RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**199-8223**
SRP Section:	**03.08.01 – Concrete Containment**
Application Section:	**03.08.01**
Date of RAI Issue:	**09/08/2015**

Question No. 03.08.01-7

Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50, provide the regulatory requirements for the design of the concrete containment. Standard Review Plan (SRP) 3.8.1, Section II.1 discusses the general information related to the internal and external attachments to the concrete containment.

In DCD Tier 2, Section 3.8.1.1.3, "Containment Shell," the applicant discussed the physical characteristics of the of the containment shell, including the attachment of the polar crane into the cylindrical wall. The staff reviewed Section 3.8.1.1.3 and noted that the additional information is needed in order to better understand how equipment such as the electrical conduit, cable tray, spray piping, etc., are attached to the inside and outside surface of the concrete containment. In accordance with GDCs 1, 2, 4, 16, and 50, and SRP 3.8.1, the applicant is requested to provide a description of how attachments to the inside and outside of the concrete containment are designed.

Response

Structural steel supports are provided for distribution systems on the containment, including the electrical conduit, cable tray, and spray system piping. The supports are welded to embedment plates on the inside and outside of the containment wall and dome. This description will be added to DCD Tier 2, Subsection 3.8.1.1.3.1 as shown in the attachment associated with this response.

Impact on DCD

DCD Tier 2, Subsection 3.8.1.1.3.1 will be revised as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

The general configuration and dimensions of the containment structure are shown in Figures 3.8-1 and 3.8-2. Local areas at the equipment hatch and two personnel airlock areas are thickened as shown in Figure 3.8-3.

The containment has the following dimensions:

a. Inside diameter of containment: 45.72 m (150 ft)

b. Inside height of containment: 76.66 m (251.5 ft) from the top of base slab to the ceiling of dome apex

c. Thickness of containment wall: 1.37 m (4 ft 6 in)

d. Dome thickness: 1.22 m (4 ft)

3.8.1.1.2 Foundation Basemat

A description of the foundation basemat is given in Subsection 3.8.5.

Appendix 3.8A shows the reinforcement details of the intersection where the containment wall intersects with nuclear island (NI) common foundation basemat.

3.8.1.1.3 Containment Shell

3.8.1.1.3.1 General

The cylindrical containment shell has a constant thickness of 1.37 m (4 ft 6 in) from the top of the foundation basemat to the springline. The shell is thickened locally around the equipment hatch, two personnel airlocks, feedwater, and main steam line penetrations. The containment reinforcing consists primarily of hoop and meridional steel. Prestressing tendons are also arranged in hoop and meridional directions. The tendons in the meridional directions extend over the dome to form an inverted "U" shape.

Structural steel supports are provided for distribution systems on the containment shell and dome, including the electrical conduit, cable tray, and spray system piping. The supports are welded to embedment plates on the inside and outside of the containment shell and dome.

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Question No. 03.08.01-8

10 CFR Part 50.44(c)(5) provides the regulatory requirements for analyzing an accident release of hydrogen generated from 100 percent fuel clad-coolant reaction accompanied by hydrogen burning. Standard Review Plan (SRP) 3.8.1, Section II.4.K and Regulatory Guide (RG) 1.216, "Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure," provide guidance for demonstrating the structural integrity of the containment in accordance with the requirements in 10 CFR 50.44.

The staff reviewed Section 3.8.1.3, "Loads and Load Combinations," of the DCD and noted that hydrogen generation pressure load due to fuel-clad and water interaction is included. However, DCD Sections 3.8.1.4 and 3.8.1.5 do not describe the design and analysis procedures, and the acceptance criteria for this loading condition. Regulatory Guide 1.216, Position 2, "Combustible Gas Control Inside Containment," states that containment should be evaluated for the pressure arising from the fuel cladding-water reaction, hydrogen burning, and post-accident inerting. In accordance with 10 CFR 50.44, SRP 3.8.1 and RG 1.216, the applicant is requested to provide a description of the design and analysis approach, and the acceptance criteria for the structural evaluation of this loading condition. If the approach is different from the criteria presented in SRP 3.8.1 and RG 1.216, then provide the technical basis for this difference.

