# 3.8 Seismic Category I Structures

A cathodic protection system is provided for the Seismic Category I structures as described in Section 8A.2. Its design is plant unique as it must be tailored to the site conditions.

## 3.8.1 Concrete Containment

The containment structure is designed to house the primary nuclear system and is part of the containment system, whose functional requirement is to confine the potential release of radioactive material in the event of a LOCA. This subsection describes the concrete containment structure. Steel components of the containment that resist pressure and are not backed by structural concrete are discussed in Subsection 3.8.2. A detailed description of the containment system is presented in Section 6.2.

### 3.8.1.1 Description of the Containment

#### 3.8.1.1.1 Concrete Containment

The containment is shown in the summary report contained in Section 3H.1. This report contains a description of the containment, figures, loads, load combinations, concrete stresses, reinforcement stresses, and liner strains for the concrete containment vessel.

The structural system is a low-leakage reinforced concrete structure with an internal steel liner in the drywell and suppression chamber to serve as a leaktight membrane. The containment is a cylindrical shell structure which is divided by the diaphragm floor and the reactor pedestal into an upper drywell chamber, a lower drywell chamber and a suppression chamber. The top slab of the containment is an integral part of the fuel pool with the pool girders rigidly connected to the containment top slab and the reactor building walls. The Reactor Building (R/B) floors that abut the containment are integrated structurally with the concrete containment. The containment foundation mat is continuous with the R/B foundation mat. The containment wall, top slab, R/B floor slabs and foundation mat are constructed of cast-in-place, conventionally reinforced concrete.

The containment foundation mat is 5.5m thick. The foundation mat reinforcement consists of a top layer of reinforcement, a bottom layer of reinforcement, and vertical shear reinforcement. The bottom layer of reinforcement is arranged in a rectangular grid. The top layer of reinforcement is arranged in a rectangular grid at the center of the mat and then radiates outward in a polar pattern in order to avoid interference with the containment wall reinforcement.

The containment wall is a right, circular cylinder, 2m thick, with an inside radius of 14.5m and has a height of 29.5m measured from the top of the foundation mat to the bottom of the containment top slab. The main reinforcement in the wall consists of inside and outside layers of hoop and vertical reinforcement and radial bars for shear reinforcement.

Reinforcement is placed at major discontinuities in the wall, including the intersection of the wall and foundation mat, the vicinity of the wall intersection with the top slab, around major piping penetrations, the upper drywell equipment hatch and personnel airlock, the lower drywell equipment hatch and personnel airlock tunnels, and suppression chamber access hatch.

The containment top slab is nominally 2.2m thick. The slab thickness is increased to 2.4m beneath the fuel pool, steam dryer and steam separator pool, and around the drywell head opening.

The containment top slab main reinforcement consists of a top and bottom layer of reinforcement. The top layer of reinforcement is arranged in a rectangular grid. The bottom layer of reinforcement is arranged in a rectangular grid and then is bent near the containment wall into a radial pattern to avoid interference with the containment wall vertical reinforcement. Hoop reinforcement is provided in the area of the drywell head opening.

[*Table 2 of DCD/Introduction identifies the commitments of Code editions for design and construction of the concrete containment (Subsection 3.8.1) and buckling analysis of drywell head (Subsection 3.8.2.4.1.4), which, if changed, requires NRC Staff review and approval prior to implementation. The applicable portions of the Tier 2 sections and tables, identified on Table 2 of DCD/Introduction for this restriction, are italicized on the sections and tables themselves.*]*

### 3.8.1.1.2 Containment Liner Plate

The internal surface of the containment is lined with welded steel plate to form a leaktight barrier. The liner plate is fabricated from carbon steel, except that stainless steel plate or clad is used on wetted surfaces of the suppression chamber.

The liner plate is stiffened by use of structural sections and plates to carry the design loads and to anchor the liner plate to the concrete, as shown Figure 3.8-9. The liner plate is thickened locally and additional anchorage is provided at major structural attachments such as penetration sleeves, structural beam brackets, the RPV pedestal and the SRV quencher support connection to the basemat, and the diaphragm floor connection to the containment wall.

The erection of the liner is performed using standard construction procedures. The containment wall liner and top slab liner are used as a form for concrete placement. The liner on the bottom of the suppression chamber and lower drywell is placed after the foundation mat concrete is in place.

* See section 3.5 of DCD/Introduction.

### 3.8.1.2 Applicable Codes, Standards, and Specifications

The design, fabrication, construction, testing, and inservice inspection of the containment conforms to the applicable codes, standards, specifications, and regulations listed below, except where specifically stated otherwise.

#### 3.8.1.2.1 Regulations

(1) Code of Federal Regulations, Title 10, Energy, Part 50, "Licensing of Production and Utilization Facilities."

(2) Code of Federal Regulations (CFR), Title 10 - Energy, Part 100, Reactor Site Criteria, (10CFR100), including Appendix A thereto, "Seismic and Geologic Siting Criteria for Nuclear Power Plants."

#### 3.8.1.2.2 Construction Codes of Practice

[*American Society of Mechanical Engineers(ASME) Boiler and Pressure Vessel Code, Section III, Division 2, Subsection CC.*]*

#### 3.8.1.2.3 General Design Criteria, Regulatory Guides, and Industry Standards

(1) 10CFR50, Appendix A, "General Design Criteria for Nuclear Power Plants", Criteria 1, 2, 4, 16 and 50. Conformance is discussed in Section 3.1.

(2) U.S. Nuclear Regulatory Commission (NRC) Regulatory Guides. Regulatory Guide 1.136, "Materials, Construction and Testing of Concrete Containment".

(3) Industry Standards

Nationally recognized industry standards such as those published by the American Society for Testing and Materials (ASTM) and the American National Standards Institute (ANSI) as referenced by the Applicable Codes, Standards, and Regulations are used.

#### 3.8.1.2.4 Containment Boundary

The jurisdictional boundary for application of Section III, Division 2 of the ASME Code to the concrete containment is shown in Figure 3H.1-2. The boundary extends to the:

(1) Outside diameter of the containment wall from the foundation mat to the containment top slab.

(2) The foundation mat within the outside diameter of the containment wall.

* See Subsection 3.8.1.1.1.

(3) The containment top slab from the drywell head opening to the outside diameter of the containment wall.

(4) The intersection of the RPV pedestal on top of the basemat.

(5) The intersection of the diaphragm floor with the containment wall.

The concrete containment pressure boundary is limited to the cylindrical wall of the drywell and wetwell, and the drywell top slab.

They are included in ASME Code jurisdiction boundary for design, material, fabrication, inspection, testing, stamping, etc., requirements of the code. However, the fuel pool girders and any other structural components which are integral with the containment structure are treated the same as the containment only as far as loads and loading combinations are concerned in the design. Similarly, the R/B floor slabs that are integrated with the containment are not included in the ASME Code jurisdictional boundaries, but are treated the same as the containment only as far as loads and load combinations are concerned.

The reactor pedestal and diaphragm floor slab, which partition the containment into drywell and suppression chamber, are not part of the containment boundary. The reactor pedestal, steel structures filled with concrete, and the diaphragm floor slab are designed according to codes given in Subsections 3.8.3 and 3.8.4, respectively.

Those portions of the structure outside the indicated Code jurisdictional boundary will be designed, analyzed and constructed as indicated in Subsections 3.8.3, 3.8.4 and 3.8.5. The analytical models will include both the containment and Reactor Building and therefore will provide continuity in the analysis.

### 3.8.1.3 Loads and Load Combinations

The containment is analyzed and designed for all credible conditions of loading, including normal loads, preoperational testing loads, loads during severe environmental conditions, loads during extreme environmental conditions and loads during abnormal plant conditions.

#### 3.8.1.3.1 Normal Loads

(1) D — Dead load of the structure and equipment plus any other permanent loads, including vertical and lateral pressures of liquids.

(2) L — Live loads, including any moveable equipment loads and other loads which vary in intensity and occurrence, such as forces exerted by the lateral pressure of soil.

Live Load L, includes floor area live loads, laydown loads, nuclear fuel and fuel transfer casks, equipment handling loads, trucks, railroad vehicles and similar items. The floor area live load shall be omitted from areas occupied by equipment whose weight is specifically included in dead load. Live load shall not be omitted under equipment where access is provided, for instance, an elevated tank on four legs.

The criteria for consideration of live loads for the designs of structural elements of the Reactor Building and Control Building are provided in Subsections 3H.1.4.3.1 and 3H.2.4.3.1, respectively. The inertial properties include all tributary mass expected to be present in operating conditions at the time of earthquake. This mass includes dead load, stationary equipment, piping and appropriate part of live load established in accordance with the layout and mechanical requirements. In the ABWR design, 25% of full live load L (designated as $L_o$), is used in the load combinations that include seismic loads. This value of $L_o$ is justifiable on the following consideration:

(a) Because of the overall light occupancy of the power plants during their operation, it is a general practice to use a minimum of $L_o$ to be 25% of the full live load L.

(b) Section 9.3 of ASCE Standards 7-88 and Section 12.7.2 of ASCE 7-05 specify that a minimum of 25% of the floor live loads should be considered for the computation of design seismic forces for storage and warehouse type occupancies. The variation in live load intensity and occurrence in operating nuclear plants is expected to be no higher than that for storage and warehouse occupancies. A 25% of full live loads is, therefore, equally applicable to the nuclear plants

However, the live load values used in the governing loading combination for design of local elements such as beams and slabs, are the full values. For example in the loading combination for RCCV shown in Subsection 3H.1.4.3.2.1 for load combination No. 15, the value of SSE is computed using 25% of the live load and in addition full value of live load is used for L for the design of structural components.

(3) $T_o$ — Thermal effects and loads during normal operating, startup or shutdown conditions, including liner plate expansion, equipment and pipe reactions, and thermal gradients based on the most critical transient or steady- state thermal gradient.

(4) $R_o$ — Pipe reactions during normal operating or shutdown conditions based on the most critical transient or steady-state conditions.

(5) $P_o$ — Pressure loads resulting from the pressure difference between the interior and exterior of the containment, considering both interior pressure changes because of heating or cooling and exterior atmospheric pressure variations.

(6) Construction Loads — Loads which are applied to the containment from start to completion of construction. The definitions for D, L and $T_o$ given above are applicable, but are based on actual construction methods and/or conditions.

(7) SRV — Safety/relief valve loads. Oscillatory dynamic pressure loadings resulting from discharge of safety/relief valves (SRVs) into the suppression pool. The development of these loads is with the methods described in Section 3B. The R/B vibration dynamic effects shall be included in the load combinations. The number and combinations of valves that will open during an RPV pressure transient are as follows:

(a) $G_1$ — Design pressure load on the suppression pool boundary resulting from discharge of one SRV into the suppression pool. First actuation and subsequent actuation shall be considered.

(b) $G_2$ — Design pressure load on the suppression pool boundary resulting from discharge of two adjacent SRVs, first actuation, into the suppression pool.

(c) $G_{ALL}$ — Design pressure load on the suppression pool boundary resulting from discharge of all SRVs, first actuation, into the suppression pool.

(d) ADS — Design pressure load on the suppression pool boundary resulting from the SRV Automatic Depressurization System (ADS) discharge into the suppression pool.

#### 3.8.1.3.2 Preoperational Testing Loads

(1) $P_t$ — Test loads are loads which are applied during the structural integrity test.

(2) $T_t$ — Thermal effects and loads during the structural integrity test.

#### 3.8.1.3.3 Severe Environmental Loads

(1) W — Loads generated by the design wind specified for the plant site as defined in Section 3.3.

#### 3.8.1.3.4 Extreme Environmental Loads

(1) E'— Safe shutdown earthquake (SSE) loads as defined in Section 3.7.

(2) W' — Loads generated by the tornado specified in Section 3.3.

#### 3.8.1.3.5 Abnormal Plant Loads

(1) $F_L$ — Hydrostatic load due to post-LOCA flooding of the containment for fuel recovery subsequent to a design basis accident.

(2) $R_a$ — Pipe reactions (including $R_o$) from thermal conditions generated by a LOCA.

(3) $T_a$ — Thermal effects (including $T_o$) and loads generated by a LOCA.

(4) $P_a$ — Design accident pressure load within the containment generated by large break LOCA (LBL), based upon the calculated peak pressure with an appropriate margin.

(5) $P_i$ — Design accident pressure load within the containment generated by an intermediate break LOCA (IBL).

(6) $P_s$ — Design accident pressure load within the containment generated by a small break LOCA (SBL).

(7) Y — Local effects on the containment due to a LOCA. The local effects shall include the following:

(a) $Y_r$ — Load on the containment generated by the reaction of a ruptured high-energy pipe during the postulated event of the DBA. The time-dependent nature of the load and the ability of the containment to deform beyond yield shall be considered in establishing the structural capacity necessary to resist the effects of $Y_r$.

(b) $Y_j$ — Load on the containment generated by the jet impingement from a ruptured high-energy pipe during the postulated event of the DBA. The time-dependent nature of the load and the ability of the containment to deform beyond yield shall be considered in establishing the structural capacity necessary to resist the effects of $Y_j$.

(c) $Y_m$ — The load on the containment resulting from the impact of a ruptured high-energy pipe during the DBA. The type of impact (e.g., example plastic or elastic), together with the ability of the containment to deform beyond yield, shall be considered in establishing the structural capacity necessary to resist the impact.

(8) CO — An oscillatory dynamic loading (condensation oscillation) on the suppression pool boundary due to steam condensation at the vent exits during the period of high steam mass flow through the vents following a LOCA.

(9) CHUG — An oscillatory dynamic loading (chugging) in the top vent and on the suppression pool boundary due to steam condensation inside the top vent or at the top vent exit during the period of low steam mass flow in the top vent following a LOCA.

(10) VLC — Loads from component response or direct fluid forces, on components located in the suppression pool, caused by the main vent line clearing phenomenon.

(11) PS — Pool swell bubble pressure (axisymmetrical and nonaxisymmetrical) on the suppression pool boundary due to a LOCA.

#### 3.8.1.3.6 Load Combinations for the Containment Structure and Liner Plate

The containment structure is designed using the loads, load combinations, and load factors listed in Table 3.8-1.

Loads and load combinations listed in Table 3.8-1 shall be used for the design of the steel liner and liner anchors, but the load factor for all loads in the load combinations shall be 1.0.

### 3.8.1.4 Design and Analysis Procedures

This section describes the analytical and design procedures used in designing the containment.

#### 3.8.1.4.1 Containment Cylindrical Wall, Top Slab, and Foundation Mat

##### 3.8.1.4.1.1 Analytical Methods

The containment structure is analyzed by the use of the linear elastic finite element computer program STARDYNE described in Section 3C. The containment and Reactor Building layout utilizes an integrated structural system. The structure is idealized as a three-dimensional assemblage of beam elements, and iso-parametric membrane-bending plate elements.

Since the containment and Reactor Building are essentially symmetrical about the centerline of the plant parallel to the fuel pool girders and steam tunnel, only 180° of the structure is modeled. Boundary conditions are applied along the centerline of the plant that simulate the symmetry of the whole structure.

The foundation soil is simulated by a set of horizontal and vertical springs. The soil spring constraints are calculated based on using correction factors to account for the R/B embedment.

The containment and reactor building 180° finite element model is shown in Figure 3H.1-12.

###### 3.8.1.4.1.1.1 Nonaxisymmetrical Loads

Nonaxisymmetrical loads imposed on the structure include the following, and are as defined in Subsection 3.8.1.3:

(1) Tornado wind

(2) Design wind

(3) Safe shutdown earthquake

(4) Local pipe rupture forces, including local compartmental pressures from ruptured pipes in compartments inside or outside the containment

(5) Pool swell bubble pressure

(6) SRV actuation in the suppression pool

(7) Loadings from embedded steel brackets in the wall and top slab

The containment structure is analyzed for the nonaxisymmetrical pool swell bubble pressure, and nonaxisymmetrical pressures from discharge.

An equivalent static analysis is performed for the nonaxisymmetrical pool swell bubble pressure loading using the peak pressures for this loading.

Input data for nonaxisymmetrical pool swell bubble pressures is described in Subsection 3.8.1.3.5.

Seismic inertial forces (two orthogonal horizontal and one vertical) based on the analysis described in Section 3.7 are applied to the finite element model as equivalent static forces. The resulting moments and forces at various sections of the containment structure are combined by the square-root-of-the-sum-of the-squares (SRSS) method.

The containment wall is shielded from the design wind by the Reactor Building, which completely encloses the structure. Forces from the design wind are transmitted directly to the containment wall through the R/B connections.

The actuation of SRVs results in dynamic loads on the suppression pool boundaries. These dynamic loads are formulated by applying a time function to the attentuated pressures in the suppression pool which result from single and multiple valve discharge. These attenuated pressures are calculated based upon the methodology presented in Appendix 3B. The time function is an oscillation of the bubble pressure within the suppression pool, which is shown in Appendix 3B. The magnitude of the pressure at any point within the pool decreases with time, with the duration of the load being less than 1 second. This pressure time history is represented in terms of an equivalent static load and then used as input for the structural analysis with a dynamic load factor.

The containment wall and containment basemat are extremely stiff steel-lined reinforced concrete structures which form the suppression pool boundary. Thus, effects of fluid-structure interaction upon the total containment building response due to dynamic suppression pool boundary loads are small. Suppression pool boundary loads, defined in Appendix 3B, are applied to the mathematical model as rigid wall loads. The mass of the suppression pool water has been lumped at those node points that form the suppression pool boundary.

#### 3.8.1.4.1.1.2 Axisymmetrical Loads

Axisymmetric loads imposed on the containment structure include the following, and are as defined in Subsection 3.8.1.3:

(1) Structure dead load

(2) Surcharge loads from adjacent structures

(3) Hydrostatic load from probable maximum flood

(4) Hydrostatic load from normal site water table

(5) Hydrostatic load from post-LOCA flooding of the containment

(6) Local dead and live loads from embedded brackets, treated as axisymmetrical loads for overall structural response

(7) Dead and live loads from internal structures imposed on the foundation mat

(8) Normal operating thermal gradients

(9) Abnormal plant thermal gradients (including those from LBL, IBL and SBL)

(10) Preoperational test pressure

(11) Abnormal plant pressure loads (including those from LBL, IBL and SBL)

(12) Normal external pressure load

(13) Safety/relief valve actuation in suppression pool

(14) Pool swell bubble pressure

A LOCA and SRV actuation result in dynamic loads on the suppression pool boundaries. These hydrodynamic loads are formulated by applying a time function to the attenuated pressures in the suppression pool. The attenuated pressures are calculated based on the methodology presented in Appendix 3B. Once the pressure time histories are formulated, they are represented in terms of an equivalent static load and then used as input for the finite element analysis with a dynamic load factor.

#### 3.8.1.4.1.1.3 Major Penetrations

The major penetrations in the containment wall include: (1) the upper drywell equipment and personnel hatches, (2) the lower drywell equipment and personnel tunnels and hatches, (3) the suppression chamber access hatch, and (4) the main steam and feedwater pipe penetrations. The state of stress and behavior of the containment wall around these openings is determined by the use of analytical numerical techniques. The analysis of the area around the penetrations consists of a three-dimensional finite element analysis with boundaries extending to a region where the discontinuity effects of the opening are negligible.

Displacements compatible with the global analysis of the containment are applied at these boundaries. The stresses and strains in the reinforcement, concrete and liner plate are obtained from the local finite element model. The analysis considers concrete cracking and thermal strains.

#### 3.8.1.4.1.1.4 Variation of Physical Material Properties

In the design analysis of the containment, the physical properties of materials are based on the values specified in applicable codes and standards. Reconciliation evaluation will be performed if the as-built properties differ significantly from the design values.

#### 3.8.1.4.1.2 Design Methods

The design of the containment structure is based on the membrane forces, shear forces and bending moments for the load combinations defined in Subsection 3.8.1.3.6. The membrane forces, shear forces and bending moments in selected sections are obtained by the computer program STARDYNE, as described in Subsection 3.8.1.4.1.1. The selected sections are shown in Figure 3H.1-21.

The Concrete Element Cracking Analysis Program (CECAP), described in Section 3B, is used to determine the extent of concrete cracking at these sections, and the concrete and rebar stresses and liner plate strains. The CECAP program models a single element of unit height, unit width, and depth equal to the thickness of the wall or slab. The calculations used in CECAP assume that the concrete is isotropic and linear elastic but with zero tensile strength. CECAP also can calculate the reduced thermal forces and moments due to concrete cracking. However, the redistribution of forces and moments is not calculated. To account for the concrete cracking effects on the redistribution of forces and moments, an iterative procedure described in Subsection 3.8.1.4.1.3 is used.

The input data for the CECAP program consist of the membrane forces, shear forces and bending moments calculated by the STARDYNE analysis. The areas of the reinforcing steel in terms of steel area to concrete cross-section ratio are based on the design shown in Section 3H. The evaluation of containment structural adequacy is shown in Subsection 3.8.1.5.

