REVISIONS TO BE INCLUDED IN DCD, REV 8

3.3 Wind and Tornado Loadings

3.3.1 Wind Loadings

The wind loadings for seismic Category I structures are in accordance with American Society of Civil Engineers, "Minimum Design Loads for Buildings and Other Structures," ASCE 7-98 (Reference 1).

3.3.1.1 Design Wind Velocity

The design wind is specified as a basic wind speed of 145 mph with an annual probability of occurrence of 0.02 based on the most severe location identified in Reference 1. This wind speed is the 3 second gust speed at 33 feet above the ground in open terrain (Reference 1, exposure C). The basic wind speed of 145 mph is the 3 second gust speed that has become the basis of wind design codes since 1995. It corresponds to the 110 mph fastest mile wind used as the basis for the AP600 design in accordance with the 1988 edition of Reference 1.

Higher winds with a probability of occurrence of 0.01 are used in the design of seismic Category I structures by using an importance factor of 1.15. This is obtained by classifying the AP1000 seismic Category I structures as essential facilities and using the design provisions for Category IV of Reference 1.

Velocity pressure exposure coefficients and gust response factors are calculated according to Reference 1 for exposure C, which is applicable to shorelines in hurricane prone areas in the 1998 edition of Reference 1. The topographic factor is taken as unity.

The design wind loads calculated as described above exceed those required at other locations in the United States where the more severe Exposure Category D is specified in Reference 1. Exposure Category D is applicable for sites near open inland waterways, the Great Lakes and coastal areas of California, Oregon, Washington and Alaska. For such locations the basic wind speed is less than 130 mph.

3.3.1.2 Determination of Applied Forces

The procedures used in transforming the wind velocity into an effective pressure to be applied to structures and parts and portions of structures follow the guidelines of Reference 1.

Effective pressures applied to interior and exterior surfaces of the buildings and corresponding shape coefficients are calculated according to Reference 1 for exposure C. Shape coefficients defining the variation around the circumference of ~~for~~ the shield building are calculated using ASCE Paper No. 3269 (Reference 2).). These shape coefficients are consistent with those observed in the model tests described in Reference 6.

3.3.2 Tornado Loadings

Seismic Category I structures are designed to resist tornado wind loads without exceeding the allowable stresses defined in subsection 3.8.4. These tornado loads exceed the loads for hurricanes with a probability of occurrence comparable to that of the tornado. In addition, seismic Category

Attachment 7

- Coupled auxiliary and shield building at shield building roof — Figure 3.7.2-15, Sheets 13–15
- Steel containment vessel at polar crane support — Figure 3.7.2-16, Sheets 1–3

Site-specific soil structure interaction analyses must be performed by the Combined License applicant to demonstrate acceptability of sites that have seismic and soil characteristics outside the site parameters in Table 2-1. These analyses would use the site-specific soil conditions (including variation in soil properties in accordance with Standard Review Plan 3.7.2). The three components of the site-specific ground motion time history must satisfy the enveloping criteria of Standard Review Plan 3.7.1 for the response spectrum for damping values of 2, 3, 4, 5, and 7 percent and the enveloping criterion for power spectral density function. Floor response spectra determined from the site-specific analyses should be compared against the design basis of the AP1000 described above. Member forces in each of the sticks should be compared against those given in Tables 3.7.2-11 to 3.7.2-13. These evaluations and comparisons will be provided and reviewed as part of the Combined License application.

2.5.3 Surface Faulting Combined License Information

Combined License applicants referencing the AP1000 certified design will address the following surface and subsurface geological, seismological, and geophysical information related to the potential for surface or near-surface faulting affecting the site:

- Geological, seismological, and geophysical investigations
- Geological evidence, or absence of evidence, for surface deformation
- Correlation of earthquakes with capable tectonic sources
- Ages of most recent deformation
- Relationship of tectonic structures in the site area to regional tectonic structures
- Characterization of capable tectonic sources
- Designation of zones of quaternary deformation in the site region
- Potential for surface tectonic deformation at the site

2.5.4 Stability and Uniformity of Subsurface Materials and Foundations

Combined License applicants referencing the AP1000 certified design will address the following site-specific information related to the stability and uniformity of subsurface materials and foundations.

- Excavation
- Bearing capacity
- Settlement
- Liquefaction

Seismic analysis and foundation design for rock sites is described in Sections 3.7 and 3.8. The AP1000 certified design is based on the nuclear island being founded on rock. Soils may be present above the foundation level.

