3.8 Seismic Category I Structures

The information in this section of the reference ABWR DCD, including all subsections is incorporated by reference with the following standard departures and supplements.

STD DEP T1 2.15-1

STD DEP 1.8-1

STD DEP 12.3-3

STD DEP Admin

3.8.1.3.1 Normal Loads

STD DEP T1 2.15-1

STD DEP 1.8-1

(2)

The criteria for consideration of live loads for the designs of structural elements of the Reactor Building and *Control Building~~ and the Radwaste Building~~ are provided in Subsections 3H.1.4.3.1*~~,~~ and *3H.2.4.3.1, ~~and 3H.3.4.3.1,~~ respectively.*

(b) *Section 9.3 of ASCE Standards 7-88 and ~~Section 2334(a) of the 1991 Uniform Building Code~~* 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 ~~in~~* and *warehouse occupancies. A 25% of full live loads is, therefore, equally applicable to the nuclear plants.*

3.8.1.7.3 Preservice and Inservice Inspection

3.8.1.7.3.1 Scope

This subsection describes the Preservice and Inservice Inspection (ISI) Program requirements for ASME B&PV Code, Class CC and MC pressure retaining components of the Containment Structure and their integral attachments. It describes those programs implementing the requirements of the ASME B&PV Code Section XI (ASME Section XI), subsection IWE and subsection IWL. Subsection IWE of ASME Section XI applies to Class MC components and metallic shell and penetration liners of Class CC pressure retaining components and their integral attachments. Subsection IWL of ASME Section XI applies to the Class CC reinforced concrete containment structure.

The Preservice and ISI program plans are based on ASME Section XI, Edition and Addenda per the requirements of 10 CFR 50, Section 50.55a. The Containment

Structure is designed to provide access for the examinations required by ASME Section XI, IWE-2500 and IWL-2500. The actual Edition of ASME Section XI to be used is specified based on the procurement date of the component per 10 CFR 50, Section 50.55a. The ASME Code requirements discussed in this section are provided for information and are based on the 2004 Edition of ASME Section XI, and the supplemental requirements provided in 10 CFR 50.55a for the 2004 Edition of the ASME Code.

3.8.1.7.3.2 Components Exempted From Examination

During the detailed design phase, the goal is to minimize the number of inaccessible areas and thus reduce the number of ISI exclusion areas. Furthermore, remote tooling will be used in high radiation areas where feasible.

Portions of the Containment Structure that are excluded from Preservice and ISI examination requirements of ASME Section XI, Subsections IWE and IWL are as follows:

(1) For Class MC components and metallic shell and penetration liners of Class CC components and their integral attachments:

   a. Vessels, parts, and appurtenances outside the boundaries of the containment system as defined in the Design Specifications;

   b. Embedded or inaccessible portions of containment vessels parts, and appurtenances that meet the requirements of the Edition and Addenda of ASME Section III used for construction;

   c. Portions of containment vessels, parts and appurtenances that become embedded or inaccessible as a result of vessel repair/replacement activities if the prerequisites for exemption of inaccessible surface areas under ASME Section XI, IWE-1232(a) and (b) and IWE-5220 are satisfied;

   d. Piping, pumps, and valves that are part of the containment system, or which penetrate or are attached to the containment vessel. These components are examined in accordance with the requirements of ASME Section XI, Subsection IWB or IWC, applicable to their classification as defined in the associated Design Specification.

(2) For Class CC reinforced concrete, those portions of the concrete surface that are covered by the liner, foundation material, or backfill, or are otherwise obstructed by adjacent structures, components, parts, or appurtenances.

3.8.1.7.3.3 Accessibility for Examination

For the entire life of the plant, the following portions of Class MC Containment vessels, parts and appurtenances, and Class CC metallic shell and penetration liners shall remain accessible for direct or remote visual examination in accordance with IWE-1230:

(1) Openings and penetrations;

(2) Structural discontinuities;

(3) 80% of the pressure retaining boundary, excluding attachments, structural reinforcement, and areas made inaccessible during construction;

(4) Surface areas requiring augmented examination as identified in IWE-1240.

3.8.1.7.3.4 Preservice Examination

The preservice examinations are performed prior to plant startup but after performance of the Containment Structural Integrity Test. Visual examinations are performed after the application of any required protective coatings. The preservice examinations include those examinations listed in ASME Section XI, Table IWE-2500-1, IWL-2510 and Table IWL-2500-1, per Articles IWE-2200 and IWL-2200.

Per Table IWE-2500-1, examinations for Class MC Components are general visual examinations for accessible surface areas and moisture barriers such as caulking, flashing and other sealants used to prevent intrusion of moisture into inaccessible areas. In addition, VT-3 examination methods are used to conduct examinations of wetted surfaces of submerged areas and accessible portions of the containment vent system. Containment surface areas requiring augmented examination are those listed in IWE-1241.

Table IWL-2500-1 for examinations of Class CC concrete requires general visual examination of accessible concrete surface areas and detailed visual examination of suspect surface areas.