#### 3.8.1.4.1.3 Concrete Cracking Considerations

The membrane forces, shear forces and bending moments in the containment structure subjected to loads are obtained by applying the STARDYNE computer program to the finite element model that was developed on the basis of an uncracked section. This model is called the uncracked model. In sizing the reinforcing steel or in calculating the rebar stresses, the concrete is not relied upon for resisting tension. Thus, those portions of structures which are either in membrane tension or in flexural tension are cracked to transfer loads from concrete to rebar. The CECAP program, described in Section 3C, is used for calculating the extent of concrete cracking and the stresses in the concrete and in the steel. Because of concrete cracking that leads to stiffness changes, the distribution of forces and moments is different from those calculated from the uncracked model described above. To determine the effects due to concrete cracking, an axisymmetric finite element model which takes into account the concrete cracking, was developed for applying the FINEL computer program to the SIT loadings. The FINEL program (Subsection 3C.4) performs the non-linear static analysis utilizing a stepwise linear iteration solution technique. Within each solution cycle, status of all elements is determined and their stiffness adjusted by the program prior to the next iteration cycle.

The procedures for the design and analysis of the liner plate and its anchorage system are in accordance with the provisions of the ASME Code Section III, Division 2, Subarticle CC-3600. The liner plate analysis considers deviations in geometry due to fabrication and erection tolerances. The strains and stresses in the liner and its anchors are within allowable limits defined by the ASME Code Section III, Division 2, Subarticle CC-3720.

#### 3.8.1.4.1.4 Corrosion Prevention

Type 304L stainless steel or clad carbon steel plate will be used for the containment liner in the wetted areas of the suppression pool as protection against any potential pitting and corrosion on all wetted surfaces and at the water-to-air interface area.

The suppression pool contains air-saturated, stagnant, high purity water and is designed for a 60-year life. The amount of corrosion is based on the annual temperature profile of suppression pool water for a typical plant in southern states under normal operation (Figure 3.8-20). The following conditions can cause the pool temperature to rise above normal:

(1) Reactor core isolation mode: pool temperature can rise 17°C above normal for a total of 165 days during the 60-year lifetime

(2) Suppression pool cooling mode: pool temperature can rise 17°C above normal for a total of 540 days during the 60-year lifetime.

The corrosion allowance for Type 304L stainless steel in air-saturated water for any oxygen level and temperatures up to 316°C for 60 years is 0.12 mm. The major concern has involved the air/water interface area where pitting is most likely to occur. The 0.12 mm corrosion allowance is a small fraction of the stainless steel thickness, which will be a nominal 2.5 mm if clad carbon steel plate is used.

Water used to fill the suppression pool is either condensate or demineralized. No chemicals are added to the suppression pool water.

Observations made on suppression pool water quality over a period of several years indicate that periodic pool cleaning such as by underwater vacuuming will be required, as well as the use of the Suppression Pool Cleanup (SPC) System to maintain water quality standards. The SPC System (Subsection 9.5.9) also acts to maintain purity levels.

An ultrasonic thickness measurement program will be performed to detect any general corrosion at underwater positions. A visual examination for local pitting on the underwater portions of the steel containment will be made at refueling outages using underwater lighting and short focus binoculars. This covers 10% of the surface at the first refueling outage after the start of commercial operation, 5% additional surface approximately two to five years later and 5% at five-year intervals thereafter. If pits are detected at any examination, representative ones are ultrasonically tested and the depth of those large enough for measurement will be determined. Appropriate repairs can be made as required.

#### 3.8.1.4.2 Ultimate Capacity of the Containment

An analysis is performed to determine the ultimate capacity of the containment. The results of this analysis are summarized in Appendix 19F.

### 3.8.1.5 Structural Acceptance Criteria

For evaluation of the adequacy of the containment structural design, the major allowable stresses of concrete and reinforcing steel for service load combinations and factored load combinations according to ASME Code Section III, Division 2 (except for tangential shear stress carried by orthogonal reinforcement for which a lower allowable is adopted for ABWR) are shown in Table 3.8-2.

The allowable tangential shear strength provided by orthogonal reinforcement without inclined reinforcement is limited to 3.9 MPa for factored load combinations. Inclined reinforcement is not used to resist tangential shear in the ABWR containment. The maximum tangential shear stress calculated for factored load combinations is 3.6 MPa. The maximum membrane shear strain value for governing loading combination is 0.00295 which is based on very conservative calculations with fully cracked concrete and without any consideration of the stiffness provided by steel liner.

The maximum tangential shear strain value for the seismic load alone, based on elastic analysis is 0.000355.

### 3.8.1.6 Material, Quality Control and Special Construction Techniques.

Materials used in construction of the containment are in accordance with Regulatory Guide 1.136 and ASME Code Section III, Division 2, Article CC-2000. Specifications covering all materials are in sufficient detail to assure that the structural design requirements of the work are met.

#### 3.8.1.6.1 Concrete

All concrete materials are approved prior to start of construction on the basis of their characteristics in test comparisons using ASTM standard methods. Concrete aggregates and cement, conforming to the acceptance criteria of the specifications, are obtained from approved sources. Concrete properties are determined by laboratory tests. Concrete admixtures are used to minimize the mixing water requirements and increase workability. The specified compressive strength of concrete at 28 days, or earlier, is:

| Structure | Specified Strength $f_c'$ MPa |
|---|---|
| Containment | 27.56 |
| Foundation Mat | 27.56 |

All structural concrete is batched and placed in accordance with Subarticle CC-2200 and Article CC-4000 of ASME Code Section III, Division 2.

(1) Cement

Cement is Type II conforming to the Specification for Portland Cement (ASTM C 150). The cement contains no more than 0.60% by weight of alkalies calculated as sodium oxide plus 0.658 percent by weight potassium oxide. Certified copies of material test reports showing the chemical composition and physical properties are obtained for each load of cement delivered.

For sites where concrete may come into contact with soils having more than 0.20% water soluble sulfate (as $SO_4$) of ground- water with a sulfate concentration exceeding 1500 ppm, only Type V cement shall be used unless other suitable means are employed to prevent sulfate attack and concrete deterioration.

(2) Aggregates

All aggregates conform to the Specification for Concrete Aggregates (ASTM C 33).

(3) Water

Water and ice for mixing is clean, with a total solids content of not more than 2000 ppm as measured by ASTM D-1888. The mixing water, including that contained as free water in aggregate, contains not more than 250 ppm of chlorides as Cl as determined by ASTM D-512. Chloride ions contained in the aggregate are included in calculating the total chloride ion content of the mixing water. The chloride content contributed by the aggregate is determined in accordance with ASTM D-1411.

(4) Admixtures

The concrete may also contain an air-entraining admixture and/or a water-reducing admixture. The air-entraining admixture is in accordance with the Specification of Air Entraining Admixtures for Concrete (ASTM C-260). It is capable of entraining 3 to 6% air, is completely water soluble, and is completely dissolved when it enters the batch. Superplasticizers, entraining from 1.5 to 4.5% air, may be used in concrete mixes (f ' = 34.42 MPa, maximum) for congested areas to improve workability and prevent the formation of voids around reinforcement. The water-reducing admixture conforms to the standard specification for Chemical Admixtures for Concrete (ASTM C-494), Types A and D. Type A is used when average ambient temperature for the daylight period is below 21.1$^{o}$C. Type D is used when average ambient air temperature for the daylight period is 21.1$^{o}$C and above. Pozzolans, if used, conform to Specification for Fly Ash and Raw or Calcined Natural Pozzolans for Use in Portland Cement Concrete (ASTM C-618), except that the loss on ignition shall be limited to 6%. Admixtures containing more than 1% by weight chloride ions are not used.

(5) Concrete Mix Design

Concrete mixes are designed in accordance with ACI 211.1 (Recommended Practice for Selecting Proportions for Normal and Heavy Weight Concrete), using materials qualified and accepted for this work. Only mixes meeting the design requirements specified for concrete are used.

#### 3.8.1.6.2 Reinforcing Steel

Reinforcing bars for concrete are deformed bars meeting requirements of the Specification for Deformed and Plain Billet Steel Bars for Concrete Reinforcement (ASTM A-615, Grade 60). Mill test reports, in accordance with ASTM A-615, are obtained from the reinforcing steel supplier to substantiate specification requirements.

The test procedures are in accordance with ASTM A-370, and acceptance standards are in accordance with ASTM A-615.

#### 3.8.1.6.3 Splices of Reinforcing Steel

Sleeves for reinforcing steel mechanical splices conform to ASTM A-513, A-519 or A- 576 Grades 1008 through 1030. Certified copies of material test reports indicating chemical composition and physical properties are furnished by the manufacturer for each sleeve lot.

Placing and splicing of reinforcing bars is in accordance with Article CC-4300 and Subarticle CC-3530 of ASME Code Section III, Division 2.

#### 3.8.1.6.4 Liner Plate and Appurtenances

The materials conform to all applicable requirements of ASME Code Section III, Division 2.

Steel plate is tested at the mill in full conformance to the applicable ASTM specifications, and certified mill test reports are supplied for review and approval. The plate is visually examined for laminations and pitting. Identity of the plate is maintained throughout fabrication.

Dimensional tolerances for the erection of the liner plate and appurtenances are detailed in the Construction Specification based on the structure geometry, liner stability, concrete strength, and the construction methods to be used.

#### 3.8.1.6.5 Quality Control

Quality control procedures are established in the Construction Specification and implemented during construction and inspection. The Construction Specification covers the fabrication, furnishing, and installation of each structural item and specifies the inspection and documentation requirements to ensure that the requirements of ASME Code Section III, Division 2, and the applicable Regulatory Guides are met.

#### 3.8.1.6.6 Welding Methods and Acceptance Criteria for Containment Vessel Lines and Appurtenances

Welding methods and acceptance criteria for the containment vessel liner and appurtenance are the same as those for the steel components of the concrete containment vessel (i.e., personnel air locks, equipment hatches, penetrations, and drywell head) given in Subsection 3.8.2.7.1.

### 3.8.1.7 Testing and Inservice Inspection Requirements

#### 3.8.1.7.1 Structural Integrity Pressure Test

A structural integrity test of the containment structure will be performed by the COL applicant in accordance with Article CC-6000 of ASME Code Section III, Division 2 and Regulatory Guide 1.136, after completion of the containment construction. The test is conducted at 115% of the design pressure condition of 309.9 kPaG in both the drywell and suppression chamber, simultaneously. A pressure test for the design differential pressure condition of 172.6 kPaG between the drywell and the suppression chamber is also performed where the drywell pressure is greater than the suppression chamber pressure.

During these tests, the suppression chamber and spent fuel pool are filled with water to the normal operational water level. Deflection and concrete crack measurements are made to determine that the actual structural response is within the limits predicted by the design analysis.

In addition to the deflection and crack measurements, the first prototype containment structure is instrumented for the measurement of strains in accordance with the provisions of Subarticle CC-6230 of ASME Code Section III, Division 2. See Subsection 3.8.6.3 for COL license information.

#### 3.8.1.7.2 Preoperational and Inservice Integrated Leak Rate Test

Preoperational and inservice integrated leak rate testing is discussed in Subsection 6.2.6.

## 3.8.2 Steel Components of the Reinforced Concrete Containment

### 3.8.2.1 Description of the Containment

The ABWR has a reinforced concrete containment vessel (RCCV) as described in Subsection 3.8.1. This section will describe the following steel components of the concrete containment vessel:

(1) Personnel Air Locks

(2) Equipment Hatches

(3) Penetrations

(4) Drywell Head

#### 3.8.2.1.1 Description of Penetrations

The penetrations through the RCCV include the following.

##### 3.8.2.1.1.1 Personnel Air Locks

Two personnel air locks with an inside diameter sufficient to provide 1850 mm high by 750 mm wide minimum clearance above the floor at the door way are provided. One of these air locks provides access to the upper drywell and the other provides access to the lower drywell via the access tunnel.

Lock and swing of the doors is by manual and automatic means. The locks extend radically outward from the RCCV into the Reactor Building and are supported by the RCCV only. The minimum clear horizontal distance not impaired by the door swing is 1850 mm.

Each personnel air lock has two pressure-seated doors interlocked to prevent simultaneous opening of both doors and to ensure that one door is completely closed before the opposite door can be opened. The design is such that the interlocking is not defeated by postulated malfunctions of the electrical system. Signals and controls that indicate the operational status of the doors are provided. Provision is made to permit temporary bypassing of the door interlock system during plant cold shutdown. The door operation is designed and constructed so either door may be operated from inside the containment vessel, inside the lock, or from outside the containment vessel.

The lock is equipped with a digital readout pressure transducer system to read inside and outside pressures. Quick-acting valves are provided to equalize the pressure in the air lock when personnel enter or leave the containment vessel. The personnel air locks have a double sealed flange with provisions to pressure test the space between the seals of the flange.

#### 3.8.2.1.1.2 Equipment Hatch

Three equipment hatches are provided. One of these serves the upper drywell and the other serves the lower drywell via the access tunnel. The third equipment hatch provides personnel and equipment access to the suppression chamber airspace.

The equipment hatch covers have a double sealed flange with provisions to pressure test the space between the seals of the flange. A means for removing and handling the equipment hatch cover is provided. The hoisting equipment and hoisting guides are arranged to minimize contact between the doors and seals during opening and closing. The equipment hatch includes the electric-motorized hoist with pushbutton control stations, lifting slings, hoist supports, hoisting guides, access platforms, and ladders for access to the dogged position of the door and hoist, latches, seats, dogging devices, and tools required for operation and maintenance of the hatch.

The equipment hatches and covers are entirely supported by the RCCV. Figure 3.8-15 shows general details of the equipment hatch and cover.

#### 3.8.2.1.1.3 Other Penetrations

The RCCV penetrations are categorized into two basic types. These types differ with respect to whether the penetration is subjected to a hot or cold operational environment.

The cold penetrations pass through the RCCV wall and are embedded directly in it. The hot penetrations do not come in direct contact with the RCCV wall but are provided with a thermal sleeve which is attached to the RCCV wall. The thermal sleeve is attached to the process pipe at distance from the RCCV wall to minimize conductive heat transfer to the RCCV wall.

Besides piping penetrations, several electrical penetrations also exist. A description of the various penetrations is given Chapter 8.

#### 3.8.2.1.1.4 Drywell Head

A 10,300 mm diameter opening in the RCCV upper drywell top slab over the RPV is covered with a removable steel torispherical drywell head which is part of the pressure boundary. The drywell head is designed for removal during reactor refueling and for replacement prior to reactor operation using the reactor building crane. One pair of mating flanges is anchored in the drywell top slab and the other is welded integrally with the drywell head. Provisions are made for testing the flange seals without pressurizing the drywell. Figure 19F-4 shows the drywell head.

### 3.8.2.1.2 Boundaries

The boundaries of the steel components of the RCCV consist of those defined in Paragraph NE-1132, ASME Code Section III, Division 1.

### 3.8.2.2 Applicable Codes, Standards, and Specifications

#### 3.8.2.2.1 Codes and Standards

In addition to the codes and standards specified in Subsection 3.8.1.2.2, the following codes and standards apply:

(1) American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Division 1, Nuclear Power Plant Components, Subsection NE, Class MC.

(2) AISC Manual for Steel Construction.

#### 3.8.2.2.2 Code Classification

The steel components of the RCCV are classified as Class MC in accordance with Subarticle NA-2130, ASME Code Section III.

#### 3.8.2.2.3 Code Compliance

[*The steel components within the boundaries defined in Subsection 3.8.2.1.2, are designed, fabricated, erected, inspected, examined, and tested in accordance with Subsection NE, Class MC Components and Articles NA-4000 and NA-5000 of ASME Code Section III, Division 1.*]*

Structural steel attachments beyond the boundaries established for the steel components of the RCCV are designed, fabricated, and constructed according to the AISC Manual for Steel Construction.

### 3.8.2.3 Loads and Load Combinations

The applicable loads and load combinations are described in Subsection 3.8.1.3.

### 3.8.2.4 Design and Analysis Procedures

The steel components of the RCCV are designed in accordance with the General Design Rules of Subarticles NE-3100 (General Design), NE-3200 (Design by Analysis), and NE-3300 (Vessel Design) of ASME Code Section III. For the configurations and loadings which are not explicitly treated in Subarticle NE-3130, the design is in accordance with the applicable Subarticles designated in paragraphs (b) and (d) of Subarticles NE-3130 of ASME Code Section III.

The design of nonpressure-resisting parts is performed in accordance with the general practices of the AISC Manual of Steel Construction.

* See Subsection 3.8.1.1.1 as applied in Subsection 3.8.2.4.1.4.

#### 3.8.2.4.1 Description

Following are individual descriptions of the design and analysis procedures required to verify the structural integrity of critical areas present within the steel components of the RCCV.

##### 3.8.2.4.1.1 Personnel Air Locks

The personnel air lock consists of four main sections: doors, bulkheads, main barrel, and reinforcing barrel with collar. The personnel air locks are supported entirely by the RCCV wall. The lock barrel is welded directly to the containment liner penetration through the RCCV wall. The personnel lock and penetration through the RCCV wall will be analyzed using a finite element computer program. The discontinuity stresses induced by the combination of external, dead, and live loads, including the effects of earthquake loadings, are evaluated. The required analyses and limits for the resulting stress intensities are in accordance with Subarticles NE-3130 and NE-3200 of ASME Code Section III, Division 1.

The piping system and components inside the personnel air locks are Class 2 and are designed in accordance with ASME Code Section NC.

##### 3.8.2.4.1.2 Equipment Hatches

An equipment hatch assembly consists of the equipment hatch cover and the equipment hatch body ring which is imbedded in the RCCV wall and connects to the RCCV liner.

A finite-element analysis model will be used to determine the stresses in the body ring and hatch cover of the equipment hatch. The equipment analysis and the stress intensity limits are in accordance with Subarticles NE-3130 and NE-3200 of ASME Code Section III. The hatch cover with the bolted flange is designed in accordance with Subarticle NE-3326 of ASME Code Section III.

##### 3.8.2.4.1.3 Penetrations

Piping penetrations and electrical penetrations are subjected to various combinations of piping reactions, mechanical, thermal and seismic loads transmitted through the RCCV wall structure. The resulting forces due to various load combinations are combined with the effects of external and internal pressures.

The stresses in the penetrations are evaluated using a finite-element model for stress analysis. For penetrations subjected to cyclic loads, the peak stress intensities are also evaluated. The required analysis and associated stress intensity limits are in accordance with Subarticles NE-3130 and NE-3200 of ASME Code Section III, Division 1.

##### 3.8.2.4.1.4 Drywell Head

The drywell head, consisting of shell, flanged closure and drywell-head anchor system, will be analyzed using a finite-element stress analysis computer program. The stresses, including discontinuity stresses induced by the combination of external pressure or internal pressure, dead load, live load, thermal effects and seismic loads, are evaluated. The required analyses and limits for the resulting stress intensities are in accordance with Subarticles NE-3130 and NE-3200 of ASME Code Section III, Division 1.

[*The compressive stress within the knuckle region caused by the internal pressure and the compression in other regions caused by other loads are limited to the allowable buckling stress values in accordance with Subarticle NE-3222 of ASME Code Section III, Division 1*]*, or Code Case N-284.

### 3.8.2.5 Structural Acceptance Criteria

The structural acceptance criteria for the steel components of the RCCV (i.e., the basis for establishing allowable stress values, the deformation limits, and the factors of safety) are established by and in accordance with ASME Code Section III, Subsection NE.

In addition to the structural acceptance criteria, the RCCV is designed to meet minimum leakage rate requirements discussed in Section 6.2. Those leakage requirements also apply to the steel components of the RCCV.

The combined loadings designated under “Normal”, “Construction”, “Severe Environmental”, “Extreme Environmental”, “Abnormal”, “Severe Environmental” and “Abnormal/Extreme Environmental” in Table 3.8-1 are categorized according to Level A, B, C and D service limits as defined in NE-3113. The resulting primary and local membrane, bending, and secondary stress intensities, including compressive stresses, are calculated and their corresponding allowable limit is in accordance with Subarticle NE-3220 of ASME Code Section III.

In addition, the stress intensity limits for testing, design and post-LOCA flooding conditions are summarized in Table 3.8-3.

Stability against compression buckling is assured by an adequate factor of safety.

The allowable stress limits used in the design and analysis of nonpressure-resisting components are in accordance with Subsection 3.8.2.2.1 (2).

### 3.8.2.6 Materials, Quality Control, and Special Construction Techniques

The steel components of the RCCV locks, hatches, penetrations, and drywell head will be fabricated from the following materials:

(1) Plate (SA-516 grade 70, SA-240 type 304L, SA-516 grade 60 or 70 purchased to SA-264)

* See Subsection 3.8.1.1.1.