2. The finite element shell model of the containment internal structures is a finite element model using primarily shell elements. It is developed using the solid model features of ANSYS, which allow definition of the geometry and structural properties. This model is used in both static and dynamic analyses. It models the concrete structures inside the shield building including the basemat. This model is used to develop modal properties (frequencies and mode shapes). Analyses are performed on portions of this model to define properties for the stick model. Static analyses are also performed on the model to obtain member forces in the walls. The walls and basemat inside containment for this model is shown in Figure 3.7.2-2. This model is also used as a superelement in both the finite element shell dynamic model of the nuclear island and in the 3D finite element basemat model (see subsection 3.8.5.4-1).

3. The finite element model of the containment vessel is an axisymmetric model fixed at elevation 100'. This model is used in both static and dynamic analyses. The model is used to develop modal properties (frequencies and mode shapes). Analyses are performed on portions of this model to define properties for the stick model. Static analyses are also performed on the model to obtain shell stresses. This model is shown in Figure 3.8.2-6.

4. The nuclear island lumped mass stick model consists of the stick models of the individual buildings interconnected by rigid links. Each individual stick model is developed to match the modal properties of the finite element models described in 1, 2, and 3 above. Modal analyses and seismic time history analyses are performed using this model. Plant design response spectra are developed from these analyses along with equivalent static seismic accelerations for analysis of the building structures. The individual stick models are shown in Figures 3.7.2-4, 3.7.2-5, and 3.7.2-6. The reactor coolant loop model is shown in Figure 3.7.2-7. The polar crane model is shown in Figure 3.7.2-8. The interconnection between the sticks is shown in Figure 3.7.2-18.

5. The finite element shell dynamic model of the nuclear island is also used in seismic time history analyses. This model uses the coupled auxiliary and shield building described in 1 above. It also includes the finite element model of the basemat inside the shield building and a superelement of the containment internal structures generated from the finite element model described in 2 above. Results from time history analyses from this model are compared to the results from the nuclear island lumped mass stick model. The results are used for development of vertical response spectra and for the equivalent static seismic acceleration of flexible floors and walls and the shield building roof.

The models of the containment internal structures and containment vessel described in 2 and 3 above are also used in equivalent static analyses to provide design member forces in each structure. A separate GTSTRUDL model as shown in Figure 3.8.4-3 is used for static analyses of the shield building roof. Member forces in the auxiliary and shield building are obtained from static analyses of the following model:

6. The equivalent static ANSYS finite element model of the auxiliary and shield building is more refined than the finite element model described in 1 above. This model is developed by meshing one area of the solid model with four finite elements. The nominal element size in this auxiliary building model is about 4.5 feet so that each wall has four elements for the wall height of about 18 feet between floors. This refinement is used to calculate the design member forces and

discussed in subsection 3.7.2.3. Figure 3.7.2-2 shows the finite element model of the containment internal structures.

3.7.2.1.2 Time-History Analysis

Mode superposition time-history analyses using computer program ANSYS are performed to obtain the in-structure seismic response needed in the analysis and design of seismic subsystems.

The three-dimensional, lumped-mass stick models of the nuclear island structures developed as described in subsection 3.7.2.3 are used to obtain the in-structure responses. The lumped-mass stick models of the nuclear island structures are presented in Figure 3.7.2-4 for the coupled shield and auxiliary buildings, in Figure 3.7.2-5 for the steel containment vessel, in Figure 3.7.2-6 for the containment internal structures, and in Figure 3.7.2-7 for the reactor coolant loop model. The individual building lumped-mass stick models are interconnected with rigid links to form the overall dynamic model of the nuclear island.

The three-dimensional finite element model of the auxiliary and shield building, or a portion thereof, developed as described in subsections 3.7.2.3 and 3.7.2.3.1 is used to obtain the in-structure vertical response spectra of the auxiliary building including flexible floors. This model is used for the vertical analysis of the auxiliary building since the stick model is developed to match the fundamental vertical frequency of the shield building and does not represent the fundamental vertical frequencies of the auxiliary building, which is significantly lower than the shield building.