3.8.1.7.3.5 Visual Examination Methodology

Visual examination types VT-1 and VT-3 shall be conducted in accordance with ASME Section XI, IWA-2200. When performing IWE examinations remotely, the maximum direct examination distance specified in Table IWA-2210-1 may be extended and the minimum illumination requirements specified in Table IWA-2210-1 may be decreased provided that the conditions or indications for which the visual examination is performed can be detected at the chosen distance and illumination. The "owner defined" visual examination provisions in IWE-2310(a) shall not be used for VT-1 and VT-3 examinations.

3.8.1.7.3.6 Visual Examination of Surfaces

When performing visual examinations of Class MC pressure retaining components and their integral attachments, and of metallic shell and penetration liners of Class CC pressure retaining components, the examinations shall be performed in accordance with IWE-2500 and Table IWE 2500-1. General visual examinations shall be used to conduct the examinations in Items E1.11 and E1.30 of Table IWE-2500-1 in accordance with Examination Category E-A. The VT-3 examination method shall be used to conduct the examinations in Items E1.12 and E1.20 of Table IWE-2500-1. Augmented examinations shall be in accordance with Examination Category E-C in

Table IWE-2500-1 to assess the condition of surfaces when required to determine the magnitude of deterioration and extent of any deteriorated or distressed surfaces. The VT-1 examination method shall be used to conduct the examination in Item E4.11 of Table IWE-2500-1.

Visual examinations of concrete surfaces shall be performed in accordance with IWL-2300. Visual examinations shall be performed directly or remotely, with adequate illumination, by personnel with visual acuity sufficient to detect evidence of degradation.

3.8.1.7.3.7 Visual Examination of Bolted Connections

A general visual examination of the pressure-retaining bolted connections that are identified as part of Accessible Surface Areas in Item E1.11 of Table IWE-2500-1, Examination category E-A, shall be conducted using the VT-3 examination method once during each interval as defined by IWE-2412 in ASME Section XI. This includes the containment bolted connections that are disassembled during the scheduled performance of the examinations in Item E1.11 of Table IWE-2500-1. As an alternative to performing the VT-3 examinations of containment bolted connections that are disassembled during the scheduled performance of Item E1.11, the VT-3 examinations of containment bolted connections may be conducted whenever the bolted connections are disassembled for any reason. Flaws or degradation identified during the performance of a VT-3 examination shall be examined in accordance with the VT-1 examination method. The criteria given in the material specification or in ASME Section XI, IWB-3517.1, shall be used to evaluate containment bolting flaws or degradation.

3.8.1.7.3.8 Ultrasonic Examination

The ultrasonic thickness measurements used for surfaces requiring augmented examination in accordance with ASME Section XI, Table IWE-2500-1, Examination Category E-C, Item E4.12, are conducted using a technique demonstrated on a calibration standard. Methods such as those described in Section V, Article 23, SE-797, "Standard Practice for Thickness Measurement by Manual Contact Ultrasonic Method", are acceptable. The ultrasonic thickness measurements are performed for both Class MC Components and metallic shell and penetration liners of Class CC components if augmented examination is necessary under the provisions of ASME Section XI, IWE-1240.

3.8.1.7.3.9 Alternative Examination Techniques

As provided by ASME Section XI, IWA-2240, "Alternative Examinations", a combination of methods, or newly developed techniques may be substituted for methods specified for a given item, provided that they are demonstrated to be equivalent or superior to the specified method. This provision allows for the use of newly developed examination methods, techniques, etc., which may result in improvements in examination reliability and reductions in personnel exposure.

3.8.1.7.3.10 Qualification of Examination Personnel and Systems for Ultrasonic Examination

Personnel performing preservice and inservice examinations of the containment system are qualified in accordance with the applicable requirements of ASME Section XI. Personnel shall conduct VT-1 and VT-3 examinations in accordance with IWA-2200. Personnel conducting examinations in accordance with the VT-1 or VT-3 examination method shall be qualified in accordance with IWA-2300. Personnel performing detailed visual examination and general visual examination of concrete surfaces are qualified in accordance with IWA-2300 to perform examinations as described in IWL-2300. The "owner defined" personnel qualification provisions in IWE-2330(a) for personnel that conduct VT-1 and VT-3 examinations and IWL-2310(d) are not approved for use. Ultrasonic examination systems shall be qualified in accordance with an industry accepted program for implementation of ASME Section XI, Appendix VIII, "Performance Demonstration for Ultrasonic Examination Systems".

3.8.1.7.3.11 Inservice Inspection Schedule

The ISI interval for Class MC Components and metallic shell and penetration liners of Class CC components and their supports shall conform to the 10 year inspection interval of Inspection Program B as described in ASME Section XI, IWE-2412 and Table IWE-2412-1. Except where deferral is permitted until the end of an inspection interval as specified in Table IWE-2500-1, the percentages of minimum examinations completed and maximum examinations credited within each period of the interval shall correspond to Table IWE-2412-1.

The ISI of Class CC reinforced concrete is per Section IWL-2400. It shall be performed at 1, 3, and 5 years following the completion of the Containment Structural Integrity Test and every 5 years thereafter in accordance with ASME Section XI, IWL-2510 and Table IWL-2500-1.