(2) Pipe (seamless SA-333 grade 1 or 6 or SA-106 grade B or SA-312 type 304L)

(3) Forgings (SA-350 grade LFl or LF2)

(4) Bolting (SA-320-L43 or SA-193-B7 bolts with SA-194-7 or A325 or A490 nuts)

(5) Castings (SA-216, grade WCB or SA-352, grade LCB, A27, or 7036)

(6) Cold finished steel (A108 grade 1018 to 1050)

(7) Bar and machine steel (A576, carbon content not less than 0.3%)

(8) Clad (SA-240 type 304L)

The structural steel materials located beyond the containment vessel boundaries are as follows:

(1) Carbon steel (A36 or SA-36)

(2) Stainless steel extruded shapes (SA-479)

The materials meet requirements as specified in Subarticle NE-2000 of ASME Code Section III. The lowest service metal temperature is -1.1°C.

### 3.8.2.7 Testing and Inservice Inspection Requirements

Leakage of the containment vessel, including the steel components, is described in Subsection 3.8.1.7.

#### 3.8.2.7.1 Welding Methods and Acceptance Criteria

Welding activities shall be performed in accordance with requirements of Section III of the ASME Code. The required nondestructive examination and acceptance criteria are provided in Table 3.8-8.

#### 3.8.2.7.2 Shop Testing Requirements

The shop tests of the personnel air locks include operational testing and an overpressure test. After completion of the personnel air locks tests (including all latching mechanisms and interlocks), each lock is given an operational test consisting of repeated operating of each door and mechanism to determine whether all parts are operating smoothly without binding or other defects. All defects encountered are corrected and retested. The process of testing, correcting defects, and retesting is continued until no defects are detectable.

For the operational test, the personnel air locks are pressurized with air to the maximum permissible code test pressure. All welds and seals are observed for visual signs of distress or noticeable leakage. The lock pressure is then reduced to design pressure and a thick bubble solution is applied to all welds and seals and observed for bubbles or dry flaking as indications of leaks. All leaks and questionable areas are clearly marked for identification and subsequent repair.

During the overpressure testing, the inner door is blocked with holddown devices to prevent unseating of the seals. The internal pressure of the lock is reduced to atmospheric pressure and all leaks are repaired. Afterward, the lock is again pressurized to the design pressure with air and all areas suspected or known to have leaked during the previous test are retested by the bubble technique. This procedure is repeated until no leaks are discernible.

## 3.8.3 Concrete and Steel Internal Structures of the Concrete Containment

### 3.8.3.1 Description of the Internal Structures

The functions of the containment internal structures include (1) support of the reactor vessel radiation shielding, (2) support of piping and equipment, and (3) formation of the pressure suppression boundary. The containment internal structures are constructed of reinforced concrete and structural steel. The containment internal structures include the following:

(1) Diaphragm floor

(2) Reactor pedestal

(3) Reactor shield wall

(4) Drywell and equipment pipe support structure

(5) Miscellaneous platforms

(6) Lower drywell equipment tunnel

(7) Lower drywell personnel tunnel

Figures 3.8-17 and 3.8-18 and Figures 1.2-2 through 1.2-13 show an overview of the containment including the internal structures.

The summary report contained in Section 3H.1 contains the figures for the reactor pedestal and the diaphragm slab. Including but not limited to structural steel details, reinforcement details, loads, load combinations, concrete stresses, reinforcement stresses, liner stresses, and structural shell stresses.

#### 3.8.3.1.1 Diaphragm Floor

The diaphragm floor serves as a barrier between the drywell and the suppression chamber. It is a reinforced concrete circular slab, with an outside diameter of 14.5m , and a thickness of 1.2m.

The diaphragm floor is supported by the reactor pedestal and the containment wall. The connection of the diaphragm floor to the containment wall is a fixed support. The diaphragm floor connection to the reactor pedestal is a hinged support. The diaphragm floor is penetrated by 18-508 mm diameter sleeves for the SRV lines.

A 6.4 mm thick, carbon steel liner plate is provided on the bottom of the diaphragm floor, and is anchored to it. The liner plate serves as a form during construction and prevents the bypass flow of steam from the upper drywell to the suppression chamber air space during a LOCA.

#### 3.8.3.1.2 Reactor Pedestal

A composite steel and concrete pedestal provides support for the reactor pressure vessel, the reactor shield wall, the diaphragm floor, access tunnels, horizontal vents, and the lower drywell access platforms. The pedestal consists of two concentric steel shells tied together by vertical steel diaphragms. The regions formed by the steel shells and the vertical diaphragms, except the vents and the vent channels, are filled with concrete. There are ten drywell connecting vent (DCV) channels connecting the upper drywell to the lower drywell and the horizontal vents.

The wetted portion of the exterior surface of the reactor pedestal steel shell in the suppression chamber is clad with stainless steel to provide corrosion protection. The extent of the cladding and the reactor pedestal configuration is provided in
Figure 1.2-2.

#### 3.8.3.1.3 Reactor Shield Wall

The reactor shield wall is supported by the reactor pedestal and surrounds the reactor pressure vessel. Its function is to attenuate radiation emanating from the reactor vessel. In addition, the reactor shield wall provides structural support for the reactor vessel stabilizer, the reactor vessel insulation and the drywell equipment and pipe support structure. Openings are provided in the shield wall to permit the routing of necessary piping to the RPV and to permit in-service inspection of the RPV and piping.

The shield wall is shaped as a right cylinder. The shield wall consists of two concentric steel cylindrical shells joined together by horizontal and vertical steel plate diaphragms. Full depth stiffeners are provided in the reactor shield wall at the attachment locations of major pipe supports, pipewhip restraints and beam supports. The annular region between the outer and inner shells is filled with concrete. The arrangement of the reactor shield wall is provided in Figure 1.2-3.

#### 3.8.3.1.4 Drywell Equipment and Pipe Support Structure

The drywell equipment and pipe support structure (DEPSS) consists of various structural components such as beams and columns. Built-up box shapes are used for beams and columns that must resist torsion and biaxial bending. The beams span between the reactor shield wall and the vertical support columns which are anchored to the diaphragm floor. The DEPSS provides support for piping, pipe whip restraints, mechanical equipment, electrical equipment and general access platforms and stairs.

#### 3.8.3.1.5 Other Internal Structures

##### 3.8.3.1.5.1 Miscellaneous Platforms

Miscellaneous platforms are designed to allow access and to provide support for equipment and piping. The platforms consist of steel beams and grating.

##### 3.8.3.1.5.2 Lower Drywell Equipment Tunnel

A steel tunnel is provided at azimuth 180° for equipment access to the lower dry- well from the Reactor Building. The tunnel has an inside diameter of 4.3m, is 20 mm in thickness, and has a flanged closure at the R/B end. The wetted portion of the tunnel is stainless steel or carbon steel with stainless steel cladding. The tunnel is attached rigidly to the containment wall at one end and the reactor pedestal at the other end and is partially submerged in the suppression pool at normal water level. The tunnel has one or two flexible rings to accommodate differential displacement of the containment wall and reactor pedestal. The configuration of the tunnel and the connection details at the containment wall and reactor pedestal are shown in Figure 1.2-2. Fine motion control rod drive (FMCRD) piping is routed through the tunnel. The tunnel permits entry from the R/B into the lower drywell without exposure to the suppression chamber atmosphere.

##### 3.8.3.1.5.3 Lower Drywell Personnel Tunnel

The lower drywell personnel tunnel is located at azimuth 0° and is similar to the lower drywell equipment tunnel described in Subsection 3.8.3.1.5.2. However, it has a personnel lock at the R/B end. The arrangement and details of the tunnel are shown in Figure 1.2-2.

#### 3.8.3.2 Applicable Codes, Standards, and Specifications

The design of the concrete and steel internal structures of the containment conform to the applicable codes, standards, and specifications and regulations listed in Table 3.8-4 except where specifically stated otherwise.

| Structure or Component | Specific Reference Number |
|---|---|
| Diaphragm Floor | 13 |
| Reactor Pedestal | 1-12, 15-20 |
| Reactor Shield Wall | 1-12, 15-20 |
| DEPSS | 15-20 |
| Miscellaneous platforms | 15-20 |

| Structure or Component | Specific Reference Number |
|---|---|
| L/D Equipment Tunnel | 15-20 |
| L/D Personnel Tunnel | 15-20 |

[*Table 3 of DCD/Introduction identifies the commitments on use of ACI 349 Code, which, if changed, requires NRC Staff review and approval prior to implementation. The applicable portions of the Tier 2 sections and tables, identified on Table 3 of DCD/Introduction for this restriction, are italicized on the sections and tables themselves.*]*

[*Table 4 of DCD/Introduction identifies the commitments on use of Standard ANSI/AISC N690, which, if changed, requires NRC review and approval prior to implementation. The applicable portions of the Tier 2 sections and tables, identified on Table 4 of DCD/Introduction for this restriction, are italicized on the sections and tables themselves.*]†

### 3.8.3.3 Loads and Load Combinations

#### 3.8.3.3.1 Load Definitions

The loads and applicable load combinations for which the structure is designed depend on the conditions to which the particular structure is subjected.

The containment internal structures are designed in accordance with the loads described in Subsection 3.8.1.3. These loads and the effects of these loads are considered in the design of all internal structures as applicable. The loads within the loading combinations are combined using the absolute sum technique. (Those loads which are defined as reversible in algebraic sign are combined in such a way as to produce the maximum resultant stresses in the structure. All other loads are combined in accordance with their direction of application to the structure.) The loads are defined in Subsection 3.8.1.3 except as follows:

(1) $P_o$—Pressure loads resulting from the normal operating pressure difference between the drywell (upper and lower) and the suppression chamber of the containment.

(2) Construction Loads—Loads which are applied to the containment internal structures from start to completion of construction. The definitions for D, L and $T_o$ are applicable, but are based on actual construction methods and/or conditions.

* See section 3.5 of DCD/Introduction.

† See section 3.5 of DCD/Introduction.

(3) RV2—Loads from component response or direct fluid forces, on components located in the suppression pool, caused by SRV air cleaning loads.

(4) RBV—Loads due to reactor building vibrations caused by an SRV and LOCA event.

(5) AP—Loads and pressures directly on the reactor shield wall and loads from component response or direct steam flow forces on components located in the reactor vessel shield wall annulus region, caused by a rupture of a pipe within the reactor vessel shield wall annulus region.

(6) SL—Loads from component response or direct fluid forces, on components located in the sloshing zone of a pool or component, caused by the sloshing phenomenon from any dynamic event.

#### 3.8.3.3.2 Load Combination

The load combinations and associated acceptance criteria for concrete and steel internal structures of the containment are listed in Tables 3.8-5 and 3.8-6, respectively.

### 3.8.3.4 Design and Analysis Procedures

#### 3.8.3.4.1 Diaphragm Floor

The design and analysis procedures used for the diaphragm floor are similar to those used for the containment structure. The diaphragm slab is included in the finite- element model described in Subsection 3.8.1.4.1.1.

#### 3.8.3.4.2 Reactor Pedestal

The reactor pedestal is included in the finite-element model described in Subsection 3.8.1.4.1.1.

The design and analysis is based on the elastic method. All loads are resisted by the integral action of the inner and outer steel shells. The concrete placed in the annulus between the inner and outer shells acts to distribute loads between the steel shells, and provides stability to the compression elements of the pedestal.

#### 3.8.3.4.3 Reactor Shield Wall

The design and analysis procedures used for the reactor shield wall are similar to those used for the reactor pedestal described in Subsection 3.8.3.4.2.

#### 3.8.3.4.4 Drywell Equipment and Pipe Support Structure

The drywell equipment and pipe support structure (DEPSS) is designed using the AISC working stress methods for steel safety-related structures for nuclear facilities (ANSI/AISC N690). The DEPSS is designed to support the deadweight of non-safety-related equipment and support safety-related and non-safety-related piping. The non-safety-related equipment are the drywell cooling coils and fans. The safety-related items include safety-relief valves, mainsteam isolation valves, ECCS isolation valves, and feedwater check valves. In addition the DEPSS provides access platforms such that all of these pieces of equipment can be accessed, inspected, and removed from the drywell if necessary. The DEPSS is a 2 level, 3D space frame, consisting of columns, radial beams, circumferential beams, and steel grating. The DEPSS is shown in Figures 1.2-3, 1.2-3a, 1.2-13a, 1.2-13b, and 1.2-13c.

The DEPSS provides piping systems within the drywell a stable platform for pipe support, and pipe whip restraints. It is designed in accordance with ANSI/AISC-N690. In addition, the criteria given in Subsection 3.7.3.3.4 is applied to the DEPSS. If the criteria can not be met, the COL applicant will generate the ARS at piping attachment points considering the DEPSS as part of the structure using the dynamic analysis methods described in Subsection 3.7.2, or will analyze the piping systems treating the DEPSS as part of pipe support.

Those beams and columns supporting pipe supports will carry piping dynamic loads without buckling and while remaining elastic. Those beams and columns supporting pipe whip restraints allow inelastic deformations due to pipe rupture loads.

All safety-related items which the inelastic beam deformations may effect are evaluated to verify that no required safety function would be compromised.

#### 3.8.3.4.5 Other Internal Structures

The design and analysis procedures used for other internal structures are similar to those used for the drywell equipment and pipe support structure as described in Subsection 3.8.3.4.4.

### 3.8.3.5 Structural Acceptance Criteria

#### 3.8.3.5.1 Drywell Equipment and Pipe Support Structure

[*The structural acceptance criteria for the DEPSS are in accordance with ANSI/AISC-N690.*]*

#### 3.8.3.5.2 Other Internal Structures

[*The structural acceptance criteria for other internal concrete or steel structures are in accordance with ACI-349 and ANSI/AISC-N690, respectively.*]*

### 3.8.3.6 Materials, Quality Control, and Special Construction Techniques

#### 3.8.3.6.1 Diaphragm Floor

The materials, quality control, and construction techniques used for the diaphragm floor and liner plate are the same as those used for the containment wall and liner plate in Subsection 3.8.1.6.

* See Subsection 3.8.3.2.

#### 3.8.3.6.2 Reactor Pedestal

The materials conform to all applicable requirements of ANSI/AISC N690 and ACI 349 and comply with the following:

| Item | Specification |
|---|---|
| Inner and outer shells (excluding the portions submerged in the suppression pool) | ASTM A441 or A572 |
| Internal stiffeners | ASTM A441 or A572 |
| Concrete fill | $f_c'$= 27.56 MPa |
| Outer shell submerged in the suppression pool | ASTM A533, Type B, Class 2 with SA-240 Type 304 L clad |

#### 3.8.3.6.3 Reactor Shield Wall

The materials conform to all applicable requirements of ANSI/ASIC N690 and ACI 349 and comply with the following:

| Item | Specification |
|---|---|
| Inner and outer shells | ASTM A441 or A572 |
| Internal stiffeners | ASTM A441or A572 |
| Concrete fill | $f_c'$= 27.56 MPa minimum |

#### 3.8.3.6.4 Drywell Equipment and Pipe Support Structure

The materials conform to all applicable requirements of ANSI/AISC N690 and comply with the following:

| Item | Specification |
|---|---|
| Structural steel and connections | ASTM A36 |
| High strength structural steel plates | ASTM A572 or A441 |
| Bolts, studs, and nuts (dia. > 19 mm) | ASTM A325 |
| Bolts, studs, and nuts (dia. ≤ 19 mm) | ASTM A307 |

#### 3.8.3.6.5 Other Internal Structures

The materials conform to all applicable requirements of ANSI/AISC N690 and comply with the following:

| Item | Specification |
|---|---|
| Miscellaneous platforms | Same as Subsection 3.8.3.6.4 |
| Lower drywell equipment tunnel | ASTM A533, Type B, Class 2 with SA-240 Type 304 L clad |
| Lower drywell personnel tunnel | ASTM A533, Type B, Class 2 with SA-240 Type 304 L clad |
| Lower drywell floor fill material | A material other than limestone concrete |

### 3.8.3.7 Testing and Inservice Inspection Requirements

A formal program of testing and inservice inspection is not planned for the internal structures except the diaphragm floor, reactor pedestal, and lower drywell access tunnels. The other internal structures are not directly related to the functioning of the containment system; therefore, no testing or inspection is performed.

Testing and inservice inspection of the diaphragm floor, reactor pedestal and lower drywell access tunnels are discussed in Subsection 3.8.1.7.

### 3.8.3.8 Welding Methods and Acceptance Criteria for Structural and Building Steel

Welding activities shall be accomplished in accordance with written procedures and shall meet the requirements of the American Institute of Steel Construction (AISC) Manual of Steel Construction. The visual acceptance criteria shall be as defined in American Welding Society (AWS) Structural Welding Code D1.1 and Nuclear Construction Issue Group (NCIG) Standard, “Visual Weld Acceptance Criteria for Structural Welding at Nuclear Plants”, NCIG-01.

## 3.8.4 Other Seismic Category I Structures

Other Seismic Category I structures which constitute the ABWR Standard Plant are the Reactor Building and Control Building. Figure 1.2-1 shows the spatial relationship of these buildings. The only other structure in close proximity to these structures are the Radwaste Building and the Turbine Building. These are structurally separated from the other ABWR Standard Plant buildings.

The Seismic Category I structures within the ABWR Standard Plant, other than the containment structures, that contain high-energy pipes are the Reactor Building and Control Building. The steam tunnel walls protect the R/B and C/B from potential impact by rupture of the high-energy pipes. These buildings are designed to accommodate the guard pipe support forces.

The R/B, steam tunnel, Residual Heat Removal (RHR) System, Reactor Water Cleanup (CUW) System, and Reactor Core Isolation Cooling (RCIC) System rooms are designed to handle the consequences of high-energy pipe breaks. The RHR, RCIC, and CUW rooms are designed for differential compartment pressures, with the associated temperature rise and jet force. The steam tunnel is vented to the Turbine Building (T/B) through the seismic interface restraint structure (SIRS). The steam tunnel, which contains several pipelines (e.g., main steam, feedwater, RHR), is also designed for a compartment differential pressure with the associated temperature changes and jet force.

Seismic Category I masonry walls are not used in the design. The ABWR Standard Plant does not contain Seismic Category I pipelines buried in soil.

The COL applicant will identify all Seismic Category I structures. See Subsection 3.8.6.4 for COL license information.

### 3.8.4.1 Description of the Structures

#### 3.8.4.1.1 Reactor Building Structure

The Reactor Building (R/B) is constructed of reinforced concrete. The R/B has four stories above the ground level and three stories below. Its shape is a rectangle of 59.6m by 56.6m and a height of about 57.9m from the top of the basemat.

The Reinforced Concrete Containment Vessel (RCCV) in the center of the R/B encloses the Reactor Pressure Vessel (RPV). The RCCV supports the upper pool and is integrated with the R/B structure from the basemat up through the elevation of the RCCV top slab. The interior floors of the R/B are also integrated with the RCCV wall. The R/B has slabs and beams which join the exterior wall. Columns support the floor slabs and beams. The fuel pool girders are integrated with the RCCV top slab and with R/B wall-columns. The R/B is a shear wall structure designed to accommodate all seismic loads with its walls. Therefore, frame members such as beams or columns are designed to accommodate deformations of the walls in case of earthquake conditions.

The summary report for the Reactor Building is in Section 3H.1. This report contains a description of the Reactor Building, the loads, load combinations, reinforcement stresses, and concrete stresses at locations of interest. In addition, the report contains reinforcement details for the basemat, seismic walls, and fuel pool girders.

### 3.8.4.1.2 Control Building

The Control Building (C/B) is located between the Reactor Building and the Turbine Building (see Section 1.2).

The C/B houses the essential electrical, control and instrumentation equipment, the control room for the Reactor and Turbine Buildings, the C/B HVAC equipment, R/B cooling water pumps and heat exchangers, the essential switchgear, essential battery rooms, and the steam tunnel.

The C/B is a Seismic Category I structure that houses control equipment and operation personnel and is designed to provide missile and tornado protection. The C/B is constructed of reinforced concrete. The C/B has two stories above the ground level and four stories below. Its shape is a rectangle of 56m by 24m, and a height of about 30.4m from the top of the basemat.

The C/B 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 summary report for the control building is in Section 3H.2. This report contains a description of the control building, the loads, load combinations, reinforcement stresses, and concrete reinforcement details for the basemat, seismic walls, steam tunnel, and floors.

### 3.8.4.1.3 Not Used

### 3.8.4.1.4 Seismic Category I Cable Trays, Cable Tray Supports, Conduit, and Conduit Supports

Electrical cables are carried on continuous horizontal and vertical runs of steel trays supported at intervals by structural steel frames. The tray locations and elevations are predetermined based on the requirements of the electrical cable network. Generally, several trays of different sizes are grouped together and connected to a common support.

The support frame spacing is determined by allowable tray spans, which are governed by rigidity and stress. The frames may be ceiling-supported, or wall-supported, or a combination of both. Various types of frames form a support system with transverse and longitudinal bracing to the nearest wall or ceiling to take the seismic loads.

### 3.8.4.1.5 Seismic Category I HVAC Ducts and Supports

HVAC ducts are supported at intervals by structural steel frames. The duct locations and elevations are predetermined based on the requirements of the HVAC system.