For the hard rock site, the soil-structure interaction effect is negligible. Therefore, for the hard rock site, the nuclear island is analyzed as a fixed-base structure, using computer program ANSYS without the foundation media. The three components of earthquake (two horizontal and one vertical time histories) are applied simultaneously in the analysis. The base of the stick model is fixed at the bottom of the basemat at elevation 60′~~-~~6″. The basemat is 6 feet thick. Since ~~T~~the finite element model of the auxiliary and shield building uses shell elements to represent the 6 foot thick basemat, the nodes of the basemat element are at the center of the basemat (elevation 63′-6). The finite element model of the containment internal structures uses solid elements, which extend down to elevation 60′-6″. When the finite element models are combined and used in the time history analyses, ~~T~~the ~~base of the~~ auxiliary building finite element model is fixed at the ~~middle of the~~ shell element basemat nodes ~~at~~ (elevation 63′-6″) and the base of the containment internal structures is fixed at the bottom of the solid element base nodes (elevation 60′-6″). This difference in elevation of the base fixity is not significant since the concrete between elevations 60′6″ and 63′6″, below the auxiliary building, is nearly rigid. There is no lateral support due to soil or hard rock below grade. This case results in higher response than a case analyzed with full lateral support below grade.

3.7.2.1.3 Response Spectrum Analysis

Equivalent static acceleration and mode superposition time-history methods are primarily used for the evaluation of the nuclear island structures. Response spectrum analyses may be used to perform an analysis of a particular structure or portion of structure using the procedures described in subsections 3.7.2.6, 3.7.2.7, and 3.7.3.

Table 3.7.2-14

SUMMARY OF MODELS AND ANALYSIS METHODS

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
3D finite element model of the shield building roof	Modal analysis Equivalent static analysis using nodal accelerations from 3D shell model	ANSYS GT STRUDL	To obtain dynamic properties. To obtain SSE member forces for the shield building roof.
3D finite element shell dynamic model of auxiliary and shield building	Modal analysis	ANSYS	To obtain dynamic properties.
3D finite element shell model of containment internal structures	Modal analysis Equivalent static analysis using nodal accelerations and member forces from 3D stick model	ANSYS	To obtain dynamic properties. Performed for the hard rock profile with equivalent static acceleration input. To obtain forces for the design of floors and walls of the containment internal structures.
3D shell of revolution model of steel containment vessel	Modal analysis Equivalent static analysis using nodal accelerations from 3D stick model	ANSYS	To obtain dynamic properties. To obtain SSE stresses for the containment vessel.
3D lumped mass stick model of Nuclear Island	Modal analysis Mode superposition time history analysis	ANSYS	To obtain dynamic properties. Performed for hard rock profile. To develop time histories for generating seismic response spectra. To obtain the following: Maximum absolute nodal accelerations (ZPA). Maximum displacements relative to basemat. Maximum member forces and moments.
3D finite element shell dynamic model of nuclear island (coupled aux/shield building shell model, with superelement of containment internal structures)	Mode superposition time history analysis	ANSYS	Performed for hard rock profile. To develop time histories for generating vertical response spectra for auxiliary building and flexible floors. To obtain maximum absolute nodal accelerations (ZPA) for flexible floors and walls and for shield building roof.
3D finite element refined shell model of Auxiliary and Shield Building	Equivalent static analysis using nodal accelerations from 3D stick model	ANSYS	Performed for the hard rock profile with equivalent static acceleration input. To obtain the forces for the design of floors and walls of the auxiliary and shield building.

Table 3.7.2-16

SUMMARY OF DYNAMIC ANALYSES & COMBINATION TECHNIQUES

Model	Analysis Method	Program	Three Components Combination	Modal Combination
3D lumped mass stick, fixed base models	Mode superposition time history analysis	ANSYS	Algebraic Sum	n/a
3D finite element, fixed base models, coupled aux/shield building shell models, with ~~stick models~~superelement -of containment internal structures	Mode superposition time history analysis	ANSYS	Algebraic Sum	n/a
3D finite element, fixed base models, coupled Aux/Shield buildings and Cont. internal structures	Equivalent static analysis using nodal accelerations from 3D stick model	ANSYS	SRSS or 100%,40%,40%	n/a
3D finite element model of the nuclear island basemat	Equivalent static analysis using nodal accelerations from 3D stick model	ANSYS	100%,40%,40%	n/a
3D shell of revolution model of steel containment vessel	Equivalent static analysis using nodal accelerations from 3D stick model	ANSYS	SRSS or 100%,40%	n/a
3D finite element model of the shield building roof	Equivalent static analysis using nodal accelerations from 3D stick model	ANSYS GT STRUDL	SRSS	n/a
PCS valve room and miscellaneous steel frame structures, miscellaneous flexible walls, and floors	Response spectrum analysis	ANSYS	SRSS	Grouping

than the established maximum limit of 0.1". The effective load length of the shear studs on the carbon steel plate that act to restrain the plate is 7 ½'. This is consistent with the design criterion used for the stud spacing that required that the studs over a length of 7.5 feet be capable of developing yield in the plate.