3.8.1.7.3.12 Acceptance Criteria and Evaluation of Examination Results

For Preservice and ISI examinations, the requirements of IWE-3000 for ASME Class MC Components and metallic liners and IWL-3000 for ASME Class CC concrete components are used for evaluation of examination results. The ultrasonic acceptance standard of IWE-3511.3 for ASME Class MC Components is applied to metallic liners of Class CC components for containment surfaces requiring augmented examination. The criteria for the evaluation of containment bolting flaws or degradation are in accordance with IWB-3517.1 or the material specification.

3.8.1.7.3.13 System Pressure Tests

System pressure tests of the Containment Structure are conducted in accordance with ASME Section XI, IWE-5000 and IWL-5000. Per IWE-5221, except as noted in IWE-5222, repair/replacement activities performed on the pressure retaining boundary of the Class MC or Class CC components shall be subjected to a pneumatic leakage test in accordance with provisions of 10 CFR 50, Appendix J. In addition to the Class CC requirements stated in IWL-5000 pertaining to pressure tests, IWL-4000 provides requirements for repair/replacement activities on the concrete containment structure.

3.8.1.7.3.14 Evaluation of Inaccessible Areas

During operation, areas inaccessible for examination for acceptability are evaluated if conditions exist in accessible areas that indicate the presence of or result in the degradation of the inaccessible areas. For each such area identified, the following information is included in the Inservice Inspection Summary report required by ASME Section XI, IWA-6000:

(1) A description of the type and estimated extent of degradation, and the conditions that led to the degradation.

(2) An evaluation of each area and the result of the evaluation.

(3) A description of necessary corrective actions.

3.8.4 Other Seismic Category I Structures

STD DEP T1 2.15-1

STD DEP 12.3-3

Other Seismic Category I structures which constitute the ABWR Standard Plant are the Reactor Building, Control Building, and Diesel Generator Fuel Oil Tunnels.~~*Radwaste Building substructure.*~~ *Figure 1.2-1 shows the spatial relationship of these buildings. The* ~~*only other*~~non-Category I *structure*s ~~*in close proximity to*~~which could interact with *these structures* ~~*is*~~are the Radwaste Building, Service Building, Control Building Annex, the stack on the Reactor Building roof, and *the Turbine Building.* ~~*It is*~~These structures, except the stack, are *structurally separated from the other ABWR Standard Plant buildings.* The analysis and design of these non-Category I structures are described in Sections 3.7.2.8 and 3.7.3.16.

Details of the Diesel Generator Fuel Oil Tunnels are provided in Section 3H.7.

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. ~~*Steam generated in the RHR compartment from the postulated pipe break exits to the steam tunnel through blowout panels.*~~*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.*

3.8.4.1.3 ~~Radwaste Building Substructure~~ (Not Used)

STD DEP T1 2.15-1

~~*The Radwaste Building (RWB) Substructure is shown in Section 1.2.*~~

The Radwaste Building is a reinforced concrete structure 60.4 66.2m by 41.2 38.8m and a height of 29.5 27.4m from the top of the basemat. The building consists of a below grade substructure consisting of walls (1.2m thick) and slabs of reinforced concrete forming a rigid box structure which serves as a container to hold radioactive waste in case of an accident. This substructure is located below grade to increase shielding capability and to maximize safety. It is supported on a separate foundation mat whose top is 13.7m below grade. In addition, a reinforced concrete superstructure

15.7 13.4m high extends above grade floor level and houses the balance of the radwaste equipment.

The RWB Substructure houses the high and low conductivity tanks, clean up phase sperarators, spent resin storage tanks, a concentrated waste storage tank, distillate tank and associated filters, and pumps for the radioactive liquid and solid waste treatment systems.

Although the radwaste superstructure is not a Seismic Category I structure, its major structural concrete walls, slabs, columns and roof are designed to resist Seismic Category I loads.

The summary report for the readwaste building is in Section 3H.3. This report contains a description of radwaste building, the loads, load combinations, reinforcement stresses, and concrete stresses at locations of interest. In addition, the report contains reinforcement details for the basement, seismic walls, and floors.

3.8.4.2.1 Reactor Building

STD DEP 1.8-1

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).]**

3.8.4.2.3 Radwaste Building Substructure (Not Used)

STD DEP T1 2.15-1

*[The RWB Substructure shall be designed using the same codes and standards as the reactor building. Refer to Subsection 3.8.4.2.1 for a complete list.]**

In addition, the non-Seismic Category 1 I reinforced concrete portion of the superstructure is designed according to the seismic provisions of the uniform building code.

3.8.4.3.2 Control Building and Radwaste Building Substructure

STD DEP T1 2.15-1

3.8.4.4.1 Reactor Building, and Control Building, and Radwaste Building Substructure

STD DEP T1 2.15-1

*[The Reactor Building,*and *Control Building and Radwaste Building Substructure 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. and Radwaste Building Substructure 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., and the radwaste building foundation is in Section 3H.3. This summary report contains a section detailing safety factors against sliding, over turning, and floatation.*

3.8.4.5.3 Radwaste Building Substructure (Not Used)

STD DEP T1 2.15-1

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

3.8.5.1 Description of the Foundations

STD DEP T1 2.15-1

The Radwaste Building foundation is a rectangular reinforced concrete mat 60.4m by 41.2 and 2.5m thick. The top of the Radwaste Building mat is 13.5m below grade. The foundation mat is constructed of cast-in-place conventionally reinforced concrete. It supports the Radwaste Building structure.