The support frame spacing is determined by allowable tray spans, which are governed by rigidity and stress. The frames may be ceiling-supported, or wall-supported, or a combination of both. Various types of frames form a support system with transverse and longitudinal bracing to the nearest wall or ceiling to take the seismic loads.

### 3.8.4.2 Applicable Codes, Standards, and Specifications

#### 3.8.4.2.1 Reactor Building

The major portion of the Reactor Building is not subjected to the abnormal and severe accident conditions associated with a containment. A listing of applicable documents follows:

(1) [*ACI 349, Code Requirements for Nuclear Safety-Related Concrete Structures (as modified by Table 3.8-10).*]*

(2) [*ANSI/AISC-N690, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities" (as modified by Table 3.8-9 ).*]†

(3) "ASME Boiler and Pressure Vessel Code Section III", Subsection NE, Division 1, Class MC (for design of main steam tunnel embedment piping anchorage in the R/B and C/B only).

(4) "AWS Structural Welding Code", AWS D1.1.

(5) "AWS Structural Welding Code", AWS D12.1.

(6) NRC publications TID 7024 ("Nuclear Reactors and Earthquakes") and TID 25021 ("Summary of Current Seismic Design Practice for Nuclear Reactor Facilities").

(7) The inservice inspection requirements for the fuel pool liners in the Reactor Building are in conformance with "ASME Code Section III", Division 2.

(8) NRC Regulatory Guides:

    (a) Regulatory Guide 1.10 - "Mechanical (Cadweld) Splices in Reinforcing Bars of Category I Concrete Structures"

    (b) Regulatory Guide 1.15 - "Testing of Reinforcing Bars for Category I Concrete Structures"

    (c) Regulatory Guide 1.28 - "Quality Assurance Program Requirements" (Design and Construction)

    (d) Regulatory Guide 1.29 - "Seismic Design Classification"

    (e) Regulatory Guide 1.31 - "Control of Stainless Steel Welding"

* See Subsection 3.8.3.2.

† See Subsection 3.8.3.2.

(f) Regulatory Guide 1.44 - “Control of the Use of Sensitized Stainless Steel“

(g) Regulatory Guide 1.55 - “Concrete Placement in Category I Structures”

(h) Regulatory Guide 1.60 - “Design Response Spectra for Seismic Design of Nuclear Power Plants”

(i) Regulatory Guide 1.61 - “Quality Assurance Requirements for the Design of Nuclear Power Plants”

(j) Regulatory Guide 1.69 - “Concrete Radiation-Shields for Nuclear Power Plants”

(k) Regulatory Guide 1.76 - “Design Basis Tornado”

(l) Regulatory Guide 1.142 - “Safety-Related Concrete Structures for Nuclear Power Plants” (Other than Reactor Vessels and Containment)

(m) Regulatory Guide 1.94 - “Quality Assurance Requirements for Installation, Inspection, and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants”

(9) ANSI:

(a) ANSI/ASCE 7 - “Minimum Design Loads for Buildings and Other Structures”

(b) ANSI N5.12 - “Protective Coatings (Paint) for the Nuclear Industry”

(c) NQA-1 - “Quality Assurance Program Requirements for Nuclear Facilities and NQA-1a, Addenda to ANSI/ASME NQA-1”

(d) Not Used

(e) Not Used

(f) ANSI N45.4 - “Leakage-Rate Testing of Containment Structures for Nuclear Reactors”

(g) ANSI N101.2 - “Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities”

(h) ANSI N101.4 - “Quality Assurance for Protective Coatings Applied to Nuclear Facilities”

(10) Steel Structures Painting Council Standards

(a) SSPC-PA-1 - “Shop, Field and Maintenance Painting”

(b) SSPC-PA-2 - “Measurement of Paint Film Thickness with Magnetic Gages”

(c) SSPC-SP-1 - “Solvent Cleaning”

(d) SSPC-SP-5 - “White Metal Blast Cleaning”

(e) SSPC-SP-6 - “Commercial Blast Cleaning”

(f) SSPC-SP-10 - “Near-White Blast Cleaning”

(11) ACI-ASCE Committee 326 - “Shear and Diagonal Tension, ACI Manual of Concrete Practice, Part 2.”

(12) Applicable ASTM Specifications for Materials and Standards.

(13) “AASHTO Standard Specifications for Highway Bridges for truck loading area.”

### 3.8.4.2.2 Control Building

[*Refer to Subsection 3.8.4.2.1.*]*

Add NRC Rules and Regulations Title 10, Chapter 1, Code of Federal Regulations, Part 73.2 and 73.55.

### 3.8.4.2.3 Not Used

### 3.8.4.2.4 Seismic Category I Cable Tray, Cable Tray Supports, Conduit and Conduit Supports

(1) ANSI/AISC-N690, “Specification for Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facility.”

(2) AISI SG-673 - “Cold formed Steel Design Manual.”

(3) “ANSI/NEMA FB1, Fittings and Supports for Conduit and Cable Assemblies.”

### 3.8.4.2.5 Seismic Category I HVAC Ducts and Supports

(1) ASME/ANSI AG-1, “Code on Nuclear Air and Gas Treatment.”

(2) ANSI/AISC-N690, “Specification for Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facility.”

### 3.8.4.2.6 Welding and Weld Acceptance Criteria

#### 3.8.4.2.6.1 Welding of Electrical Cable Tray and Conduit Supports

Welding activities shall be accomplished in accordance with the AWS Structural Welding Code, Dl.l. The weld visual acceptance criteria shall be as defined in AWS Structural Welding Code Dl.1 and NCIG-01.

* See Subsection 3.8.3.2.

#### 3.8.4.2.6.2 Welding of Heating Ventilation and Air Conditioning Supports

Welding activities shall be accomplished in accordance with the AWS Structural Welding Code, Dl.l. The weld visual acceptance criteria shall be as defined in AWS Structural Welding Code Dl.1 and NCIG-01.

#### 3.8.4.2.6.3 Welding of Refuel Cavity and Spent Fuel Pool Liners

Welding activities shall be accomplished in accordance with the AWS Structural Welding Code, Dl.l. The welded seams of the liner plate shall be spot radiographed where accessible, liquid penetrant and vacuum box examined after fabrication to ensure that the liner does not leak. The acceptance criteria for these examinations shall meet the acceptance criteria stated in Subsection NE-5200 of Section III of the ASME Code.

### 3.8.4.3 Loads and Load Combinations

#### 3.8.4.3.1 Reactor Building

The temperature and pressure loads caused by a LOCA do not occur on the Reactor Building (R/B). The R/B ventilation system is designed to keep the building within operating design conditions.

#### 3.8.4.3.1.1 Loads and Notations

Loads and notations are as follows:

D = Dead load of structure plus any other permanent load.

L = Conventional floor or roof live loads, movable equipment loads, and other variable loads such as construction loads. The following live loads are used:

- Concrete floors and slabs (including roofs) — 9.8 kPa.
- Stairs, stair platforms, grating floors, and platforms — 4.90 kPa.
- Concrete roofs, live or snow load (not concurrent) —2.452 kPa.
- Construction live load on floor framing in addition to dead weight of floor — 2.452 kPa*.

$R_o$ = Pipe reactions during normal operating or shutdown conditions based on the most critical transient or steady-state condition.

* If the actual construction live load is greater than this value, a design check of the structures will be made.

$R_a$ = Pipe reactions under thermal conditions generated by the postulated break and including $R_{o.}$

$Y_r$ = Equivalent static load on a structure generated by the reaction on the broken high-energy pipe during the postulated break and including a calculated dynamic factor to account for the dynamic nature of the load.

$Y_j$ = Jet impingement equivalent static load on a structure generated by the postulated break and including a calculated dynamic factor to account for the dynamic nature of the load.

$Y_m$ = Missile impact equivalent static load on a structure generated by or during the postulated break, like pipe whipping, and including a calculated dynamic factor to account for the dynamic nature of the load.

W = Wind force (Subsection 3.3.1).

$W_t$ = Tornado load (Subsection 3.3.2) (tornado-generated missiles are described in Subsection 3.5.1.4, and barrier design procedures in Subsection 3.5.3).

$P_a$ = Internal negative pressure of 13.73 kPaD due to tornado; accident pressure at main steam tunnel piping embedment.

B = Uplift forces created by the rise of the ground water table.

F = Internal pressures resulting from flooding of compartments.

E’ = Safe shutdown earthquake (SSE) loads as defined in Section 3.7.

$T_o$ = Thermal effects — load effects induced by normal thermal gradients existing through the R/B wall and roof. Both summer and winter operating conditions are considered. In all cases, the conditions are considered of long enough duration to result in a straight line temperature gradient. The temperatures are as follows:

(1) Summer operation:

(a) Air temperature inside building — 49°C

(b) Exterior temperature — $46^oC$

(2) Winter operation:

(a) Air temperature inside building — 21.1°C

(b) Exterior temperature — (-) $40^oC$

(3) Winter shutdown

(a) Air temperature inside building - 46°C

(b) Exterior temperature — (-) 40°C

For all cases, as-constructed temperature is 15.6°C.

$T_a$ = Thermal effects (including $T_o$) which may occur during a design accident at 74°C maximum 30 minutes after LOCA.

U = For concrete structures, the section strength required to resist design loads based on the strength design method described in ACI 318.

H = Loads caused by static or seismic earth pressures.

For structural steel, S is the required section strength based on the elastic design methods and the allowable stresses defined in Part 1 of the AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.

#### 3.8.4.3.1.2 Load Combinations for Concrete Members

For the load combinations in this subsection, where any load reduces the effects of other loads, the corresponding coefficient for that load shall be taken as 0.9, if it can be demonstrated that the load is always present or occurs simultaneously with the other loads. Otherwise, the coefficient for that load shall be taken as zero.

(1) Normal operating conditions — The strength design method is used and the following load combinations are satisfied:

$$U = 1.4\ D + 1.7\ L + 1.3\ T_o + 1.7\ R_o + 1.7\ H + 1.4\ B$$

$$U = 1.4\ D + 1.7\ L + 1.3\ T_o + 1.7\ R_o + 1.7\ H + 1.7\ W$$

For fluid pressure F, replace 1.7 H by 1.7 F in the second equation above.

(2) Abnormal/extreme environmental conditions — The strength design method is used and the following load combinations are satisfied:

$$U = D + L + T_o + R_o + H + B$$

$$U = D + L + T_o + R_o + H + E'$$

$$U = D + L + T_o + R_o + H$$

$$U = D + L + T_o + R_o + H + W_t$$

$U = D + L + T_a + R_a + 1.5\ P_a + H$

$U = D + L + T_a + R_a + P_a + H + E' + (Y_r + Y_j + Y_m)$

#### 3.8.4.3.1.3 Load Combinations for Steel Members

(1) Normal operating conditions — the elastic working stress design method is used for the following load combinations:

$S = D + L$

$S = D + L + W$

Since thermal stresses due to $T_o$ and $R_o$ are present and are secondary and self-limiting in nature, the following combinations are also satisfied:

$1.5\ S = D + L + T_o + R_o$

$1.5\ S = D + L + T_o + W$

In all these load conditions, both cases of L having its full value or being completely absent are checked.

(2) Abnormal/extreme environmental conditions — The elastic working stress design method is used and the following load combinations are satisfied:

$1.6\ S = D + L + T_o + R_o + E'$

$1.6\ S = D + L + T_o + R_o + W_t$

$1.6\ S = D + L + T_o + R_o + W_t + H$

$1.6\ S = D + L + T_a + R_a + P_a$

$1.6\ S = D + L + T_a + R_a + E' + P_a + (Y_j + Y_r + Y_m)$

In all these load combinations, both cases of L having its full value or being completely absent are checked.

#### 3.8.4.3.2 Control Building

Refer to the loads, notations, and combinations established in Subsection 3.8.4.3.1, except that fluid pressure F, accident pressure $P_a$, and pipe break loads $Y_r$, $Y_j$, $Y_m$ do not exist and the live loads are as follows:

– All concrete floors — 19.61 kPa

– Stairs, stair platforms, grating floors, and platforms — 4.90 kPa

– Roof live or snow load (non concurrent) —2.452 kPa

– Construction live load on floor framing in addition to dead weight of floor — 2.452 kPa*

$T_o$ = thermal effects. As-constructed temperature is 15.6°C. The temperatures inside the building are as follows:

Operating Conditions

| | | |
|---|---|---|
| Control Room: | summer | 23.9°C |
| | winter | 21.1°C |
| HVAC Room: | summer | 35°C |
| | winter | 15.6°C |
| Other Areas: | summer | 23.9°C |
| | winter | 23.9°C |

Shutdown condition

| | | |
|---|---|---|
| Control Room: | summer | 26.7°C |
| | winter | 10°C |
| HVAC Room: | summer | 40°C |
| | winter | 10°C |
| Other Areas: | summer | 32.2°C |
| | winter | 10°C |

#### 3.8.4.3.3 Seismic Category I Cable Tray, Cable Tray Supports, and Conduit Supports

Loads used in dynamic analysis for tray and conduit supports are the following:

D + L = 1.12 kg/cm used for 46 cm tray, 0.74 kg/cm used for 30 cm and narrower tray

Dynamic loads = SSE plus other RBV dynamic loads.

Load combinations used in dynamic analysis for the tray and conduit supports are the following:

D + L

D + L + SSE + RBV

* If the actual construction live load is greater than this value, a design check of the structures will be made.

Where D, L, SSE, and RBV are defined in Subsection 3.8.4.3.1.1.

#### 3.8.4.3.4 Seismic Category I HVAC Ducts and Supports

Loads and load combinations used for dynamic analysis for HVAC ducts and supports are the following:

D + L + Po

D + L + Po + SSE + RBV

Where D, L, SSE, and RBV are defined in Subsection 3.8.4.3.1.1, and Po is the internal pressure of the HVAC duct.

### 3.8.4.4 Design and Analysis Procedures

#### 3.8.4.4.1 Reactor Building and Control Building

[*The Reactor Building and Control Building will be designed in accordance with ACI-349 for concrete structures and ANSI/AISC-N690 specification for steel structures.*]*

The Reactor Building and Control Building are analyzed using the computer codes listed in Appendix 3C.

The foundation for Category I structures is contained in the summary reports for their respective buildings. The reactor building foundations is contained in Section 3H.1 and the control building foundation is in Section 3H.2. This summary report contains a section detailing safety factors against sliding, over turning, and floatation.

#### 3.8.4.4.2 Seismic Category I Cable Tray, Cable Tray Supports, and Conduit Supports

All seismic Category I cable trays and conduit supports are designed by one of the methods discussed in Subsection 3.7.3 or by design by rule methods as approved by the NRC. Design by rule methods will be based on documented performance of conduit and cable trays during prior qualification tests or analysis or exposure to natural seismic disturbances. If an analysis is performed it will use one of the codes listed in Appendix 3C.

#### 3.8.4.4.3 Seismic Category I HVAC Ducts and Supports

All seismic Category I HVAC duct and duct supports are designed by one of the methods discussed in Subsection 3.7.3 or by design by rule methods approved by the NRC. Design by rule methods will be based on documented performance of HVAC ducts during prior qualification tests or analysis or exposure to natural seismic disturbances. If an analysis is performed it will use one of the codes listed in Appendix 3C.

* See Subsection 3.8.3.2.

### 3.8.4.4.3.1 Cable Tray Supports

Wherever possible, the supporting frames for a tray or group of trays are designed to have adequate rigidity to avoid causing additional amplification of seismic acceleration transmitted by the building structures. Where rigidity cannot be achieved without an excessive increase in support member size, the design of the supports is then based on the amplified seismic load obtained from the floor response spectra.

Thus, two methods are used in design and analysis of cable tray supports.

(1) Rigid Support with Flexible Tray — In this method, trays are modeled as flexible elastic systems and analyzed by the response spectrum method. The resulting reactions are used for the design of the supports.

(2) Flexible Support with Flexible Tray — In this method, the composite system of trays and supports is modeled and analyzed by computer as a multidegree of freedom elastic system. The support motions can be prescribed by the appropriate floor response spectrum. The resulting responses are used to obtain design loads for the supports.

### 3.8.4.4.3.2 Conduit Supports

The design and analysis of conduit supports are basically the same as for cable tray supports. Since conduits are more flexible and have comparatively less dead load, a rigid support approach is used as described in method (1) of cable tray support design.

### 3.8.4.5 Structural Acceptance Criteria

### 3.8.4.5.1 Reactor Building

### 3.8.4.5.1.1 General Criteria

The first criterion is that the Reactor Building shall provide biological shielding for plant personnel and the public outside of the site boundary. This criterion dictates the minimum wall and roof thicknesses.

The second criterion is that the Reactor Building shall protect the reinforced concrete containment from environmental hazards such as tornado and other site proximity-generated missiles. The shielding thicknesses are sufficient for this purpose.

The Reactor Building provides a means for collection of fission product leakage from the reinforced concrete containment following an accident.

The Reactor Building SGTS is designed to keep the compartments surrounding the reinforced concrete containment at a negative pressure even after a LOCA. In order to achieve a maximum in-leakage rate of 50% per day under a pressure differential of 6 mm of water, the reinforcing steel is designed to remain elastic during the SSE load combinations.

#### 3.8.4.5.1.2 Structural and Materials Criteria

[*Structural acceptance criteria are defined in ANSI/AISC-N690 and ACI 349 Codes*.]*

Refer to the materials criteria established in Subsection 3.8.4.2.1 for the strength and materials requirements for the reinforced concrete Reactor Building.

#### 3.8.4.5.2 Control Building

[*Structural acceptance criteria are defined in ANSI/AISC-N690 and ACI 349 Codes.*]* In no case does the allowable stress exceed 0.9 $F_y$, where $F_y$ is the minimum specified yield stress. The design criteria preclude excessive deformation of the Control Building. The clearances between adjacent buildings are sufficient to prevent impact during a seismic event. The tornado load analysis for this building is the same as the analysis for the Reactor Building.

#### 3.8.4.5.3 Not Used

#### 3.8.4.5.4 Seismic Category I Cable Trays and Conduit Supports

Structural acceptance criteria if the analysis option is selected are defined in ANSI/AISC-N690 Code. In no case does the allowable stress exceed 0.9 $F_y$ where $F_y$ is the minimum specified yield stress.

#### 3.8.4.5.5 Seismic Category I HVAC Duct and Supports

The structural acceptance criteria for HVAC ducts if the analysis option is selected will be in accordance with ANSI/ASME AG-1 Code. The HVAC supports will be in accordance with the ANSI/AISC-N690 code.

## 3.8.5 Foundations

This section describes foundations for all Seismic Category I structures of the ABWR Standard Plant.

### 3.8.5.1 Description of the Foundations

The foundations of the Reactor Building and Control Building are reinforced concrete mat foundations.

These two foundation mats are separated from each other by a separation gap of 2m wide to minimize the structural interaction between the buildings.

The Reactor Building foundation is a rectangular reinforced concrete mat 56.6m by 59.6m and 5.5m thick. The foundation mat is constructed of cast-in-place conventionally reinforced concrete. It supports the Reactor Building, the containment structure, the reactor pedestal, and other internal structures. The top of the foundation mat is 20.2m below grade.

* See Subsection 3.8.3.2.

The containment structure foundation, defined as within the perimeter or the exterior surface of the containment structure, is integral with the Reactor Building foundation. The containment foundation mat details are discussed in Subsection 3.8.1.1.1.

The Control Building foundation is rectangular reinforced concrete mat 24m by 56m by 3.0m. The top of the foundation mat is 20.2m below grade.

The foundation for Category 1 structures is contained in the summary reports for their respective buildings. The Reactor Building foundation is contained in Section 3H.1 and the Control Building foundation is in Section 3H.2. This summary report contains a section detailing safety factors against sliding, over turning, and floatation.

### 3.8.5.2 Applicable Codes, Standards and Specifications

[*The applicable codes, standards, specifications and regulations are discussed in Subsection 3.8.1.2 for the containment foundation and in Subsection 3.8.4.2 for the other Seismic Category I foundations.*]*

### 3.8.5.3 Loads and Load Combinations

The loads and load combinations for the containment foundation mat are given in Subsection 3.8.1.3. The loads and load combinations for the other Seismic Category I structure foundations are given in Subsection 3.8.4.3.

The loads and load combinations for all Seismic Category I foundations examined to check against sliding and overturning due to earthquakes, winds and tornados, and against flotation due to floods are listed in Table 3.8-7.

### 3.8.5.4 Design and Analysis Procedures

The foundations of Seismic Category I structures are analyzed using well-established methods where the transfer of loads from the foundation mat to the supporting foundation media is determined by elastic methods.

Bearing walls and columns carry all the vertical loads from the structure to the foundation mat. Lateral loads are transferred to shear walls by the roof and floor diaphragms. The shear walls then transmit the loads to the foundation mat.