Mechanical loads

Dead and live loads that could occur during the thermal transient are not significant. Loads due to the safe shutdown earthquake are also small. The combination of the safe shutdown earthquake and thermal transient would have an extremely low probability since it is an independent event occurring during the few minutes after the LOCA when the maximum difference in temperature occurs between the steel surface plate and the concrete. Mechanical loads on the studs would not occur in the direction of free growth. They may occur in the direction normal to the free growth. These loads are small relative to those due to the thermal growth in the other direction and the biaxial loading would be acceptable.

Conclusion

The heat up of the surface plates during the initial portion of the LOCA transient results in cracking of the concrete walls except in regions where there is significant external restraint. This cracking reduces the stresses in the surface plates and the loads on the shear studs relative to the cases where there is significant external restraint. The cracking of the concrete does not cause degradation of the structural integrity of the wall.

In regions where there is significant external restraint, the structural module faceplates are restrained so that their thermal growth is uniaxial. This evaluation, using the uniaxial model with no growth of the concrete, demonstrates that the design is acceptable for the AP1000 thermal transients. Portions of the plate away from a free edge will reach yield. There are no shear loads on the studs in this central portion. The shear studs on the portions of the plate near the edge do not exceed the maximum deflection capacity. Loads in the plate and studs will be lower if there is also thermal growth of the concrete or if there is cracking.

References

3.8.4.3-1-1 Ollgaard, Jorgen, Roger Slutter, John Fisher, "Shear Strength of Stud Connectors in Lightweight and Normal-Weight Concrete," AISC Engineering Journal, April 1971.

Design Control Document (DCD) Revision: To be included in Rev 8

In response to the comment on the Revision 0 response to this open item, the following paragraph will be added after the first paragraph of subsection 3.8.3.4.3:

The structural modules are subject to a rapid temperature transient in the event of a loss of coolant accident (LOCA) or a main steam line break (MSLB). The structural modules were evaluated for these rapid temperature transients. The evaluation considered both

carbon and stainless steel faceplates. The steel plate heats up most rapidly in the LOCA event with temperatures up to 270°F in the first few minutes. The faceplate of the structural module will see differential temperatures relative to the concrete ranging from 140°F to 220°F ~~(based on an ambient temperature of 50°F)~~. The concrete heats up more slowly and does not see a significant temperature increase during the early part of the transient. There is relative thermal growth of the faceplate, causing shear loads in the shear studs, and embedded angles of the structural steel trusses that are welded to the faceplate. The heat up of the surface plates during the initial portion of the LOCA transient results in cracking of the concrete walls except in regions where there is significant external restraint. The structural module maintains its integrity throughout the rapid thermal transient.

having an ambient temperature of 50°F

PRA Revision:

None

Table 3.8.3-3

*[DEFINITION OF CRITICAL LOCATIONS AND THICKNESSES FOR CONTAINMENT INTERNAL STRUCTURES[1]]**

Wall Description	*Applicable Column Lines*	*Applicable Elevation ~~Level or Elevation~~ ~~Level~~ Range*	*Concrete Thickness[2]*	*Required Thickness of Surface Plates (inches)[3]*	*Thickness of Surface Plates Provided (inches)[4]*
Containment Structures					
Module Wall 1	*West wall of refueling cavity*	*Wall separating IRWST and refueling cavity from ~~3.3 to 5~~ elevation 103'-135'3"*	*4'-0" concrete-filled structural wall module with 0.5-in.- thick steel plate on inside and outside of wall*	~~0.12~~ 0.11	0.5
Module Wall 2	*South wall of west steam generator cavity*	*Wall separating IRWST and west steam generator cavity from ~~3.1 to 5~~ elevation 103' - 135'3"*	*2'-6" concrete-filled structural wall module with 0.5-in.-thick steel plate on inside and outside of wall*	~~0.41~~ 0.42	0.5
CA02 Module Wall	*North east boundary wall of IRWST*	*Wall separating IRWST and maintenance floor from ~~3 to 5~~ elevation 103'-135'3"*	*2'-6" concrete-filled structural wall module with 0.5-in.-thick steel plate on inside and outside of wall*	0.24	0.5

Notes:

1. *The applicable column lines and elevation levels are identified and included in Figures 1.2-9, 3.7.2-12 (sheets 1 through 12), 3.7.2-19 (sheets 1 through 3) and on Table 1.2-1.*
2. *The concrete thickness includes the steel face plates. Thickness greater than 3'-0" have a construction tolerance of + 1", -3/4". Thickness less than or equal to 3'-0" have a construction tolerance of + 1/2", -3/8".*
3. *These plate thicknesses represent the minimum thickness required for operating and design basis loads except for designed openings or penetrations. These values apply for each face of the applicable wall unless specifically indicated on the table.*
4. *These plate thicknesses represent the thickness provided for operating and design basis loads except for designed openings or penetrations. These values apply for each face of the applicable wall unless specifically indicated on the table.*

*NRC Staff approval is required prior to implementing a change in this information; see DCD Introduction Section 3.5.

Table 3H.5-2 (Sheet 2 of 2)

*[EXTERIOR WALL ON COLUMN LINE 1 FORCES AND MOMENTS IN CRITICAL LOCATIONS]**

Load Type	Load Description	Out-of-Plane Moment (k-ft/ft)						Out-of-Plane Shear (kips/ft)			
		Wall Section						Wall Section			
		7	8	9	10	11	12	7	9	10	12
D	DEAD LOAD										
	Wall Weight	-2.2	3.7	2.3	0.7	0.2	0.2	0.05	0.05	0.1	0.2
	Static Surcharge	0.3	0	0	0	0	0	0.03	0.03	0	0
L	LIVE LOAD										
	Floor Live Load	-1.6	2.0	1.3	1.4	-1.8	-0.6	0.3	-0.2	-1.6	-1.6
	Crane/Cask Load	0.4	-2.6	-2.9	9.8	0.9	-1.8	-0.2	-0.3	-0.4	-0.7
	Hydrostatic	-1.60	0	0.40	0.40	0	0	-0.1	0	0	0
H	LATERAL SOIL PRESSURE										
	At Rest Pressure	1.1	0	-0.30	-0.2	0	0	0	0	0	0
E_s	SEISMIC										
	Global Behavior	25.2	74.4	78.7	79.1	115.4	27.7	13.1	4.3	13.7	13.5
	Passive Soil Press.	8.6	0	-0.1	-0.3	0	0	0	0	0	0
	Dyn. Soil Press.	7.3	0	0	0	0	0	0	0	0	0
T_o	THERMAL										
	Operating	51.2	65.4	74.5	77.6	43.1	12.4	-0.6	-1.2	6.2	3.6

Notes:
Moment w/o sign indicates tension on the outside face of wall.
Moment w/- sign indicates tension on the inside face of wall.

12

*NRC Staff approval is required prior to implementing a change in this information; see DCD Introduction Section 3.5.

Table 3H.5-3

*[EXTERIOR WALL ON COLUMN LINE 1 DETAILS OF WALL REINFORCEMENT (in^2/ft)]**

(See Figure 3H.5-2 for Locations of Wall Sections.)

Load Combination	Location	Required			Provided		
		Vertical	Horizontal	Shear	Vertical	Horizontal	Shear
WALL SECTION 1, 2, 3							
				0.5			0.80
$1.0D+1.0L+1.0H+1.0E_s$	Outside Face	2.9	1.1		4.16	1.27	
	Inside Face	1.9	1.1		2.67	1.27	
WALL SECTION 4, 5, 6							
				0.25			0.40
$1.0D+1.0L+1.0H+T_o$	Outside Face	1.4	1.0		3.12	1.27	
	Inside Face	1.4	1.15		2.67	1.27	
WALL SECTION 7, 8, 9							
				NR			None
$1.0D+1.0L+1.0H+1.0T_o$	Outside Face	2.5	3.0		3.12	3.12	
	Inside Face	2.1	1.2		3.12	1.69	
WALL SECTION 10, 11, 12							
				NR			None
$1.0D+1.0L+1.0H+1.0T_a$	Outside Face	2.8	2.5		3.74	3.12	
	Inside Face	1.2	1.5		3.12	2.34	

Note:
NR – Not Required

13

*NRC Staff approval is required prior to implementing a change in this information; see DCD Introduction Section 3.5.