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., and the Radwaste Building foundation is in Section 3H.3. This summary report contains a section detailing safety factors against sliding, over turning, and floatation.*

3.8.5.8.1 Description of Foundations for DGFOT

Diesel Generator Fuel Oil Tunnels (DGFOT) foundation is a 2 ft thick reinforced concrete basemat placed over two feet thick lean concrete mud mat. The foundation analysis and design is performed using a three dimensional finite element analysis (FEA). The flexibility of the basemat and the supporting soil is accounted for through use of foundation soil springs. For additional analysis and design details, see Section 3H.7.

Seismic gaps between the DGFOT and adjoining Reactor Building (RB) and Diesel Generator Fuel Oil Storage Vaults (DGFOSV) as well as the differential movements for design commodities communicating between the DGFOT and the adjoining RB and DGFOSV are determined considering settlement and tilts obtained from time rate of settlement analysis accounting for construction sequence, seismic movements from seismic analysis, and translations and/or rotations from sliding and overturning stability evaluations.

3.8.5.9 Description of Foundations for Category I Site-Specific Structures

3.8.5.9.1 UHS/RSW Pump House

Ultimate Heat Sink (UHS)/Reactor Service Water (RSW) Pump House foundation is a 10 ft thick reinforced concrete basemat placed over two feet thick lean concrete mud mat. The foundation analysis and design is performed using a three dimensional finite element analysis (FEA). The flexibility of the basemat and the supporting soil is accounted for through use of foundation soil springs. For additional analysis and design details, see Section 3H.6.

Seismic gaps between the RSW Pump House and the adjoining RSW Piping Tunnels as well as the differential movements for design of commodities communicating between the RSW Pump House and RSW Piping Tunnels are determined considering settlement and tilts obtained from time rate of settlement analysis accounting for construction sequence, seismic movements from seismic analysis, and translations and/or rotations from sliding and overturning stability evaluations.

3.8.5.9.2 Reactor Service Water (RSW) Piping Tunnels

RSW Piping Tunnels foundation is a 3 ft thick reinforced concrete basemat placed over 2 ft thick lean concrete mud mat. The foundation analysis and design is performed using conservative manual calculations as described in Section 3H.6.6.2.2.

Seismic gaps between the RSW Piping Tunnels and the adjoining Control Building (CB) and RSW Pump House as well as the differential movements for design of commodities communicating between the RSW Piping Tunnels and the adjoining CB and RSW Pump House are determined considering settlement and tilts obtained from time rate of settlement analysis accounting for construction sequence, seismic movements from seismic analysis, and translations and/or rotations from sliding and overturning stability evaluations.

3.8.5.9.3 Diesel Generator Fuel Oil Storage Vaults (DGFOSV)

DGFOSV foundation is a 6 ft thick reinforced concrete basemat placed over 2 ft thick lean concrete mud mat. The foundation analysis and design is performed using a three dimensional finite element analysis (FEA). The flexibility of the basemat and the supporting soil is accounted for through use of foundation soil springs. For additional analysis and design details, see Section 3H.6.7.

Seismic gaps between the DGFOSV and the adjoining DGFOT as well as the differential movements for design commodities communicating between the DGFOSV and DGFOT are determined considering settlement and tilts obtained from time rate of settlement analysis accounting for construction sequence, seismic movements from seismic analysis, and translations and/or rotations from sliding and overturning stability evaluations.

3.8.5.10 Construction Sequencing for Seismic Category I Foundations

In order to assure that construction loading does not result in excessive stresses on the foundation mat or the superstructure, construction sequence planning will consider the following:

- Construction should proceed such that major walls at the lowest level, those providing foundation mat stiffness, are constructed across essentially the entire foundation before loads from walls and slabs above are applied.
- Loads should be uniformly applied to the foundations.
- Overall foundation tilt would remain within 1/600.

Construction specifications will include the following requirements:

- The concrete placement for the superstructure will be such that the superstructure is erected uniformly considering the following:
  - Concrete pours for major walls are limited to the lesser of about 20’-0” or to the floor above until all of the major walls at that elevation are poured.
  - Concrete pours for major floor slabs are essentially completed for the entire floor before concrete pours are started for floor above.
- For the RSW Pump House/UHS foundation, the following sequence will be specified:
  - Excavate the RSW Pump House/UHS to the bottom of the UHS foundation.
  - Place the UHS foundation concrete to a construction joint within about ten feet of the junction with the RSW Pump House.
  - Drive sheet piling along the RSW Pump House wall adjacent to the UHS and excavate to the bottom of the RSW Pump House foundation.
  - Place the RSW Pump House foundation concrete.
  - Place the RSW Pump House concrete walls up to the UHS foundation level.
  - Complete concrete placements for UHS foundations and RSW Pump House slabs at the top of the UHS foundation level.
  - For the remaining portions of the UHS basin and RSW Pump House above the UHS basemat level the concrete pour of the major walls will be limited to the

lesser of about 20’-0” or to the floor above until all of the major walls at that elevation are poured.