The design of the mat foundations for the structures of the plant involves primarily determining shear and moments in the reinforced concrete and determining the interaction of the substructure with the underlying foundation medium. For a mat foundation supported on soil or rock, the main objectives of the design are (1) to maintain the bearing pressures within allowable limits, particularly due to overturning forces, and (2) to ensure that there is adequate

* See Subsection 3.8.3.2.

frictional and passive resistance to prevent sliding of the structure when subjected to lateral loads.

The design loads considered in analysis of the foundations are the worst resulting forces from the superstructures and loads directly applied to the foundation mat due to static and dynamic load combinations.

The capability of the foundation to transfer shear with waterproofing will be evaluated. See Subsection 3.8.6.1 for COL license information requirements.

The standard ABWR design is developed using a range of soil conditions as detailed in Appendix 3A. The variations of physical properties of the site-specific subgrade materials will be determined (Subsection 3.8.6.2). Settlement of the foundations, and differential settlement between foundations for the site-specific foundations medium, will be calculated, and safety-related systems (i.e., piping, conduit, etc.) will be designed for the calculated settlement of the foundations. The effect of the site-specific subgrade stiffness and calculated settlement on the design of the Seismic Category I structures and foundations will be evaluated. See Subsection 3.8.6.2 for COL license information requirements.

A detailed description of the analytical and design methods for the Reactor Building foundation mat including the containment foundation, is included in Appendix 3H.

### 3.8.5.5 Structural Acceptance Criteria

The main structural criteria for the containment portion of the foundation are adequate strength to resist loads and sufficient stiffness to protect the containment liner from excessive strain. The acceptance criteria for the containment portion of the foundation mat are presented in Subsection 3.8.1.5. The structural acceptance criteria for the Reactor Building foundations are described in Subsection 3.8.4.5.

The calculated and allowable factors of safety of the ABWR structures for overturning, sliding, and flotation are shown in Appendix 3H for each foundation mat evaluated according to the following procedures.

The factor of safety against overturning due to earthquake loading is determined by the energy approach described in Subsection 3.7.2.14.

The factor of safety against sliding is defined as:

$$FS = (F_s + F_p)/(F_d + F_h)$$

where $F_s$ and $F_p$ are the shearing and sliding resistance, and passive soil pressure resistance, respectively. $F_d$ is the maximum lateral seismic force including any dynamic active earth pressure, and $F_h$ is the maximum lateral force due to all loads except seismic loads.

The factor of safety against flotation is defined as:

$$FS = F_{DL}/F_B$$

where $F_{DL}$ is the downward force due to dead load and $F_B$ is the upward force due to buoyancy.

### 3.8.5.6 Materials, Quality Control, and Special Construction Techniques

The foundations of Seismic Category I structures are constructed of reinforced concrete using proven methods common to heavy industrial construction. For further discussion, see Subsection 3.8.1.6.

### 3.8.5.7 Testing and Inservice Inspection Requirements

A formal program of testing and inservice inspection is not planned and is not required for the Seismic Category I structures of the ABWR.

## 3.8.6 COL License Information

### 3.8.6.1 Foundation Waterproofing

The capability of foundations to transfer shear loads where foundation waterproofing is used will be evaluated (Subsection 3.8.5.4).

### 3.8.6.2 Site Specific Physical Properties and Foundation Settlement

Physical properties of the site-specific subgrade medium shall be determined and the settlement of foundations and structures, including Seismic Category I, will be evaluated (Subsection 3.8.5.4).

### 3.8.6.3 Structural Integrity Pressure Result

Each COL applicant will perform the structural integrity test (SIT) of the ABWR containment in accordance with Subsection 3.8.1.7.1. Additionally, the first ABWR containment is considered as a prototype and its SIT performed accordingly. The details of the test and the instrumentation, as required for such a test, will be provided by the first COL applicant for NRC review and approval.

### 3.8.6.4 Identification of Seismic Category I Structures

The COL applicant will identify all Seismic Category I Structures (Subsection 3.8.4).

## Table 3.8-1 Load Combinations, Load Factors and Acceptance Criteria for the Reinforced Concrete Containment* † ‡

| Load Combination | | Load Condition | | | | | | | | | | | | | | | | | | SRV$^{f}$ | | | Acceptance Criteria |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Description** | **No.** | **D** | **L** | **$P_t$** | **$P_o$** | **$P_a$** | **$P_i$** | **$P_s$** | **$T_t$** | **$T_o$** | **$T_a$** | **E'** | **W** | **W'** | **$R_o$** | **$R_a$** | **Y**** | **$F_L$** | **$1^v$** | **ADS** | **$G_{ALL}$** | **LOCA** | |
| **Service** | | | | | | | | | | | | | | | | | | | | | | | |
| Test | 1 | 1.0 | 1.0 | 1.0 | | | | | 1.0 | | | | | | | | | | | | | | S |
| Construction | 2 | 1.0 | 1.0 | | | | | | | 1.0 | | | 1.0 | | | | | | | | | | S |
| Normal | 3 | 1.0 | 1.0 | | 1.0 | | | | | 1.0 | | | | | 1.0 | | | | 1.0 | | 1.0 | | S |
| **Factored** | | | | | | | | | | | | | | | | | | | | | | | |
| Severe | 4 | 1.0 | 1.3 | | 1.0 | | | | | 1.0 | | | | | 1.0 | | | | 1.0 | | 1.0 | | U |
| Environmental | 5 | 1.0 | 1.3 | | 1.0 | | | | | 1.0 | | | 1.5 | | 1.0 | | | | 1.0 | | 1.0 | | U |
| Extreme | 6 | 1.0 | 1.0 | | 1.0 | | | | | 1.0 | | 1.0 | | | 1.0 | | | | 1.0 | | 1.0 | | U |
| Environmental | 7 | 1.0 | 1.0 | | 1.0 | | | | | 1.0 | | | | 1.0 | 1.0 | | | | 1.0 | | | | U |
| Abnormal | 8 | 1.0 | 1.0 | | | 1.5 | | | | | 1.0 | | | | | 1.0 | | | 1.0 | | | Note†† | U |
| | 8a | 1.0 | 1.0 | | | | 1.5 | | | | 1.0 | | | | | 1.0 | | | 1.0 | 1.0 | | Note†† | U |
| | 8b | 1.0 | 1.0 | | | | | 1.5 | | | 1.0 | | | | | 1.0 | | | 1.0 | 1.0 | | Note†† | U |
| | 9 | 1.0 | 1.0 | | | 1.0 | | | | | 1.0 | | | | | 1.25 | | | 1.0 | | | Note†† | U |
| | 9a | 1.0 | 1.0 | | | | 1.0 | | | | 1.0 | | | | | 1.25 | | | 1.0 | 1.0 | | Note†† | U |
| | 9b | 1.0 | 1.0 | | | | | 1.0 | | | 1.0 | | | | | 1.25 | | | 1.0 | 1.0 | | Note†† | U |
| | 10 | 1.0 | 1.0 | | | 1.25 | | | | | 1.0 | | | | | 1.0 | | | 1.25 | | | Note†† | U |
| | 10a | 1.0 | 1.0 | | | | 1.25 | | | | 1.0 | | | | | 1.0 | | | 1.25 | 1.25 | | Note†† | U |
| | 10b | 1.0 | 1.0 | | | | | 1.25 | | | 1.0 | | | | | 1.0 | | | 1.25 | 1.25 | | Note†† | U |

# Table 3.8-1 Load Combinations, Load Factors and Acceptance Criteria for the Reinforced Concrete Containment* † ‡ (Continued)

| Load Combination | | Load Condition | | | | | | | | | | | | | | | | | | SRV$^{f}$ | | | Acceptance Criteria |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Description** | **No.** | **D** | **L** | **$P_t$** | **$P_o$** | **$P_a$** | **$P_i$** | **$P_s$** | **$T_t$** | **$T_o$** | **$T_a$** | **E'** | **W** | **W'** | **$R_o$** | **$R_a$** | **Y**** | **$F_L$** | **$1^V$** | **ADS** | **$G_{ALL}$** | **LOCA** | |
| Abnormal/ | 11 | 1.0 | 1.0 | | | 1.25 | | | | | 1.0 | | | | | 1.0 | | | 1.0 | | | Note†† | U |
| Severe | 11a | 1.0 | 1.0 | | | | 1.25 | | | | 1.0 | | | | | 1.0 | | | 1.0 | 1.0 | | Note†† | U |
| Environmental | 11b | 1.0 | 1.0 | | | | | 1.25 | | | 1.0 | | | | | 1.0 | | | 1.0 | 1.0 | | Note†† | U |
| | 12 | 1.0 | 1.0 | | | 1.25 | | | | | 1.0 | | 1.25 | | | 1.0 | | | 1.0 | | | Note†† | U |
| | 12a | 1.0 | 1.0 | | | | 1.25 | | | | 1.0 | | 1.25 | | | 1.0 | | | 1.0 | 1.0 | | Note†† | U |
| | 12b | 1.0 | 1.0 | | | | | 1.25 | | | 1.0 | | 1.25 | | | 1.0 | | | 1.0 | 1.0 | | Note†† | U |
| | 13 | 1.0 | 1.0 | | | | | | | 1.0 | | | | | | | | 1.0 | | | | | U |
| | 14 | 1.0 | 1.0 | | | | | | | 1.0 | | | 1.0 | | | | | 1.0 | | | | | U |
| Abnormal/ | 15 | 1.0 | 1.0 | | | 1.0 | | | | | 1.0 | 1.0 | | | | 1.0 | 1.0 | | 1.0 | | | Note†† | U |
| Extreme | 15a | 1.0 | 1.0 | | | | 1.0 | | | | 1.0 | 1.0 | | | | 1.0 | 1.0 | | 1.0 | 1.0 | | Note†† | U |
| Environmental | 15b | 1.0 | 1.0 | | | | | 1.0 | | | 1.0 | 1.0 | | | | 1.0 | 1.0 | | 1.0 | 1.0 | | Note†† | U |

* The loads are described in Subsection 3.8.1.3 and acceptance criteria in Subsection 3.8.1.5.

† For any load combination, if the effect of any load component (other than D) reduces the combined load, then the load component is deleted from the load combination.

‡ Since $P_a$, $P_i$, $P_s$, $T_a$, SRV and LOCA are time-dependent loads, their effects will be superimposed accordingly.

*ƒ* The sequence of occurrence of SRV loads is given in Appendix 3B.
$1^V$ ($G_1$ or $G_2$), ADS and $G_{ALL}$ are not concurrent, when they are indicated in the load combination.

** Y includes $Y_j$, $Y_m$ and $Y_r$.

†† LOCA loads, CO, CHUG, VLC and PS are time-dependant loads. The sequence of occurrence is given in Appendix 3B. The load factor for LOCA loads shall be the same as the corresponding pressure load $P_a$, $P_i$ or $P_s$.

## Table 3.8-2 Major Allowable Stresses in Concrete and Reinforcing Steel

| | Concrete | | Reinforcing Steel | |
|---|---|---|---|---|
| | **Compression** | **Tangential Shear** | **Tension** | |
| Service Load Combination | 16.54 MPa | (1) Provided by concrete $\nu_c = 0$ | 206.8 MPa | |
| | | (2) Provided by orthogonal reinforcement $\nu_{so} = 1.2\sqrt{f'_c} = 1.96$ MPa | 310.3 MPa | (For test pressure case) |
| Factored Load Combination | 23.44 MPa | (1) Provided by concrete $\nu_c = 0$ | 372.4 Mpa | |
| | | (2) Provided by orthogonal reinforcement $\nu_{so} = 2.4\sqrt{f'_c} = 3.92$ MPa | | |

## Table 3.8-3 Stress Intensity Limits

| | Primary Stresses | | | |
|---|---|---|---|---|
| | **Gen. Mem $P_m$** | **Local Mem. $P_L$** | **Bending & Local Mem. $P + P_L$** | **Primary & Secondary Stresses $P_L + P + Q$** |
| Test Condition | 0.75 Sy | 1.15 Sy | 1.15 Sy | N/A |
| Design Condition | 1.0 Sm* | 1.5 Sm | 1.5 Sm | N/A |
| Post-LOCA Flooding | The larger of 1.2 Smc or 1.0 Sy | The larger of 1.8 Smc or 1.5 Sy | The larger of 1.8 Smc or 1.5 Sy | 3 Sm* |

* The allowable stress intensity Sm is the Sm listed in Table I-10.0 and Sy is the yield strength listed in Table I-2.0 of Appendix I of ASME Code Section III.

## Table 3.8-4 Codes, Standards, Specifications, and Regulations Used in the Design and Construction of Seismic Category I Internal Structures of the Containment

| Specification Reference Number | Specification or Standard Designation | Title |
|---|---|---|
| 1 | ACI 301 | Specifications for Structural Concrete for Builders |
| 2 | ACI 307 | Recommended Practice for Concrete Formwork |
| 3 | ACI 305 | Recommended Practice for Hot Weather Concreting |
| 4 | ACI 211.1 | Recommended Practice for Selecting Proportions for Normal Weight Concrete |
| 5 | ACI 315 | Manual of Standard Practice for Detailing Reinforced Normal Weight Concrete |
| 6 | ACI 306 | Recommended Practice for Cold Weather Concreting |
| 7 | ACI 309 | Recommended Practice for Consolidation of Concrete |
| 8 | ACI 308 | Recommended Practice for Curing Concrete |
| 9 | ACI 212 | Guide for use of Admixtures in Concrete |
| 10 | ACI 214 | Recommended Practice for Evaluation of Compression Test results of Field Concrete |
| 11 | ACI 311 | Recommended Practice for Concrete Inspection |
| 12 | ACI 304 | Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete |
| 13 | [*ACI 349* | *Code Requirements for Nuclear Safety-Related Concrete Structures (as modified by Table 3.8-10)*][*] |
| 14 | [*ACI 359* | *ASME Boiler and Pressure Vessel Code, Section III, Division 2, Concrete Reactor Vessels and Containments*][†] |
| 15 | [*ANSI/AISCN690* | *Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities (as modified by Table 3.8-9 )*][*] |
| 16 | AWS D1.1 | Structural Welding Code |
| 17 | NCIG-02 | Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants |
| 18 | ANSI/ASME NQA-1-1986 | Quality Assurance Program Requirements for Nuclear Facilities |
| 19 | Not Used | |
| 20 | NRC Regulatory Guide 1.94 | Quality Assurance Requirements for Installation, Inspection, and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants |

## Table 3.8-4 Codes, Standards, Specifications, and Regulations Used in the Design and Construction of Seismic Category I Internal Structures of the Containment (Continued)

| Specification Reference Number | Specification or Standard Designation | Title |
|---|---|---|
| 21 | NRC Regulatory Guide 1.136 | Materials for Concrete Containments (Article CC-2000 of the Code for Concrete Reactor Vessels and Containments) |
| 22 | NRC Regulatory Guide 1.142 | Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments) |

**Explanation of Abbreviation**

| | |
|---|---|
| ACI | American Concrete Institute |
| AISC | American Institute of Steel Construction |
| AISI | American Iron and Steel Institute |
| ANSI | American National Standards Institute |
| ASME | American Society for Mechanical Engineers |
| AWS | American Welding Society |
| NCIG | Nuclear Construction Issues Group |
| NRC | Nuclear Regulatory Commission |

* See Subsection 3.8.3.2.

† See Subsection 3.8.1.1.1.

# Table 3.8-5 Load Combination, Load Factors and Acceptance Criteria for Reinforced Concrete Structures Inside the Containment * †

| Load Combination | | Load Condition | | | | | | | | | | | | | | | | | | | | Acceptance Criteria‡ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | SRV ƒ | | | LOCA | |
| **Description** | **No.** | **D** | **L** | **$P_t$** | **$P_o$** | **$P_a$** | **$P_i$** | **$P_s$** | **$T_t$** | **$T_o$** | **$T_a$** | **E'** | **W** | **W'** | **$R_o$** | **$R_a$** | **Y**** | **$1^V$** | **ADS** | **$G_{ALL}$** | | |
| Test | 1 | 1.0 | 1.0 | 1.0 | | | | | 1.0 | | | | | | | | | | | | | S |
| Normal | 3 | 1.0 | 1.0 | | 1.0 | | | | | 1.0 | | | | | 1.0 | | | 1.0 | | 1.0 | | S |
| | 3a | 1.4 | 1.7 | | 1.0 | | | | | | | | | | 1.7 | | | 1.7 | | 1.7 | | U |
| | 3b | 1.05 | 1.3 | | 1.0 | | | | | 1.3 | | | | | 1.3 | | | 1.3 | | 1.3 | | U |
| Severe | 4a | 1.4 | 1.7 | | 1.0 | | | | | | | | | | 1.7 | | | 1.7 | | 1.7 | | U |
| Environmental | 4b | 1.05 | 1.3 | | 1.0 | | | | | 1.3 | | | | | 1.3 | | | 1.3 | | 1.3 | | U |
| | 5a | 1.4 | 1.7 | | 1.0 | | | | | | | | 1.7 | | 1.7 | | | 1.7 | | 1.7 | | U |
| | 5b | 1.05 | 1.3 | | 1.0 | | | | | 1.3 | | | 1.3 | | 1.3 | | | 1.3 | | 1.3 | | U |
| Extreme | 6 | 1.0 | 1.0 | | 1.0 | | | | | 1.0 | | 1.0 | | | 1.0 | | | 1.0 | | 1.0 | | U |
| Environmental | 7 | 1.0 | 1.0 | | 1.0 | | | | | 1.0 | | | | 1.0 | 1.0 | | | 1.0 | | 1.0 | | U |
| Abnormal | 8 | 1.0 | 1.0 | | | 1.5 | | | | | 1.0 | | | | | 1.0 | | 1.25 | | | Note†† | U |
| | 8a | 1.0 | 1.0 | | | | 1.5 | | | | 1.0 | | | | | 1.0 | | 1.25 | 1.25 | | Note†† | U |
| | 8b | 1.0 | 1.0 | | | | | 1.5 | | | 1.0 | | | | | 1.0 | | 1.25 | 1.25 | | Note†† | |
| Abnormal/ | 11 | 1.0 | 1.0 | | | 1.25 | | | | | 1.0 | | | | | 1.0 | 1.0 | 1.0 | | | Note†† | U |
| Severe | 11a | 1.0 | 1.0 | | | | 1.25 | | | | 1.0 | | | | | 1.0 | 1.0 | 1.0 | 1.0 | | Note†† | U |
| Environmental | 11b | 1.0 | 1.0 | | | | | 1.25 | | | 1.0 | | | | | 1.0 | 1.0 | 1.0 | 1.0 | | Note†† | U |
| Abnormal/ | 15 | 1.0 | 1.0 | | | 1.0 | | | | | 1.0 | 1.0 | | | | 1.0 | 1.0 | 1.0 | | | Note†† | U |
| Extreme | 15a | 1.0 | 1.0 | | | | 1.0 | | | | 1.0 | 1.0 | | | | 1.0 | 1.0 | 1.0 | 1.0 | | Note†† | U |
| Environmental | 15b | 1.0 | 1.0 | | | | | 1.0 | | | 1.0 | 1.0 | | | | 1.0 | 1.0 | 1.0 | 1.0 | | Note†† | U |

* The Loads are described in Subsection 3.8.3.3

† (Same as Note †, Table 3.8-6)

‡ S=required strength to resist service loads per ASME Code Section III, Div. 2
U=required strength to resist factored loads per ACI 349

ƒ (Same as Note ƒ, Table 3.8-1)

** (Same as Note ** Table 3.8-1)

†† (Same as Note ††, Table 3.8-1)

## Table 3.8-6 Load Combination, Load Factors and Acceptance Criteria for Steel Structures Inside the Containment * †

| Load Combination | | Load Condition | | | | | | | | | | | | | | | SRV$^{f}$ | | | Acceptance Criteria‡ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | No. | D | L | $P_o$ | $P_a$ | $P_l$ | $P_s$ | $T_o$ | $T_a$ | E' | W | W' | $R_o$ | $R_a$ | Y** | $1^v$ | ADS | $G_{ALL}$ | LOCA | |
| Normal | 1 | 1.0 | 1.0 | 1.0 | | | | | | | | | | | | | | | | S |
| | 2 | 1.0 | 1.0 | 1.0 | | | | 1.0 | | | | | | 1.0 | | 1.0 | | 1.0 | | S†† |
| Severe Environmental | 1 | 1.0 | 1.0 | 1.0 | | | | | | | 1.0 | | | | | 1.0 | | 1.0 | | S |
| | 4 | 1.0 | 1.0 | 1.0 | | | | | | | | | | | | 1.0 | | 1.0 | | S |
| | 5 | 1.0 | 1.0 | 1.0 | | | | 1.0 | | | 1.0 | | 1.0 | | | 1.0 | | 1.0 | | S†† |
| | 6 | 1.0 | 1.0 | 1.0 | | | | 1.0 | | | | | 1.0 | | | 1.0 | | 1.0 | | S†† |
| Extreme Environmental | 7 | 1.0 | 1.0 | 1.0 | | | | 1.0 | | | | 1.0 | 1.0 | | | 1.0 | | 1.0 | | 1.6S |
| | 8 | 1.0 | 1.0 | 1.0 | | | | 1.0 | | 1.0 | | | 1.0 | | | 1.0 | | 1.0 | | 1.6S |
| Abnormal | 9 | 1.0 | 1.0 | | 1.0 | | | | 1.0 | | | | | 1.0 | | 1.0 | | | Note‡‡ | 1.6S |
| | 9a | 1.0 | 1.0 | | | 1.0 | | | 1.0 | | | | | 1.0 | | 1.0 | 1.0 | | Note‡‡ | 1.6S |
| | 9b | 1.0 | 1.0 | | | | 1.0 | | 1.0 | | | | | 1.0 | | 1.0 | 1.0 | | Note‡‡ | 1.6S |
| Abnormal/ Severe Environmental | 10 | 1.0 | 1.0 | | 1.0 | | | | 1.0 | | | | | 1.0 | 1.0 | 1.0 | | | Note‡‡ | 1.6S |
| | 10a | 1.0 | 1.0 | | | 1.0 | | | 1.0 | | | | | 1.0 | 1.0 | 1.0 | 1.0 | | Note‡‡ | 1.6S |
| | 10b | 1.0 | 1.0 | | | | 1.0 | | 1.0 | | | | | 1.0 | 1.0 | 1.0 | 1.0 | | Note‡‡ | 1.6S |
| Abnormal/ Extreme Environmental | 11 | 1.0 | 1.0 | | 1.0 | | | | 1.0 | 1.0 | | | | 1.0 | 1.0 | 1.0 | | | Note‡‡ | 1.7S |
| | 11a | 1.0 | 1.0 | | | 1.0 | | | 1.0 | 1.0 | | | | 1.0 | 1.0 | 1.0 | 1.0 | | Note‡‡ | 1.7S |
| | 11b | 1.0 | 1.0 | | | | 1.0 | | 1.0 | 1.0 | | | | 1.0 | 1.0 | 1.0 | 1.0 | | Note‡‡ | 1.7S |

* (Same as Note *, Table 3.8-5)

† Since $P_a$, $T_a$, SRV, and LOCA are time-dependent loads, their effects will be superimposed accordingly.