Table 3H.5-10 *[DESIGN SUMMARY OF ROOF AT ELEVATION 180'-0", AREA 6]** *(Near Shield Building Interface)*	
Governing Load Combination (Roof Girder)	
Combination Number	*3 – Extreme Environmental Condition Downward Seismic Acceleration*
Bending Moment	*= 6416 kips-ft*
Corresponding Stress	*= 24.4 ksi*
Allowable Stress	*= 33.3 ksi*
Shear Force	*= 403 kips*
Corresponding Stress	*= 15.3 ksi*
Allowable Stress	*= 20.1 ksi*
Governing Load Combination (Concrete Slab)	
Parallel to the Girders	
Combination Numbers	*3 – Extreme Environmental Condition Upward Seismic Acceleration*
Reinforcement (Each Face)	
Required	*= 1.50 in^2/ft*
Provided	*= 1.56 in^2/ft*
Perpendicular to the Girders	
Combination Numbers	*3 – Extreme Environmental Condition*
Reinforcement (Each Face)	
Required	*= 1.35 in^2/ft*
Provided	*= 3.12 in^2/ft*

14

*NRC Staff approval is required prior to implementing a change in this information; see DCD Introduction Section 3.5.

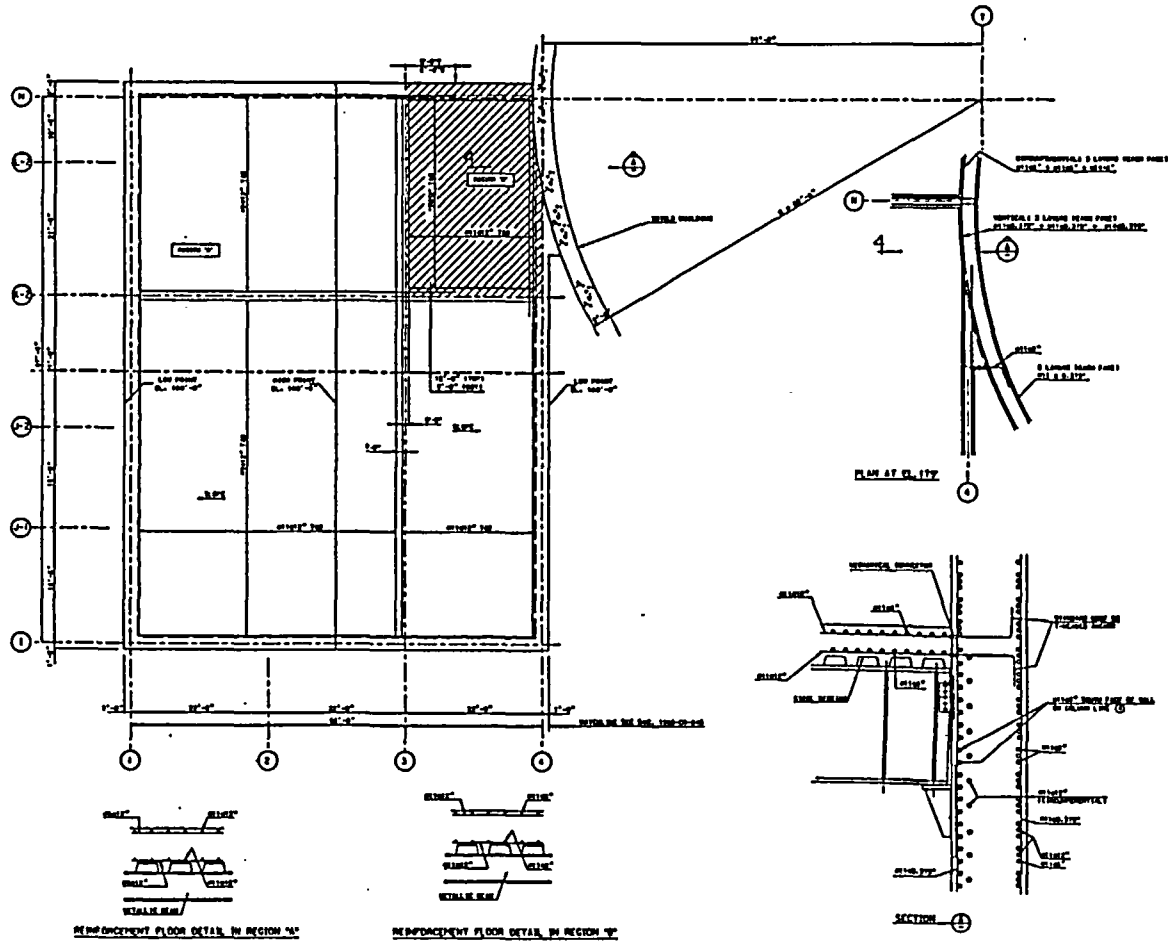

Figure 3H.5-7

*[Typical Reinforcement and Connection to Shield Building]**

44

Information; see DCD Introduction Section 3.5.