- For the buried tunnels, the following sequence will be specified:
  - Construct the tunnels uniformly and level by level to a construction joint within about ten feet of the junction with the terminating structure.
  - After placing backfill around and above each tunnel, place the last tunnel segment adjacent to the terminating structure.

3.8.6 COL License Information

3.8.6.1 Foundation Waterproofing

The following standard supplement addresses COL License Information Item 3.23.

Foundation waterproofing is done by placing a waterproofing membrane near the top elevation of the concrete fill. The remainder of the concrete fill is then poured on top of the waterproofing material. A waterproof membrane that could degrade the ability of the foundation to transfer loads is not used.

The material used for the waterproof membrane will be a two-coat color-coded Methyl Methacrylate (MMA) resin, which is an elastomeric “spray-on” membrane. The total thickness of the waterproofing membrane will be a nominal 120 mils.

Additional testing on the waterproofing membrane will be required to demonstrate the adequacy of the membrane’s performance under applicable mechanical conditions, including pressures from the backfill, hydrostatic pressure, and foundation bearing. Test conditions will simulate the environment at the walls and the base level. The horizontal membrane (located in the structural concrete fill) will also be tested for its resistance to the hydrostatic pressures at the membrane location, as the basic assumption that necessitates the use of waterproofing is that cracks in the concrete fill will allow water to propagate up to the waterproofing membrane.

The membrane will be tested in accordance with ASTM D5385, Standard Test Method for Hydrostatic Pressure Resistance of Waterproofing Membranes, which requires that the membrane be subjected to a pressure of 100 psi. The acceptance criterion is that the sample is able to resist the expected hydrostatic pressure.

The waterproofing membrane will be tested per ASTM C267 (Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacings and Polymer Concretes) for its resistance to the concrete mix chemistry, the actual backfill material chemistry, and groundwater chemistry found on site. Additional testing of the waterproofing membrane’s ability to resist the chemical reagents as specified through accelerated aging will be done per ASTM G114 (Standard Practices for Evaluating the Age Resistance of Polymeric Materials Used in Oxygen Service). The margin provided by the testing, for chemicals and pressure exposures, along with the results from accelerated age testing will ensure that the waterproofing will sufficiently resist the projected environmental pressures over its intended lifetime.

The coefficient of friction of the waterproofing material will be determined with a qualification program prior to procurement of the material. The qualification program will be developed to demonstrate that the selected material will meet the waterproofing and friction requirements. The qualification program will include testing to demonstrate that the waterproofing requirements and the coefficient of friction required to transfer seismic loads have been met. Testing methods will simulate field conditions to demonstrate that the minimum required static coefficient of friction of 0.75 is achieved by the structural concrete fill - waterproof membrane structural interface. The material will meet the required friction factor. Also, to achieve a minimum coefficient of friction of 0.75 to prevent sliding at the construction joints in the structural concrete and concrete fill, the concrete surfaces will be roughened in accordance with the provisions of Section 11.7.9 of ACI 349-97.

The test program will be based on the test methods contained in ASTM D1894. The tests will be performed with the expected range of normal compressive stresses. The coefficient of friction, as defined in ASTM D1894, is the ratio of the force required to move one surface over another to the total force applied normal to those surfaces. The test fixture assembly will be designed to obtain a series of shear / lateral forces and the corresponding applied normal compressive loads. The test data will be generally represented by a best fit straight line whose slope is the coefficient of friction.

3.8.6.2 Site Specific Physical Properties and Foundation Settlement

The following site-specific supplement addresses COL License Information Item 3.24.

Physical properties of the site-specific subgrade medium and the settlement of foundations are assessed in Sections 3H.6.4.2 and 2.5S.4.

3.8.6.3 Structural Integrity Test Result

The following standard supplement addresses COL License Information Item 3.25.

Structural Integrity Test (SIT) of the containments will be performed in accordance with Subsection 3.8.1.7.1 and ITAAC Table 2.14.1 Item #3. The Unit 3 containment will be considered a prototype and its SIT performed accordingly. The details of the test and the instrumentation are provided in the following subsections. The test and instrument plan for the Unit 3 SIT will conform to the requirements for prototype containments as delineated in Article CC-6000 of ASME Section III, Division 2. The test and instrument plan for the Unit 4 SIT will conform to the requirements for nonprototype containments as delineated in Article CC-6000 of ASME Section III, Division 2.

3.8.6.3.1 Details of the Test:

The containment is subjected to integrity tests that include both an overall internal pressure test and a differential pressure test. The SIT will be performed at a test pressure of at least 1.15 times the containment design pressure in both the drywell and suppression chamber simultaneously. The differential pressure test will be performed at a test pressure of at least 1.0 times the maximum design differential pressure. The test pressure will be held for at least 1 hour.