‡ Allowable Elastic Working Stress (S) is the allowable stress limit specified in Part 1 of ANSI/AISC N690.

*ƒ* (Same as Note *ƒ*, Table 3.8-1)

** (Same as Note **, Table 3.8-1)

†† For primary plus secondary stress, the allowable limits are increased by a factor of 1.5.

‡‡ (Same as Note ††, Table 3.8-1)

## Table 3.8-7 Load Combinations for Foundation Design

| Load Combination No. | Load Condition | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | D | L | H | F | F’ | E’ | W | W’ |
| 1 | 1.0 | 1.0 | 1.0 | 1.0 | | | | |
| 2 | 1.0 | | 1.0 | 1.0 | | | 1.0 | |
| 3 | 1.0 | 1.0 | 1.0 | 1.0 | | 1.0 | | |
| 4 | 1.0 | | 1.0 | 1.0 | | | | 1.0 |
| 5 | 1.0 | | | | 1.0 | | | |

Nomenclature:

| | |
|---|---|
| D | Dead Load |
| F | Buoyant Force of Design Ground Water |
| F’ | Buoyant Force of Design Basis Flood |
| H | Lateral Earth Pressure |
| L | Live Load |
| E’ | Basic SSE Seismic Load |
| W | Wind Load |
| W’ | Tornado Wind |

Note:

Load combinations 1 and 3 shall be evaluated for two cases where:

1. Live load is considered to have its full value, and
2. Live load is considered completely absent.

## Table 3.8-8 Welding Activities and Weld Examination Requirements for Containment Vessel (1)(2)(3)

| Component | Weld Type | NDE Requirements |
|---|---|---|
| Containment | Category A. Butt welds (Long'l) | RT |
| Containment | Category B, Butt welds (Circ.) | RT |
| Containment | Category C, Butt welds | RT |
| Containment | Category C, Nonbutt welds | UT or MT of PT |
| Containment | Category D, Butt welds | RT |
| Containment | Category D, Nonbutt welds | UT or MT of PT |
| Containment | Structural attachment welds<br>a.) Butt welds<br>b.) Nonbutt welds | <br>RT<br>UT or MT or PT |
| Special Welds | Weld metal cladding | PT |

**NOTES**:

(1) The required confirmation that facility welding activities are in compliance with the requirements will include the following third-party verifications:

- (a) Facility welding specifications and procedures meet the applicable ASME Code requirements;
- (b) Facility welding activities are performed in accordance with the applicable ASME Code requirements;
- (c) Welding activities related records are prepared, evaluated and maintained in accordance with the ASME Code requirements;
- (d) Welding processes used to weld dissimilar base metal and welding filler metal combinations are compatible for the intended applications;
- (e) The facility has established procedures for qualifications of welders and welding operators in accordance with the applicable ASME Code requirements;
- (f) Approved procedures are available and use for preheating and post heating of welds, and those procedures meet the applicable requirements of the ASME Code;
- (g) Completed welds are examined in accordance with the applicable examination method required by the ASME code.

(2) Radiographic film will be reviewed and accepted by the licensee's nondestructive examination (NDE), Level III examiner prior to final acceptance.

(3) The NDE requirements for containment vessels will be as stated in subarticle NE-5300 of Section III of the ASME Code.

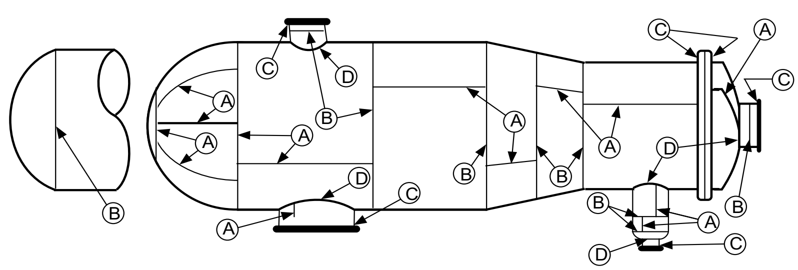
**LEGEND**:

RT – Radiographic Examination

MT – Magnetic Particle Examination

PT – Liquid Penetrant Examination

UT – Ultrasonic Examination




**Categories A, B, C, and D Welded Joint Typical Locations**

## Table 3.8-9 Staff Position on the Use of Standard ANSI/AISC N690 Nuclear Facilities-Steel Safety-Related Structures

[*The use of the Standard ANSI/AISC N690 for the design, fabrication and erection of safety-related structures in ABWR is acceptable when supplemented by the following provisions.*

*(1) In Section Q1.0.2, the definition of secondary stress should apply to stresses developed by temperature loading only.*

*(2) Add the following notes to Section Q1.3:*

*"When any load reduces the effects of other loads, the corresponding coefficient for that load should be taken as 0.9, if it can be demonstrated that the load is always present or occurs simultaneously with other loads. Otherwise, the coefficient for that load should be taken as zero."*

*"Where the structural effects of differential settlement are present, they should be included with the dead load 'D'."*

*For structures or structural components subjected to hydrodynamic loads resulting from LOCA and/or SRV actuation, the consideration of such loads should be as indicated in the Appendix to SRP Section 3.8.1. Any fluid structure interaction associated with these hydrodynamic loads and those from the postulated earthquake(s) should be taken into account."*

*(3) The stress limit coefficients (SLC) for compression in Table Q1.5.7.1 should be as follows:*

*1.3 instead of 1.5 stated in footnote (c) in load combinations 2, 5 and 6.*
*1.4 instead of 1.6 in load combinations 7, 8 and 9.*
*1.6 instead of 1.7 in load combination 11.*

*(4) Add the following note to Section Q1.5-8:*

*"For constrained (rotation and/or displacement) members supporting safety-related structures, systems or components the stresses under load combinations 9, 10 and 11 should be limited to those allowed in Table Ql.5.7.1 as modified by provision 3 above. Ductility factors of Table Ql.5.8.1 (or provision 5 below) should not be used in these cases."*

*(5) For ductility factors '$\mu$' in Sections Q1.5.7.2 and Q1.5.8, substitute provisions of Appendix A, II.2 of SRP Section 3.5.3 in lieu of Table Q1.5.8.1.*

*(6) In load combination 9 of Section Q2.1, the load factor applied to load $P_a$ should be 1.5/1.1 = 1.37, instead of 1.25.*]*

(7) Sections Q1.24 and Ql.25 should be supplemented with the following requirements regarding painting of structural steel:

(a) Shop painting to be in accordance with Section M3 of AISC LRFD Specification.
(b) All exposed areas after installation to be field painted (or coated) in accordance with the applicable portion of Section M3 of AISC, LRFD Specification.
(c) The quality assurance requirements for painting (or coating) of structural steel to be in accordance with ANSI N101.4 as endorsed by Regulatory Guide 1.54, "Quality Assurance Requirements for Protective Coatings Applied to Water Cooled Nuclear Power Plants."

* See Subsection 3.8.3.2.

## Table 3.8-10 Staff Position on Steel Embedments

[*The use of Appendix B to ACI 349 for the design of steel embedments for safety-related concrete structures in ABWR is acceptable when supplemented by the following provisions.*

*(1) Section B.4.2 - Tension and Figures B.4.1 and B.4.2.*

*This section and the figures specify that the tensile strength of concrete for any anchorage can be calculated by a 45 degree failure cone theory. The staff has disseminated the German test data questioning the validity of the 45 degree failure cone theory to licensees, A/Es, bolt manufacturers, and the code committee members in its meetings with them. The data indicated that the actual failure cone was about 35 degree and the use of the 45 degree cone theory could be unconservative for anchorage design, especially for anchorage of groups of bolts. The Code Committee, having gone through some research of its own, recently agreed with the staff's position. Changes to this section are in the making by the Code Committee. In the meantime, the staff position on issues related to this Section is to ensure adoption of design approaches consistent with the test data through case by case review.*

*(2) Section B.5.1.1 - Tension*

*This section states a criterion for ductile anchors. The criterion is that the design pullout strength (force) of the concrete as determined in Section B.4.2 exceeds the minimum specified tensile strength (force) of the steel anchor,. Any anchor that meets this criterion is qualified as a ductile anchor and, thus, a low safety factor can be used. The staff believes that the criterion is deficient in two areas. One is that the design pullout strength of the concrete so calculated is usually higher than the actual strength, which has been stated in Section B.4.2 above. The other is that anchor steel characteristics are not taken into consideration. For example, the Drillco Maxi-Bolt Devices, Ltd. claims that its anchors are ductile anchors and, thus, can use a low safety factor. The strength of the Maxi-Bolt is based on the yield strength of the anchor steel, which is 723.9 MPa. The embedment length of the anchor, which is used to determine the pullout strength of the concrete, is based on the minimum specified tensile strength of the anchor steel of 861.8 MPa. The staff believes that the 19% margin (125/105) for the embedment length calculation is insufficient considering the variability of parameters affecting the concrete cone strength. The staff also questions the energy absorption capability (deformation capability after yield) of such a high strength anchor steel. Therefore, in addition to the position taken with regard to Section B.4.2 above, the staff will review vendor or manufacturer specific anchor bolt behaviors to determine the acceptable design margins between anchor bolt strengths and their corresponding pullout strengths based on concrete cones.*

*Section B.5.1.1(a) - Lateral bursting concrete strength*

*This section states that the lateral bursting concrete strength is determined by the 45 degree concrete failure cone assumption. Since this assumption is wrong and likely to be replaced as stated before, the staff believes that the lateral bursting concrete strength determination is also wrong and needs to be replaced. The staff will review the anchor bolts and lateral bursting force created by the pulling of anchor bolts against test data to determine if adequate reinforcement against lateral bursting force need to be provided on a case by case basis.*

*(3) Section B.5.1.2.1 - Anchor, Studs, or Bars*

*This section states that the concrete resistance for shear can be determined by a 45 degree half-cone to the concrete free surface from the centerline of the anchor at the shearing surface. Since the 45 degree concrete failure cone for tension has been found to be incorrect, the staff believes that the use of the 45 degree half-cone for shear should be re-examined. In the meantime, the staff will review the adequacy of shear capacity calculation of concrete cones on a case by case basis with emphasis on methodology verification through vendor specific test data.*

## Table 3.8-10 Staff Position on Steel Embedments

*(4) Section B.5.1.2.2(c) - Shear Lugs*

*This section states that the concrete resistance for each shear lug in the direction of a free edge shall be determined based on the 45 degree half-cone assumption to the concrete free surface from the bearing edge of the shear lug. This is the same assumption as used in Section B.5.1.2.1 and the staff has the same comment as stated in that section. Therefore, the staff position related to the design of shear lugs is to perform case-by-case reviews. The staff review will emphasize methodology verification through sdpecific test data.*

*(5) Section B.7.2 - Alternative design requirements for expansion anchors*

*This section states that the design strength of expansion anchors shall be 0.33 times the average tension and shear test failure loads, which provides a safety factor of 3 against anchor failure. The staff position on safety factor for design against anchor failure is 4 for wedge anchors and 5 for shell anchors unless a lower safety factor can be supported by vendor specific test data.*

*(6) Anchors in tension zone of supporting concrete*

*When anchors are located within a tensile zone of supporting concrete, the anchor capacity reduction due to concrete cracking shall be accounted for in the anchor design.*][*]

* See Subsection 3.8.3.2.

