $+ ge_3 \cdot$ transverse shear-stiff $+ ge_4 \cdot$ bending-membrane-stiff is used
* v $\rightarrow$ MIDi values the same, vi $\rightarrow$ MIDi values different or blank $ge_i \rightarrow$ GE value from a MATj entry associated with MIDi If for row 8, a $ge_i = 0$ it is replaced by $ge_i = 1.-8$					

6. The following should be considered when using MID4.

- The MID4 field should be left blank if the material properties are symmetric with respect to the middle surface of the shell. If the element centerline is offset from the plane of the grid points but the material properties are symmetric, the preferred method for modeling the offset is by use of the ZOFFS field on the connection entry. Although the MID4 field may be used for this purpose, it may produce ill-conditioned stiffness matrices (negative terms on factor diagonal) if done incorrectly.
- Only one of the options MID4 or ZOFFS should be used; if both methods are specified the effects are cumulative. Since this is probably not what the user intented, unexpected answers will result. Note that the mass properties are not modified to reflect the existence of the offset when the ZOFFS and MID4 methods are used. If the weight or mass properties of an offset plate are to be used in an analysis, the RBAR method must be used to represent the offset. See "**Shell Elements (CTRIA3, CTRIA6, CTRIAR, CQUAD4, CQUAD8, CQUADR)**" on page 119 of the MSC.Nastran Reference Manual.
- The effects of MID4 are not considered in the calculation of differential stiffness. Therefore, it is recommended that MID4 be left blank in buckling analysis.

7. This entry is referenced by the CTRIA3, CTRIA6, CTRIAR, CQUAD4, CQUAD8, and CQUADR entries via PID.
8. For structural problems, MIDi must reference a MAT1, MAT2, or MAT8 material property entry
9. If the transverse shear material MID3 or the membrane-bending coupling term MID4 references a MAT2 entry, then G33 must be zero. If MID3 references a MAT8 entry, then G1Z and G2Z must not be zero.
10. For heat transfer problems, MIDi must reference a MAT4 or MAT5 material property entry.
11. The default for Z1 is -T/2, and for Z2 is +T/2. T is the local plate thickness defined either by T on this entry or by membrane thicknesses at connected grid points, if they are input on connection entries.
12. For plane strain analysis, set MID2=-1 and set MID1 to reference a MAT1 entry. In-plane loads applied to plain strain elements are interpreted as line-loads with a value equal to the load divided by the thickness. Thus, if a thickness of "1.0" is used, the value of the line-load equals the load value. Pressure can be approximated with multiple line loads where the pressure value equals the line-load divided by the length between the loads.

13. For the CQUADR and CTRIAR elements, the MID4 field should be left blank because their formulation does not include membrane-bending coupling.
14. If MIDi is greater than or equal to 10^8, then parameter NOCOMPS is set to +1 indicating that composite stress data recovery is desired. (MIDi greater than 10^8 are generated by PCOMP entries.)
15. For a material nonlinear property, MID1 must reference a MATS1 entry and be the same as MID2, unless a plane strain (MID2 = -1) formulation is desired. Also, MID3 cannot reference a MATS1 entry.
16. If transverse shear flexibility is specified for a model with curved shells where the loading is dominated by twist, results will not converge and may be inaccurate. PARAM,SNORM should be set for this unique model condition.