Predictions of displacements and strains will be made prior to the start of the Unit 3 test. During the SIT, the suppression chamber and spent fuel pool will be filled with water to the normal operational water level. Atmospheric air will be used as the testing medium for both the overall and the differential pressure test. The Designer or his designee will perform a pretest visual examination of the accessible portions of the Reinforced Concrete Containment Vessel (RCCV) prior to the SIT in accordance with CC-6210 of ASME Section III, Division 2. The Designer or his designee will witness the SIT and will monitor displacement measurements.

3.8.6.3.1.1 Test Description & Objectives

(1) The SIT will test the RCCV for structural performance acceptability as a prerequisite for Code Acceptance and stamping. The test will be conducted in accordance with the 2001 Edition, including 2003 addenda, of the ASME Boiler & Pressure Vessel Code, Section III, Division 2, Article CC-6000 (hereinafter referred to as the ASME Code).

(2) The SIT is performed at a test pressure of at least 1.15 times the containment design pressure of 45 psig (1.15x45=51.75 psig) (357 kPag) to demonstrate the quality of construction and to verify the acceptable performance of new design features. The structural response of the system under the required maximum test pressure - measured in terms of displacements, strain (Unit 3 only) and cracking - shall be recorded and the data shall be presented in a final report.

(3) Evaluation of SIT results will be conducted in accordance with Section CC-6400 of the ASME Code using the acceptance criteria given in Section CC-6410.

(4) The SIT shall be performed using atmospheric air.

3.8.6.3.1.2 Test Parameters:

(1) Loading

(a) Pressurization/depressurization test of the RCCV

The SIT will subject the RCCV to a pressurization/depressurization sequence during which the internal pressure is increased from atmospheric pressure to the test pressure at which point pressure inside the RCCV will be held at maximum test pressure for at least 1 hour. Afterwards, the internal pressure is decreased from the maximum test pressure to atmospheric pressure. A detailed description of the test pressurization sequence is provided in Subsection 3.8.6.3.1.2(1)(c) below.

(b) Differential pressurization/depressurization of drywell and suppression chamber

The SIT will subject the drywell of the RCCV to a differential pressurization/depressurization sequence while the suppression chamber is at the atmospheric pressure. For this test, the internal pressure of the drywell is set to 25 psig (172 kPag) and held at this level for at least 1 hour.

(c) Pressurization Sequence

The pressurization/depressurization rate during the test shall not exceed 20% of the maximum test pressure per hour, or 10.35 psig per hour. The pressurization and depressurization shall be performed using a minimum of 5 pressure steps. At the end of each step, the pressure shall be held for a minimum of 1 hour to collect a full set of strains (Unit 3 only), displacements, and temperatures. Once the full SIT test pressure is obtained, the pressure shall be held for a minimum of 2 hours to perform crack mapping in addition to collecting a full set of strains (Unit 3 only), displacements, and temperatures. The same process shall be used during the depressurization phase of the test.

(2) Response

(a) Displacement

Displacement measurements shall be taken at the following locations:

(a.1) Radial displacements in the drywell: top of the drywell, mid-height of the upper drywell, and above the diaphragm floor. Radial displacements in the suppression chamber (SC): top of the SC, mid-height of the SC, and above the basemat. Measurements shall be made at a minimum of four approximately equally spaced azimuths and should be perpendicular to the containment centerline.

(a.2) Radial displacements of the containment wall adjacent to the largest opening, at a minimum of 12 points, four equally spaced on each of three concentric circles. The diameter for the inner circle shall be large enough to permit measurements to be made on the concrete rather than on the steel sleeve; the middle approximately 1.75 times the diameter of the opening; and the outer approximately 2.5 times the diameter of the opening. The change in the diameter of the opening shall be measured on the horizontal and vertical axes.

(a.3) Vertical displacement of the RCCV walls at the top of the drywell relative to the basemat-wall junction, measured at a minimum of four approximately equally spaced azimuths.

(a.4) Vertical displacement of the drywell top slab relative to the basemat near the reactor shield wall, and vertical displacement of the drywell top slab relative to the basemat at two other approximately equally spaced locations between the reactor shield wall and the primary vertical wall of the RCCV on a common azimuth.

(b) Strain (Unit 3 Only)

Per requirements of Section CC-6370 of ASME code, the Unit 3 prototype containment shall be instrumented to measure strain. Strain measuring instrumentation will be located so as to demonstrate the structural behavior of the following areas of the RCCV, at a minimum:

(b.1) the intersection of the shell and the basemat.

(b.2) near mid-height on the suppression chamber.

(b.3) near mid-height on the upper drywell.

(b.4) the vicinity of the lower drywell access tunnel at azimuth 180 deg.

(b.5) the intersection of the shell and the top slab.

(b.6) the intersection of the shell and the diaphragm floor.

(b.7) the intersection of the top slab and the drywell head.

(c) Temperature

Ambient temperature shall be measured inside and outside the RCCV. In addition, per requirements of Section CC-6380 of ASME code, for the Unit 3 prototype containment, temperatures shall be measured at all strain gage locations to establish representative temperatures for strain measurements. Temperature measurements shall be used to correct measured strain values for thermal effects.