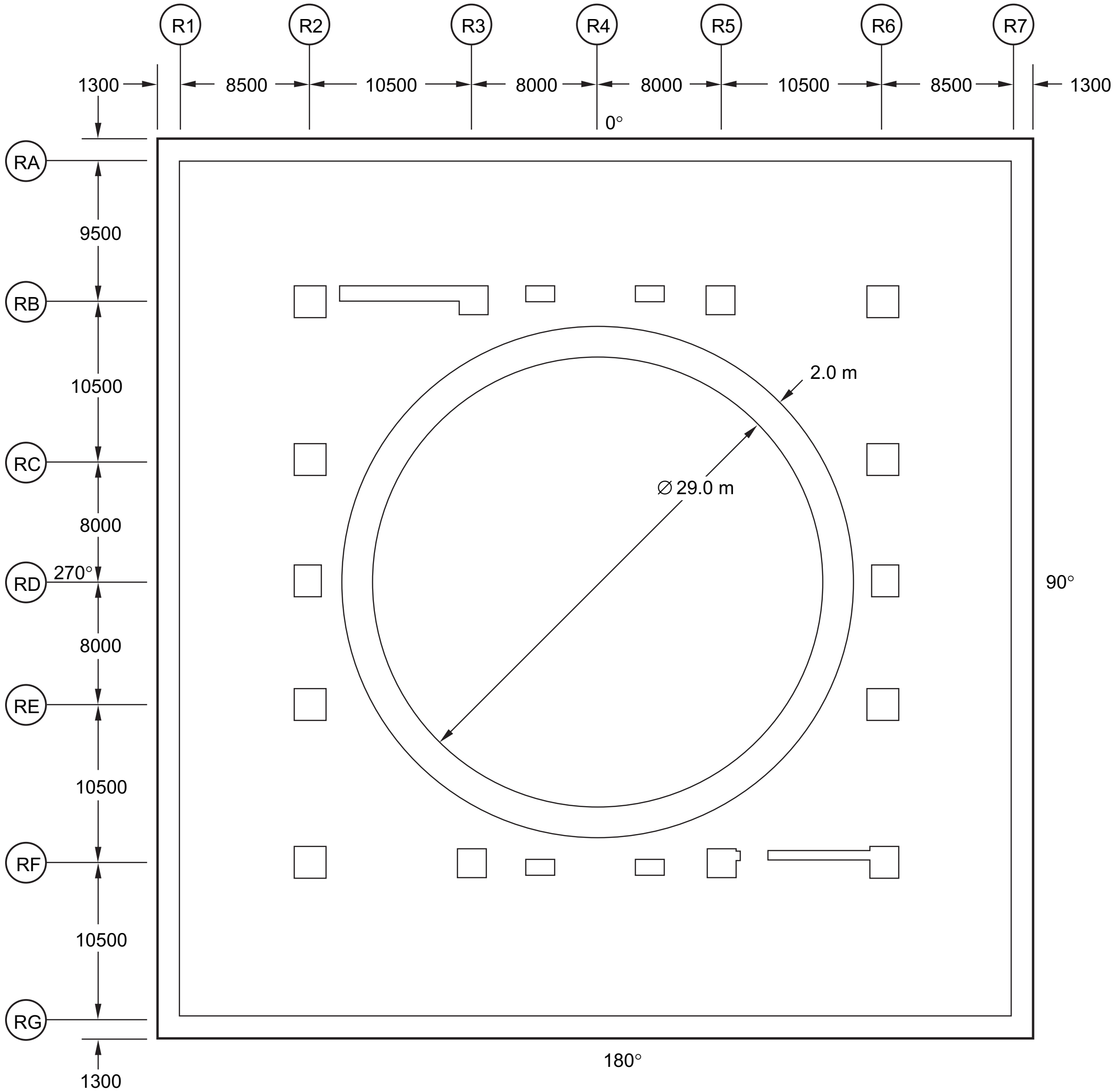



**Figure 3.8-1 Reactor Building Arrangement Floor B2F Elevation –1700 mm**

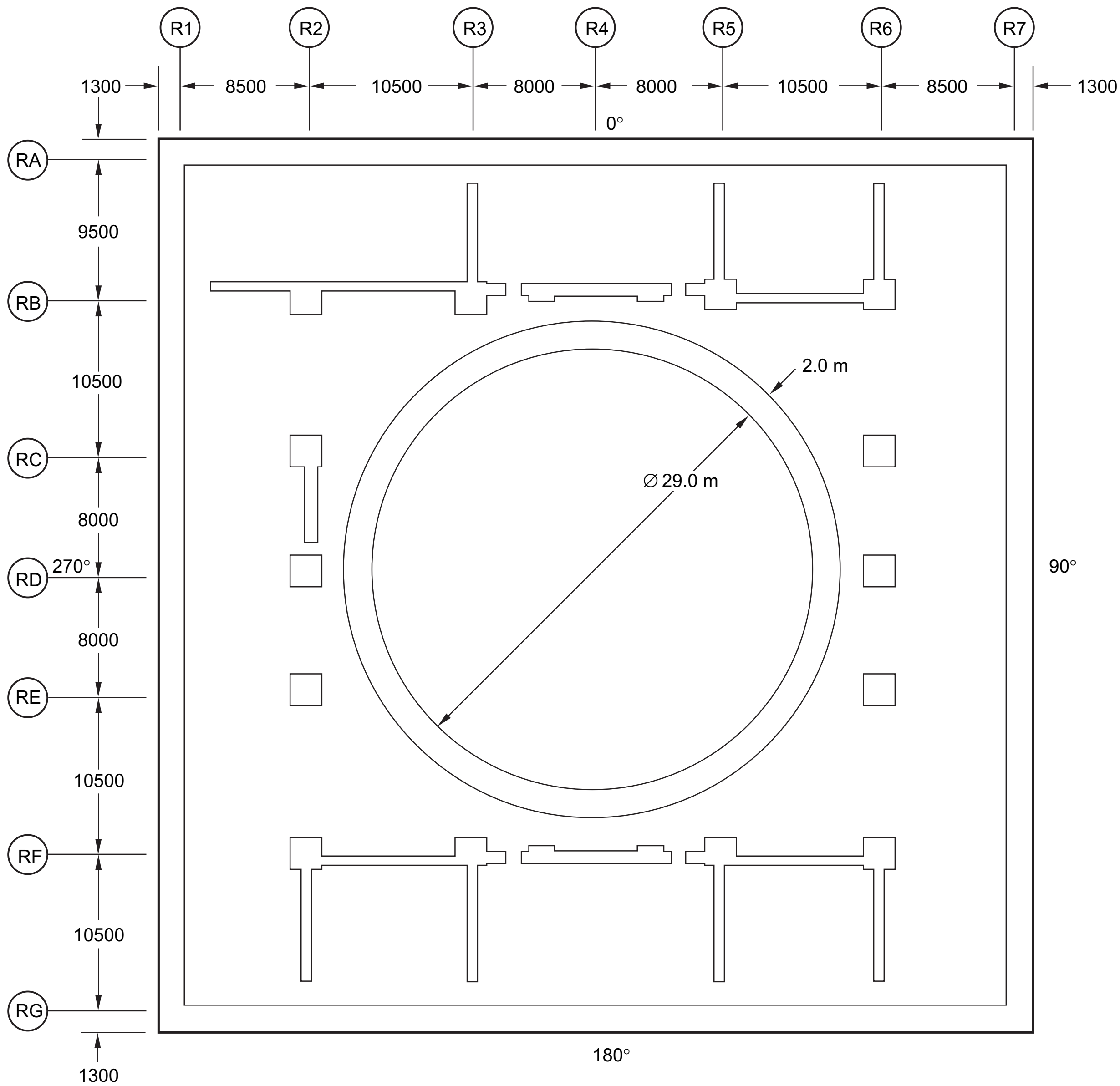



**Figure 3.8-2 Reactor Building Arrangement Floor B3F Elevation –8200 mm**

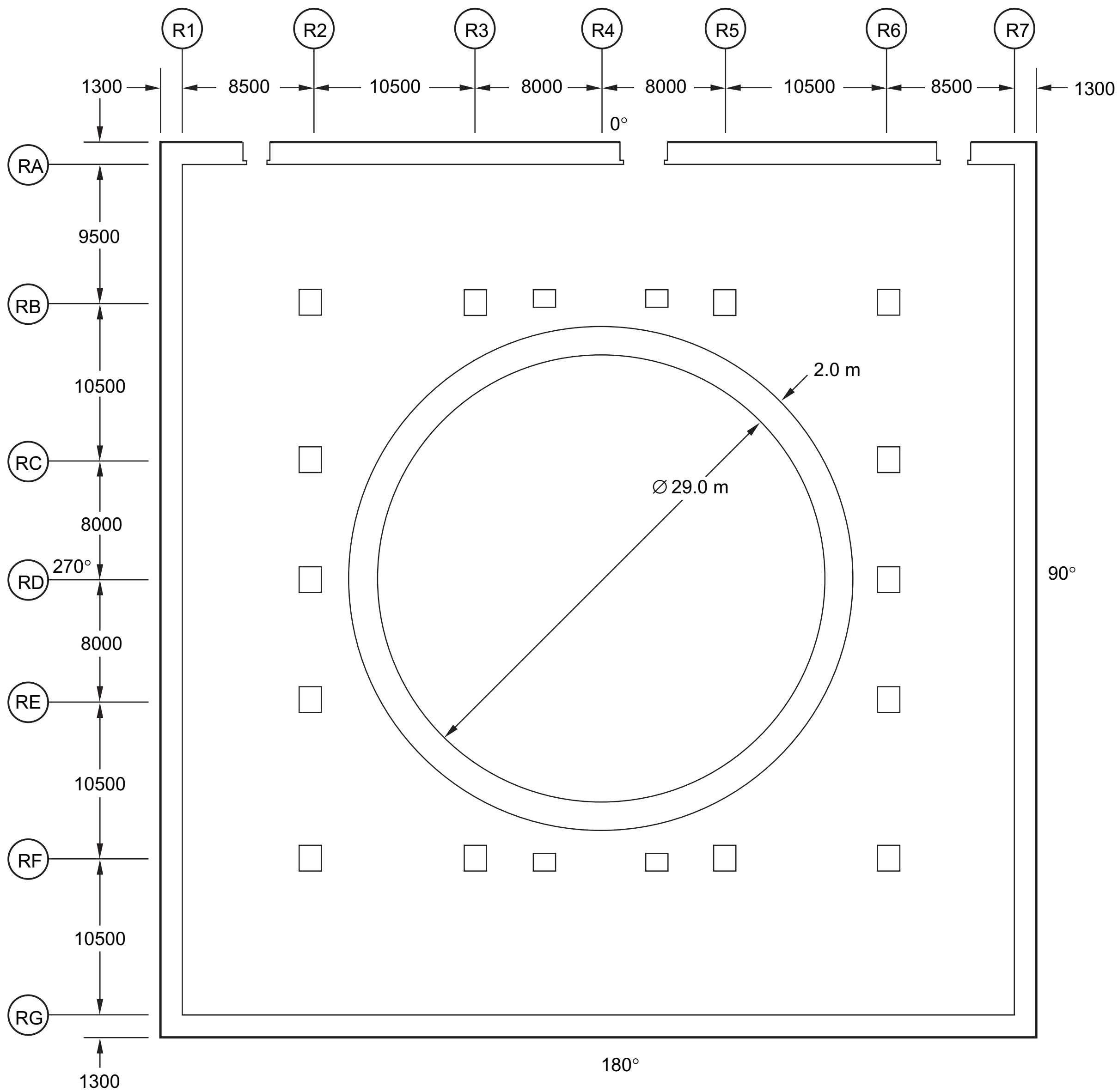



**Figure 3.8-3 Reactor Building Arrangement Floor B1F Elevation 4800 mm**

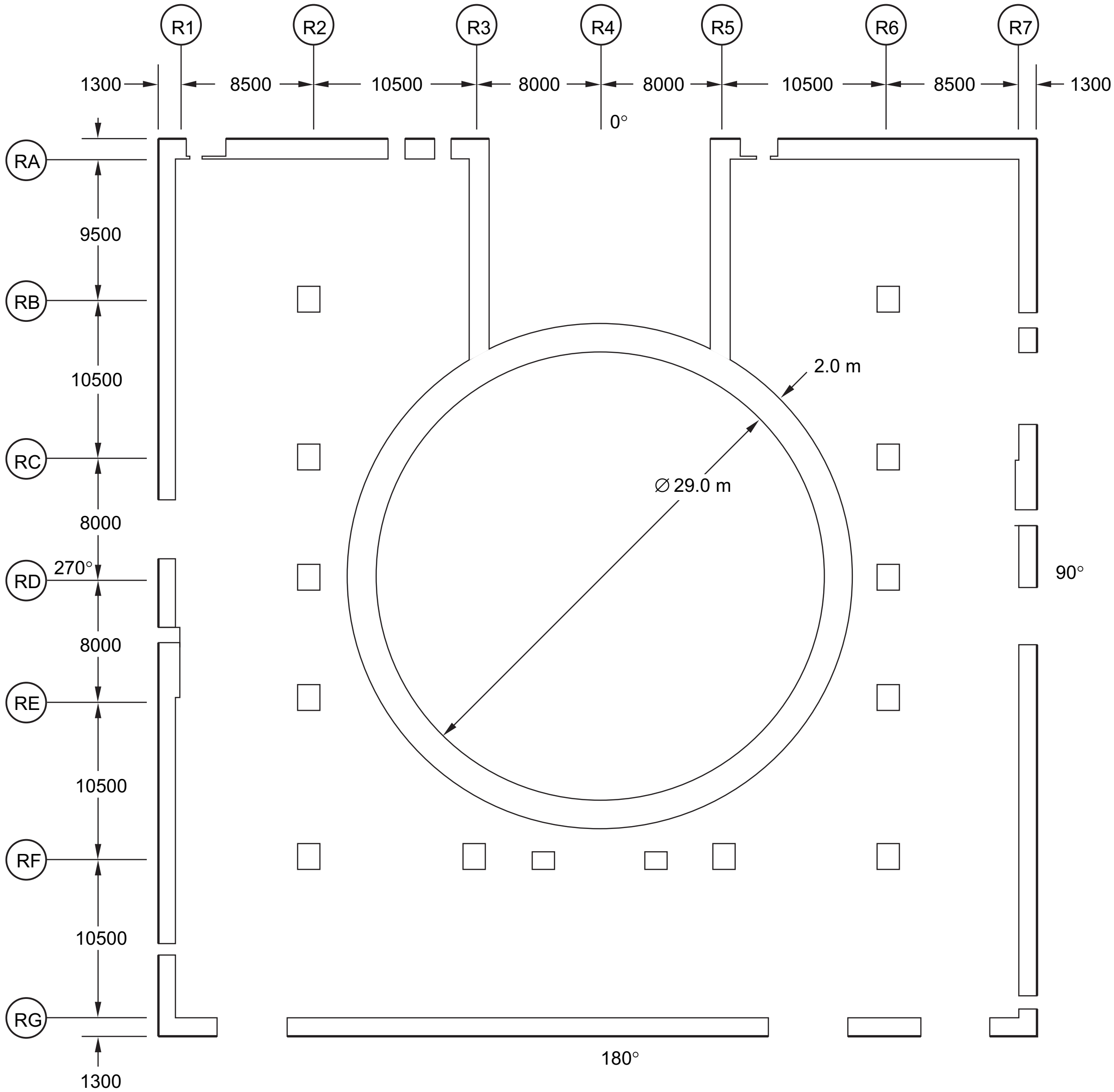



**Figure 3.8-4 Reactor Building Arrangement Floor 1F Elevation 12300 mm**

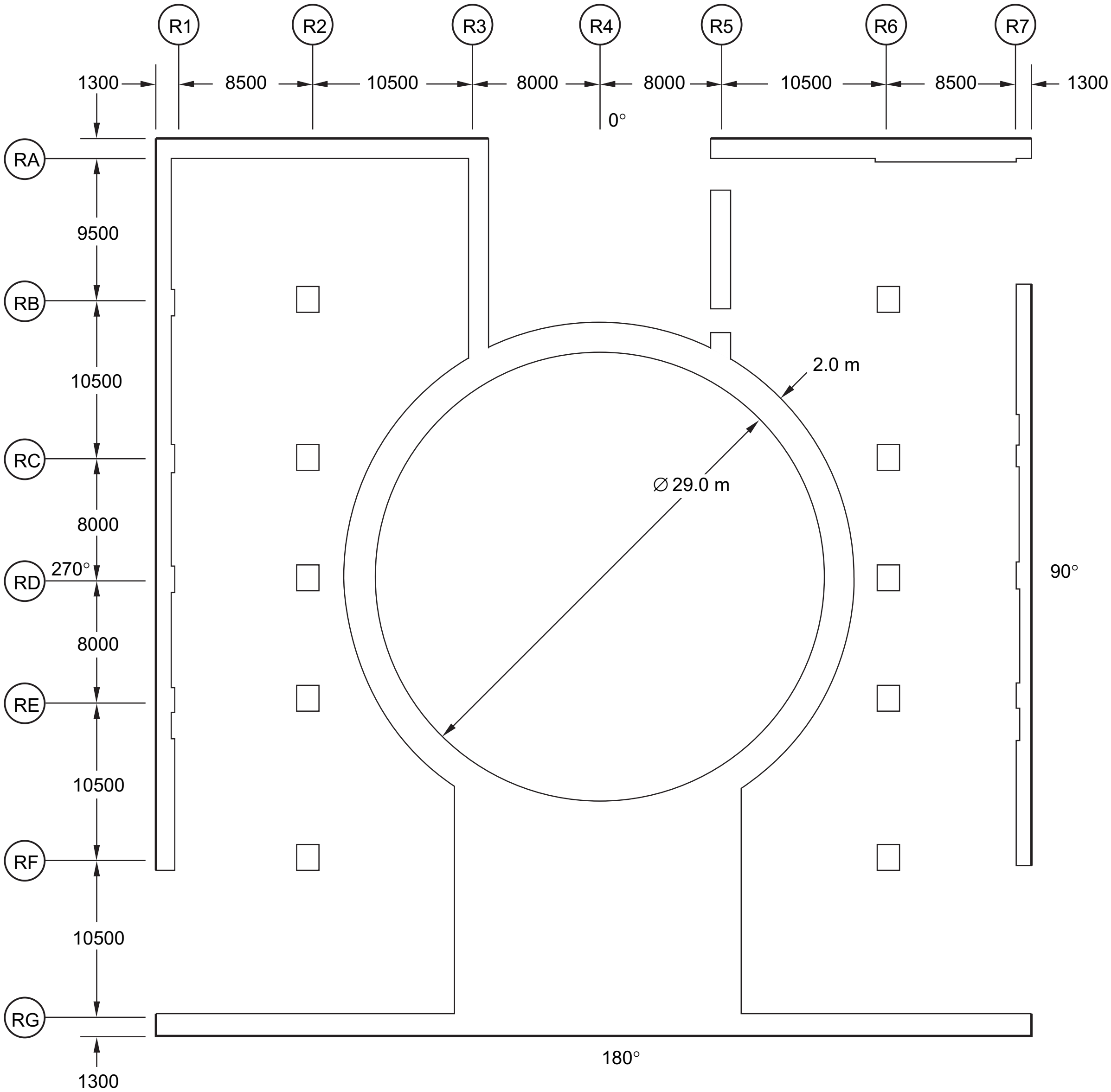



**Figure 3.8-5 Reactor Building Arrangement Floor 2F Elevation 18100 mm**

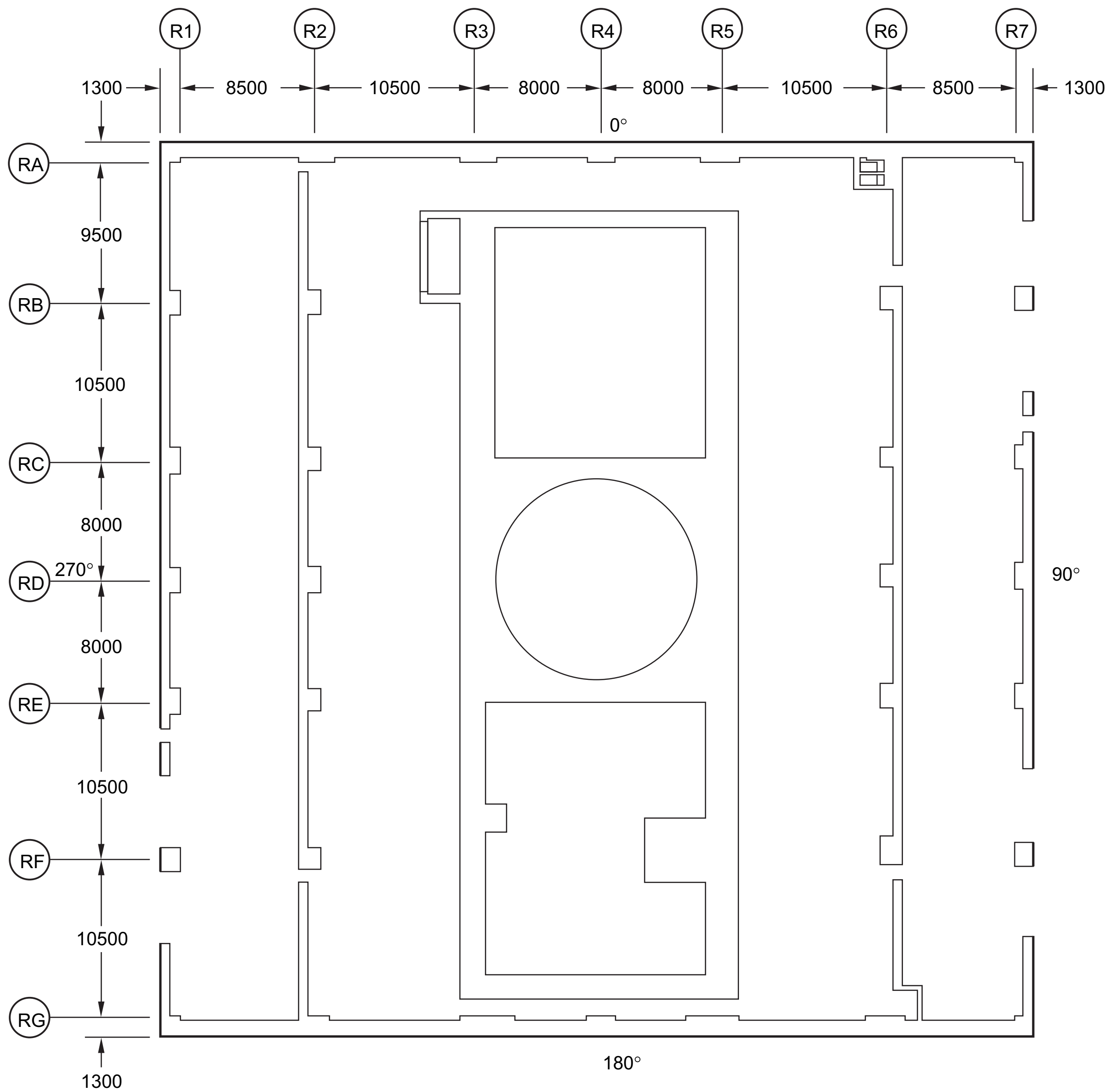



**Figure 3.8-6 Reactor Building Arrangement Floor 3F Elevation 23500 mm**

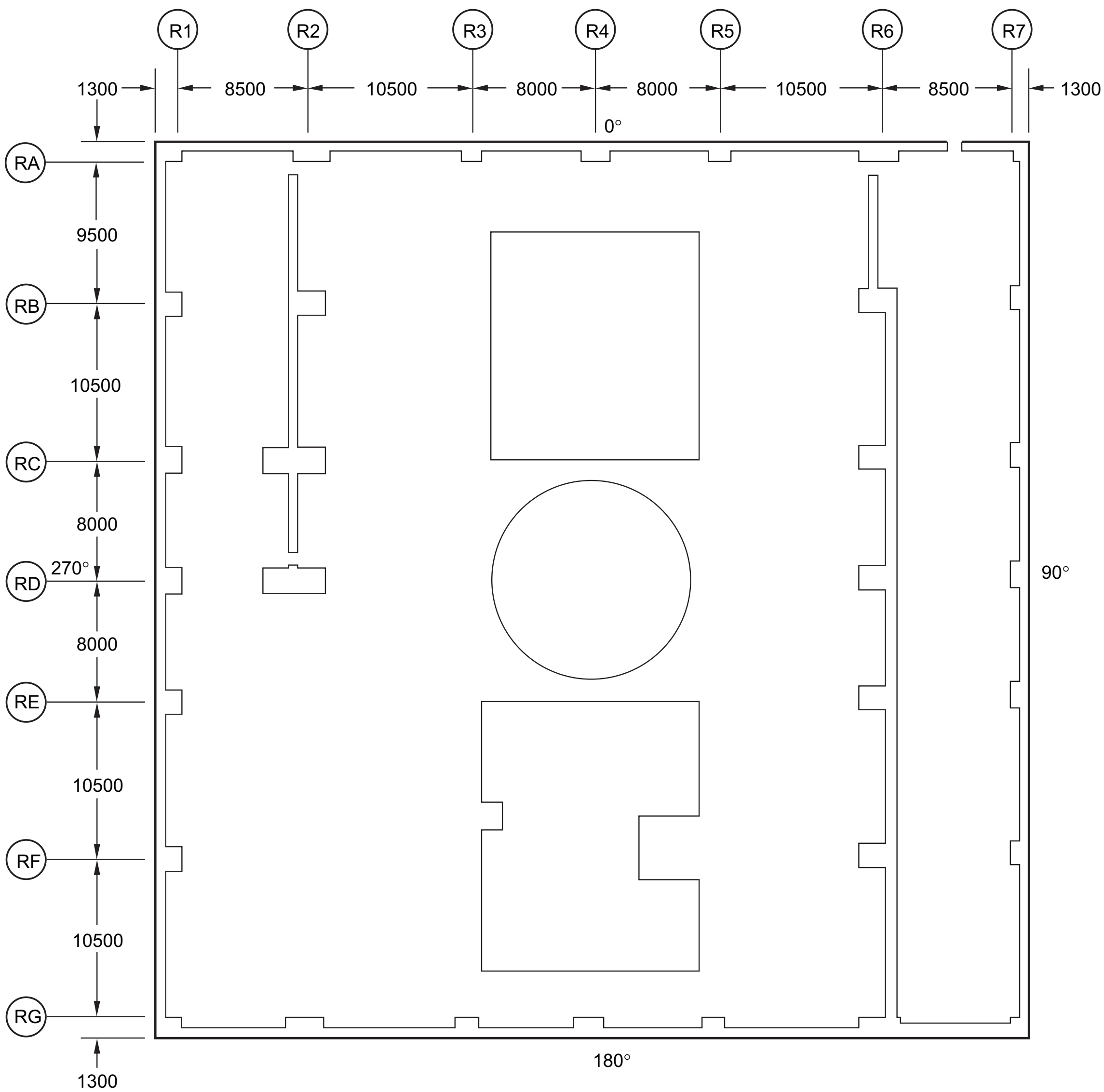



**Figure 3.8-7 Reactor Building Arrangement Floor 4F Elevation 31700 mm**

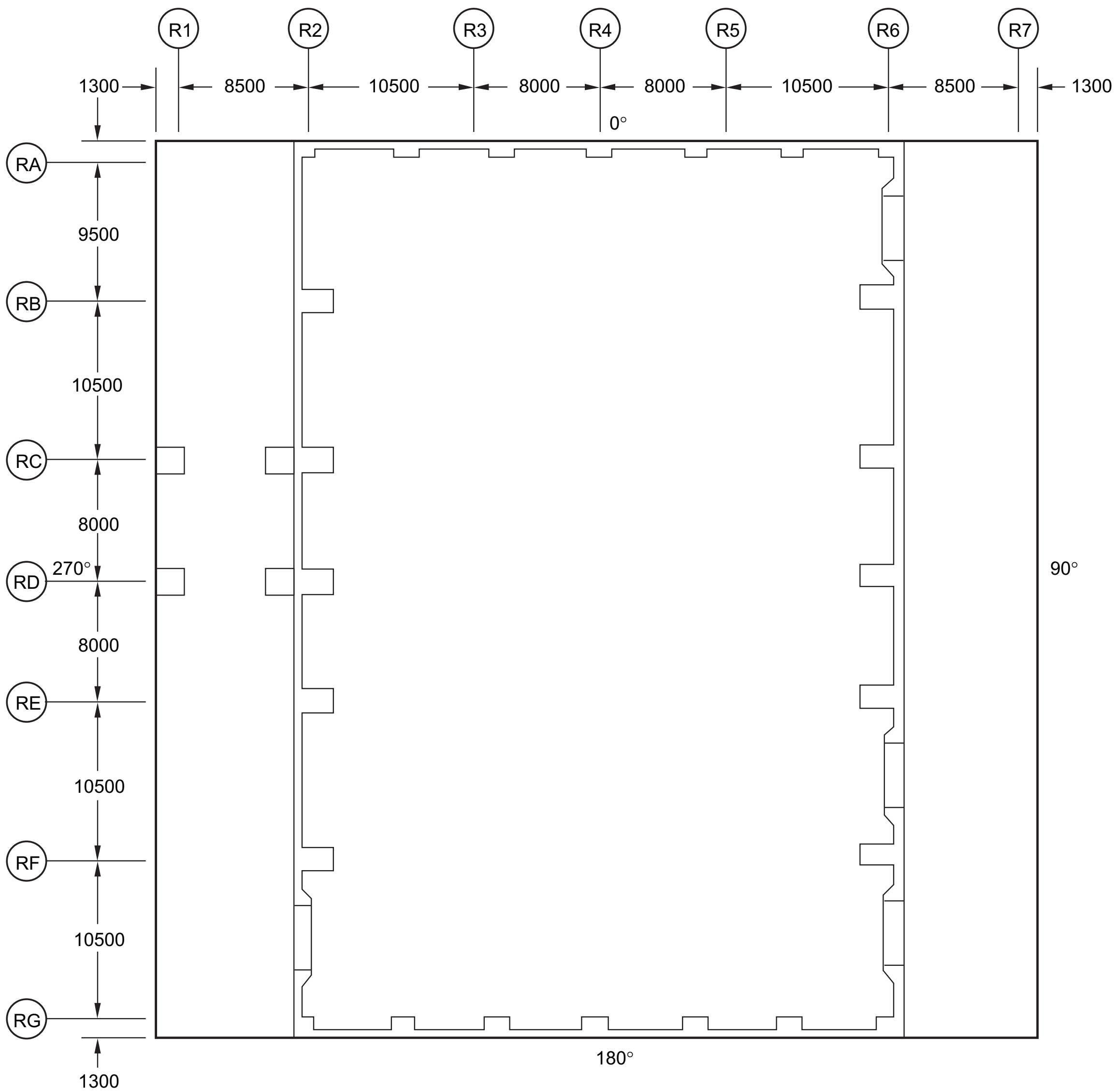
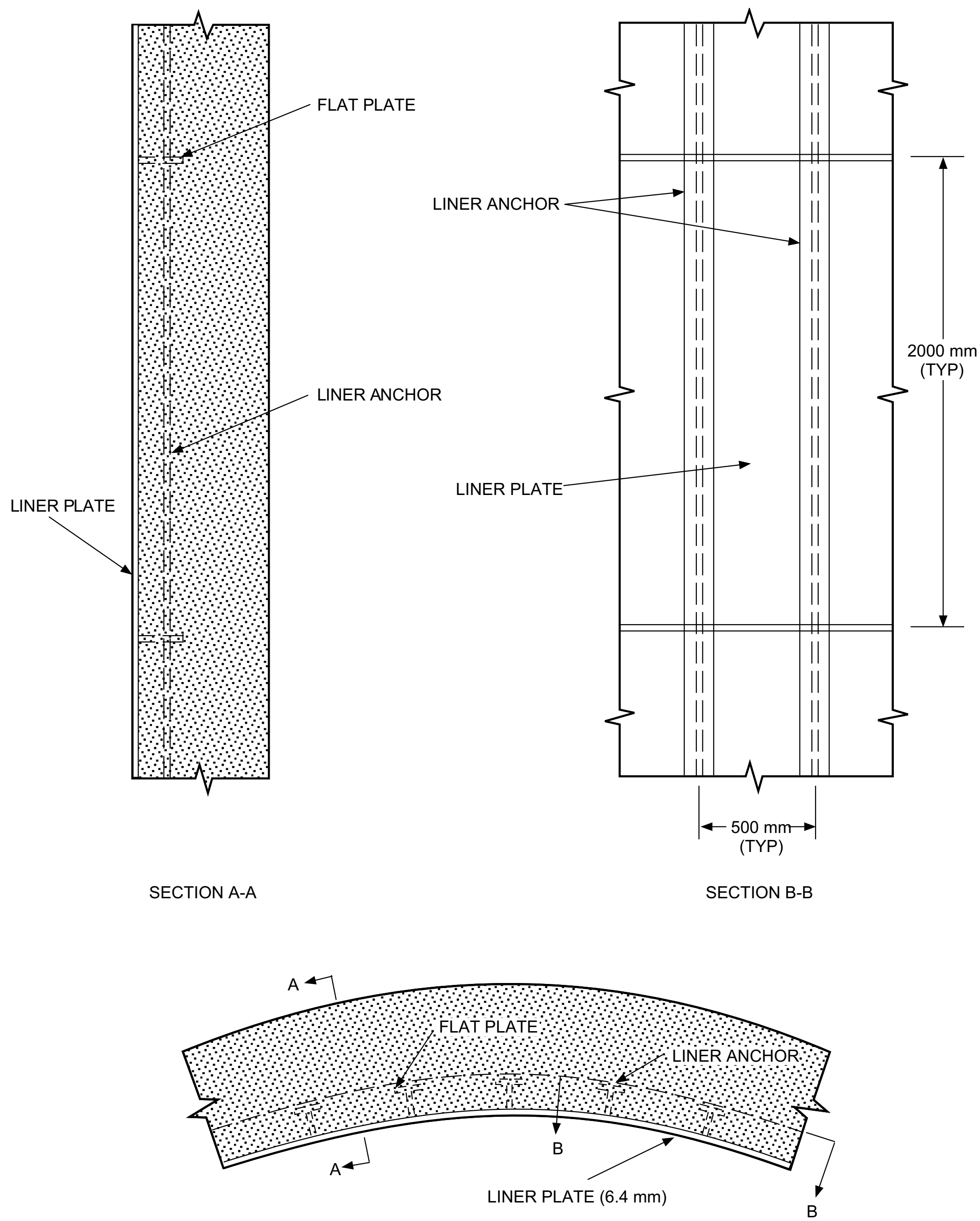



**Figure 3.8-8 Reactor Building Arrangement Elevation 38200 mm**




## Figure 3.8-9 Typical Section of Containment Liner Plate and Anchor

**Figure 3.8-10 Not Used**

**Figure 3.8-11 Not Used**

**Figure 3.8-12 Not Used**

**Figure 3.8-13 Not Used**

**Figure 3.8-14 Not Used**

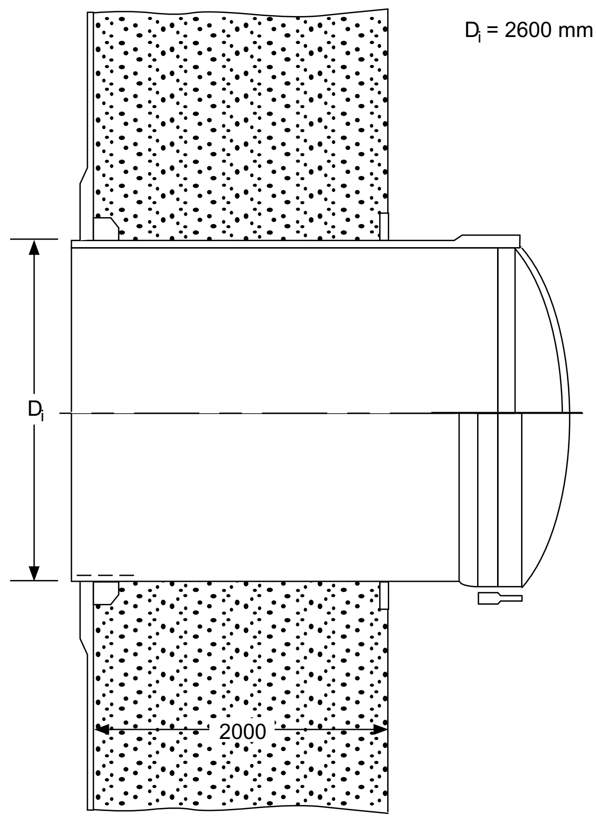



**Figure 3.8-15 Reactor Building—Containment Upper Drywell Equipment Hatch**

## Figure 3.8-16 Not Used

1. DRYWELL HEAD