(d) Crack mapping

Per requirements of Section CC-6350 of ASME code, concrete surface cracks shall be mapped. The patterns of cracks that exceed 0.01 inch (0.25 mm) in width and 6 inches (152 mm) in length shall be mapped at specified locations before the test, at maximum pressure, and after the test. At each location, an area of at least 40 sq ft (3.7 m^2) shall be mapped.

Locations for crack mapping will be finalized after the completion of the RCCV construction and SIT prediction analysis as well as the completion of engineering for placement of the equipment, piping, cables, and steel frame and galleries so that locations selected will:

(1) include areas with physical cracks that exceed 0.01 inch (0.25 mm) in width and 6 inches (152 mm) in length.

(2) include areas where high surface tensile strain is predicted.

(3) be easily accessed before, during, and after the SIT.

(e) Post-test examination

A post-test examination will be made within one (1) week of depressurization. Details of the post-test examination will be the same as those of the pretest examination required by CC-6210 of ASME Section III, Division 2.

3.8.6.3.2 Instrumentation:

Instrumentation for the measurement of pressure, displacement, strain (for Unit 3), crack width and length, and temperature will be provided in accordance with CC-6220 of ASME Section III, Division 2. Output of all instruments will be recorded prior to start of testing and any erratic readings corrected, if possible, or noted. All malfunctioning instrumentation will be reported to and evaluated by the Designer before proceeding with testing. Instruments that become erratic or inoperative during testing will be reported to the Designer before proceeding with testing.

Displacement, strain (for Unit 3), and temperature measurements will be made in accordance with CC-6300 of ASME Section III, Division 2. Displacement, strain, and temperature will be recorded at the locations specified in the test and instrument plan as defined in the Construction Specification. The test plan will be available prior to start of construction of the concrete containment so that sufficient time is available for placement of instrumentation to be embedded in concrete or otherwise installed during construction.

The primary containment will be pressurized and depressurized at rates not to exceed 20% of the test pressure per hour in accordance with CC-6321 of ASME Section III, Division 2.

Test data will be collected in accordance with CC-6340 of ASME Section III, Division 2. For the prototype Unit 3 Containment, strains and associated temperatures will be measured for a minimum period of 24 hours prior to the SIT to evaluate the strain variations resulting from temperature change. Concrete crack patterns will be mapped at locations specified by the Designer before the tests, at maximum pressure, and after the tests in accordance with CC-6350 of ASME Section III, Division 2. Mapped areas will include areas where high surface tensile strain is predicted.

A post-test examination will be made within one (1) week of depressurization. Details of the posttest examination will be the same as those of the pretest examination required by CC-6210 of ASME Section III, Division 2.

3.8.6.3.2.1 Equipment Description

(1) Pressurization system

(a) The pressurization system shall be able to attain and hold the maximum test pressure of 51.75 psig (357 kPag) during the pressurization/ depressurization of the RCCV and a test pressure of 25 psig (172 kPag) during the differential pressurization/depressurization of the drywell and suppression chamber.

(b) Equipment inside the RCCV that will be subject to pressure from the SIT sequence shall be prepared for the test appropriately, including potential for water vapor condensation.

(2) Data acquisition system specifications

(a) Data loggers will be used to collect data from various system components including thermometers, strain gauges, pressure gauges, and displacement transducers. Input/output measurement and control modules, multiplexers, communication interface equipment, battery backup power supplies and signal conditioning equipment shall be supplied as necessary based upon the configuration and features of the instrumentation equipment used.

(b) The data loggers shall have appropriate non-volatile on-board memory to minimize inadvertent loss of data. Sufficient data storage capacity will be provided to store data collected from all gauges during the structural integrity test without interruption.

(c) Data collected from all gauges shall have a time stamp.

(3) Specifications for instrumentation

(a) Sister bar strain gauges

Sister bar strain gauges are the preferred choice for measurement of strain in reinforcing steel.

(a.1) Sister bar strain gauges will be properly secured to the rebar cage at pre-defined locations (See Section 3.8.6.3.1.2(2)(b)) and embedded in the concrete during concrete placement. The end-to-end length of the bar segment used for the sister bar strain gauges shall be two times the development length of the sister bar plus either 4 in. or the protected length of the sister bar, whichever is greater. The sensing components shall be foil type resistance strain gauges as described below. The foil type resistance strain gauges shall be installed in a full bridge, 4-arm configuration for improved stability. The gauges shall be mounted at two locations around the circumference of the sister rebar at mid-length. The two locations shall be positioned at +180 degrees from each other. The strain gauges shall be bonded to the sister bar by strain gauge epoxy if directly attached to the rebar, or spot welded if previously encapsulated inside a stainless steel shim. The rebar surface at the location of the strain gauge attachment shall be prepared according to the strain gauge manufacturer installation requirements. A thermistor shall also be attached to the rebar, near the strain gauges, to permit the differentiation of thermally induced strains from load induced strains. The strain gauges and thermistor shall be protected against moisture and chemical and mechanical damage. Moisture protective material shall be a type used for underwater applications such as silicone. A protective coating such as polysulfide shall be applied over the water proofing material to protect the strain gauges against mechanical and chemical damages. A heat shrinkage protector shall be further applied over the protective coatings for further reinforcement. Each fabricated sister bar strain gauge shall be tested by complete water immersion for at least 24 hrs. The sister bar element shall be supplied with an appropriate cable as defined in Subsection 3.8.6.3.2.1(4) below with an appropriate length of cable such that there are no cable splices inside the concrete. In addition, when splices are required outside the concrete, all connections shall be soldered and then protected from moisture and other contamination with a suitable cable splice sealant. The cables shall be waterproofed and sealed as an integral part of the assembly.

(a.2) The foil type strain gauges shall have following characteristics:

a. Standard Range	3000 micro strain
b. Sensitivity	1 micro strain
c. Accuracy	5% of the maximum anticipated strain or 10 microstrain, whichever is greater

(b) Displacement transducer

(b.1) Linear variable displacement transducers (LVDTs) shall be used for both vertical and horizontal displacement measurements. Inside the suppression chamber submersible LVDTs shall be used for measurement locations that are below the water line.

(b.2) LVDTs shall have the following minimum characteristics:

a. Travel	Range 0.5 in
b. Output	4-20 mA
c. Minimum	Linearity ±0.30% full scale
d. Min Repeatability	±0 .015% full scale

(c) Temperature gauge

(c.1) Temperature devices shall be resistance type and shall be sealed against moisture. Thermistors used in fabrication of sister bar gauges shall have diffusivity approximately that of steel.

(c.2) Temperature sensing element shall be supplied with an appropriate cable as defined in Subsection 3.8.6.3.2.1(4) below. The cables shall be waterproofed and sealed as an integral part of the assembly.

(d) Pressure gauge

(d.1) Pressure gauges used in pressure testing shall be connected directly to the internal environment of the containment, and measure the differential pressure between the internal and external environments. This shall be accomplished either by using an absolute pressure gauge inside and another absolute gauge outside of the RCCV or by using a gauge pressure gauge directly attached to the pressurizing pump outlet outside of the RCCV right after the shut-off valve. The pressure gauges shall be voltage output (as compared to millivolt output type) with integrated signal conditioning electronics included. The pressure gauges shall be supplied with an appropriate cable as defined in Subsection 3.8.6.3.2.1(4) above. The pressure gauge cables shall be waterproofed and sealed as an integral part of the assembly.

(d.2) The pressure gauges shall have the following characteristics:

a. Range	0-200 psi
b. Accuracy	± 0.25 psi

(4) Cable specifications

Instrumentation cable type and size shall be shielded 16 AWG twisted paired for all instruments. The shield shall be either braided strands of copper (or other metal), a non-braided spiral winding of copper tape (or other metal), or a layer of conducting polymer. The shield shall be applied across cable splices. In addition, the cable shall have drain wire.

3.8.6.3.3 Evaluation of Test Results:

Crack and strain (for Unit 3) measurements will be reviewed by the Designer for evaluation of the overall test results. The primary containment will be considered to have satisfied the structural integrity test if the following minimum requirements specified in CC-6410 of ASME Section III, Division 2 are met.

(1) Yielding of conventional reinforcement does not develop as determined from analysis of crack width, strain, or displacement data.

(2) No visible signs of permanent damage to either the concrete structure or the steel liner are detected. Evidence, resulting from the test, of spalling, laminations, or voids behind the liner are pertinent considerations. Special care shall be exercised in the post-test examinations (CC-6390) to detect evidence of localized distress which may not be revealed by strain or displacement data. The significance of such distress, if detected, must be determined by the Designer and be acceptable to the Owner.

(3) Residual displacements at the point of maximum predicted radial and vertical displacement at the completion of depressurization or up to 24 hours later shall not exceed 30% of measured or predicted displacement at maximum test pressure, whichever is greater, plus 0.01in. (0.25mm) plus measurement tolerance. This criterion shall apply to the average of radial displacements measured at the same elevation.

(4) The measured displacements at test pressure at points of predicted maximum radial and vertical displacements do not exceed predicted values by more than 30% plus measurement tolerance. This criterion shall apply to the average of radial displacement measured at the same elevation. This requirement may be waived if the residual displacements within 24 hours are not greater than 20%.

If measurements and studies by the Designer indicate that the requirements of CC-6410 are not met, remedial measures will be undertaken or a retest will be conducted in accordance with CC-6430 of ASME Section III, Division 2.

3.8.6.3.4 Test Report:

The results of structural integrity tests will be submitted to the Designer. The report will meet the minimum requirements of CC-6530.

3.8.6.4 Identification of Seismic Category I Structures

The following site-specific supplement addresses COL License Information Item 3.26.

A complete list of Seismic Category I Structures, Systems, and Components can be found in Table 3.2-1, which includes the following site-specific Seismic Category I Structures:

- Ultimate Heat Sink
- Reactor Service Water Piping Tunnel
- Diesel Generator Fuel Oil Storage Vault

A description of these structures can be found in section 3H.6.

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

Table 3.8-10 ~~Staff Position on Steel Embedments~~ Not Used

~~*[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.*~~

Table 3.8-10 Staff Position on Steel Embedments (Continued) Not Used

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.

(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 specific 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.]**