2. RCCV WALL
3. DRYWELL HEAD FLANGE
4. RPV STABILIZER
5. PENETRATION
6. SHIELDING LIP
7. VERTICAL CHANNELS
8. LINER PLATE
9. SUPPRESSION CHAMBER ACCESS HATCH
10. DIAPHRAGM FLOOR (D/F)
11. REACTOR SHIELD WALL
12. U/D EQUIPMENT HATCH
13. U/D PERSONNEL LOCK
14. DRYWELL CONNECTING VENTS
15. LOWER DRYWELL (L/D)
16. UPPER DRYWELL (U/D)
17. REACTOR PRESSURE VESSEL
18. SUPPRESSION CHAMBER AIRSPACE
19. EQUIPMENT PLATFORM
20. L/D EQUIPMENT TUNNEL AND HATCH
21. L/D PERSONNEL TUNNEL AND LOCK
22. SUPPRESSION POOL
23. RPV SKIRT
24. RPV SUPPORT BRACKET
25. RPV PEDESTAL
26. SRVDL QUENCHER
27. QUENCHER SUPPORT
28. HORIZONTAL VENT
29. BOTTOM LINER PLATE
30. L/D SEAL PLATE
31. RETURN LINE
32. RCCV TOP SLAB
33. BASEMAT
34. REACTOR WELL
35. REFUELING SEAL
36. L/D FLOODERS

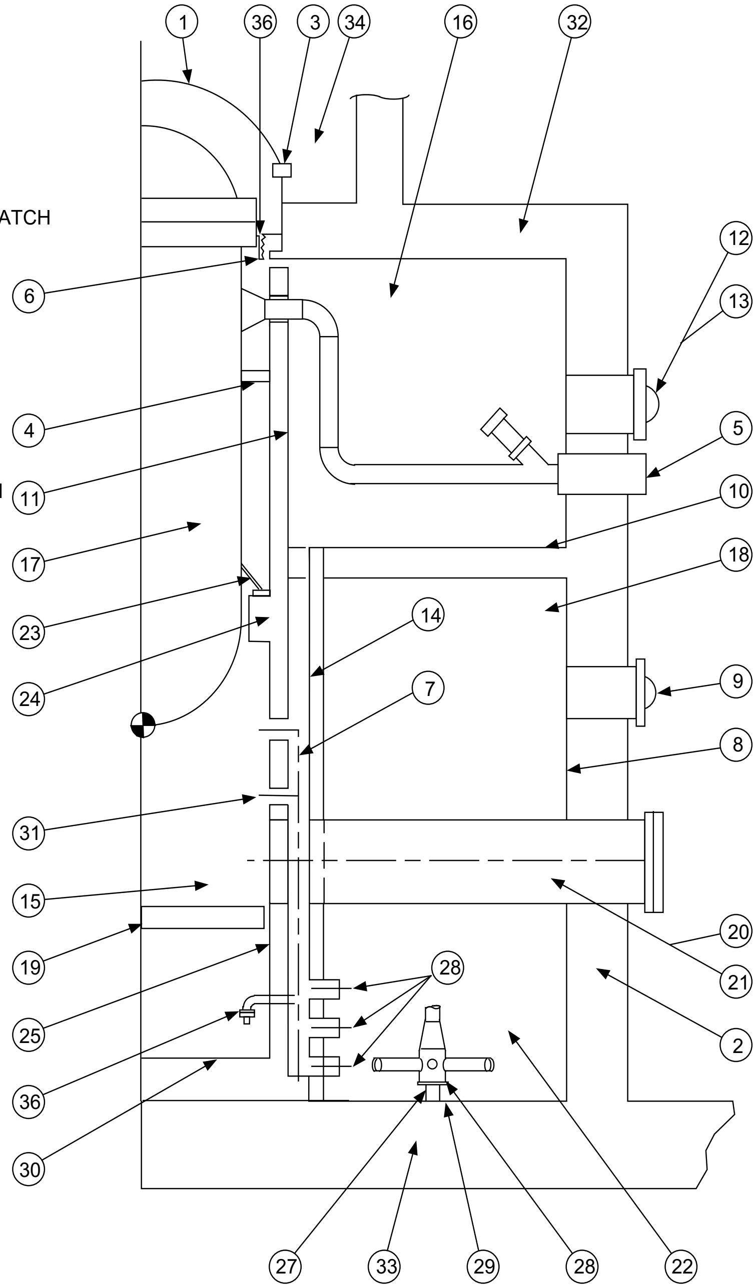
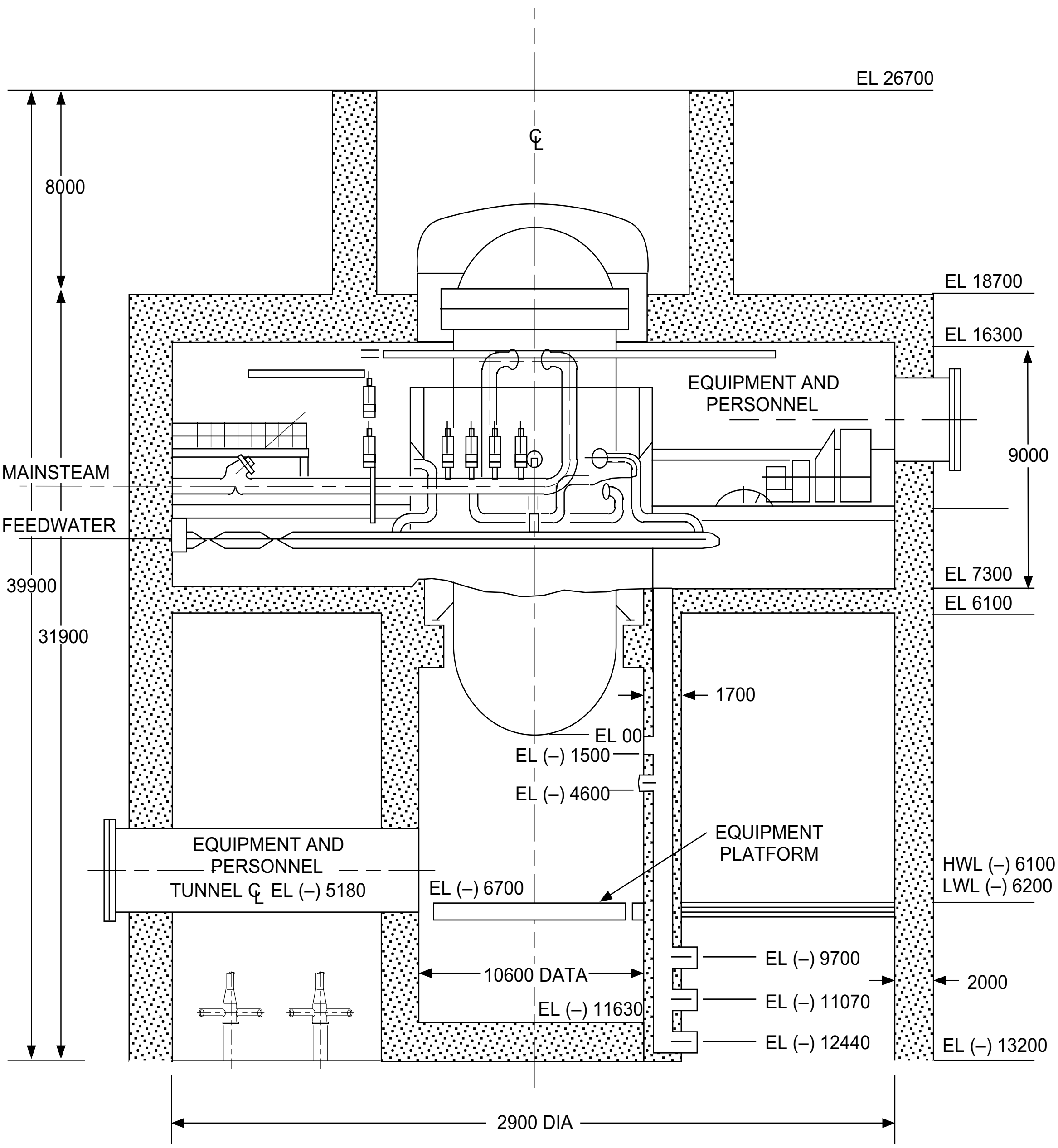


**Figure 3.8-17 Reactor Building RCCV Internal Structures Nomenclature**




NOTE: ELEVATIONS ARE WITH REFERENCE TO ZERO ELEVATION AT REACTOR PRESSURE VESSEL INVERT.

**Figure 3.8-18 Reactor Building—RCCV Configuration**

## Figure 3.8-19  Not Used

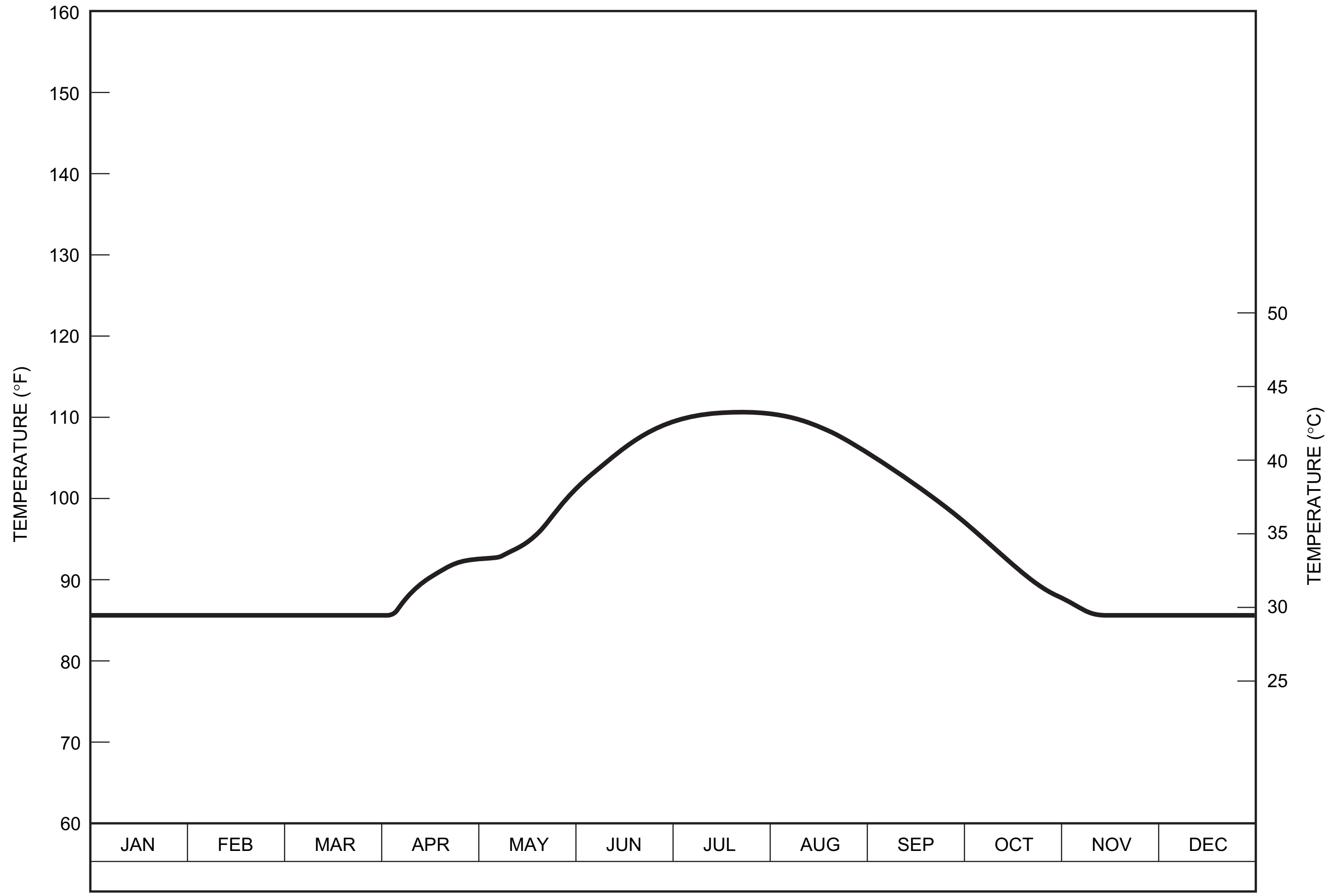



**Figure 3.8-20 Annual Temperature Profile of Suppression Pool Water During Normal Operation of a Typical Plant in Southern States**