Response

The safety of containment under the combustible gas load (P_s) condition, which includes hydrogen generation pressure load due to 100 percent fuel-clad and water interaction (P_{g1}) accompanied by hydrogen burning (P_{g2}), is assessed and demonstrated to comply with the allowable values in ASME CC-3720. In Reg. Guide 1.216, for concrete containments, the acceptance criteria are limited to demonstrating that the liner strains satisfy the Factored Load Category requirements presented in ASME Code, Section III, Division 2, Subarticle CC-3720.

Under these conditions, the loadings should not produce strains in the containment liner plate in excess of the limits established in ASME CC-3720. Allowable strains for factored loads considering membrane only are 0.005 cm/cm in compression and 0.003 cm/cm in tension. Allowable strains for factored loads considering combined membrane and bending are 0.014 cm/cm in compression and 0.010 cm/cm in tension.

The three-dimensional finite element (FE) model for safety evaluation during the combustible gas load condition is based on the structural analysis model for section design. The FE program is used for the nonlinear analysis of the containment structure. The full FE model includes the entire prestressed concrete containment structure which consists of the concrete wall and dome, the liner plate, rebars, and tendons. The solid and shell elements are used for concrete and liner plate, respectively. In addition, the rebars and tendons are modeled as truss elements. Material nonlinear models for steel and concrete are constructed on the basis of the design code and a few references. For simulating the cracking behavior of concrete, smeared crack model is adopted and the tension stiffening effect and their interaction are also taken into consideration. The steel is assumed to be a linear elasto-plastic model. The stress-strain curves for the reinforcing steel and tendons are based on the ASME code-specified minimum yield strengths. An elastic-plastic and a piece-wise linear stress-strain relationship above yield stress is used for the reinforcing steel and tendons. Based on the results of the analyses, all of the tendons and rebars are still in the elastic stage. At the maximum pressure loading level of the combustible gas load condition, the liner plate strains at the cylindrical wall base, mid-height wall, and penetration regions do not reach the allowable limit strain values.

Impact on DCD

DCD Tier2, Section 3.8.1.4.12 will be revised, as indicated in the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

The liner anchorage system is analyzed, which includes calculating the force and deflection at anchorage points. The design of the liner anchorage conforms with the force and displacement allowables in Subarticle CC-3730 of Section III of the ASME Code.

For the structural design of containment liner plates, the stresses at formworks are calculated for basemat liner, shell liner, and dome liner, respectively. The lowest ratio of allowable stress to induced stress for each part is shown in Table 3.8-12 as margins of safety for the design.

3.8.1.4.11 Ultimate Pressure Capacity

The ultimate pressure capacity (UPC) of the containment is evaluated based on the design results of the structure. The UPC is estimated based on attaining a maximum global membrane strain away from discontinuities of 0.8 percent. This strain limit is applied to the tendons, rebars, and liner. When the pressure capacity contribution is calculated from the tendons, the above-specified strain limit is applied to the full range of strain. The UPC analysis is performed considering material nonlinear behaviors for the reinforced concrete.

The stress-strain curves for the reinforcing steel and tendon are based on the code-specified minimum yield strength. An elastic-plastic and a piece-wise linear stress-strain relationship above yield stress is used for the reinforcing steel and tendon, respectively. The stress-strain curves are developed for the design basis accident temperature.

The ultimate pressure capacity of the containment is a pressure of 1.269 MPa (184 psi) at which the maximum strain of the liner plate and horizontal tendon is approximately 0.8 percent.

Combustible Gas Control Inside Containment

3.8.1.4.12 ~~Severe Accident Capability~~

~~The safety of the containment under severe accident conditions is assessed and demonstrated to conform with the allowable values in Subarticle CC-3720 of the ASME Code.~~

~~Based on the results of the analyses, all of the tendons and rebars are still in the elastic stage. At the maximum pressure loading level of the critical severe accident scenario, the~~

Section 3.8.1.4.12 is substituted as the contents on page 3 (See Page 3)

Section 3.8.1.4.12 is substituted as the contents on page 3 (See Page 3)

~~liner plate strains at the cylindrical wall base, mid-height wall, and penetration regions do not reach the limit strain of the allowable values.~~

3.8.1.4.13 Design Summary Report

A design summary report for the containment structures is presented in Appendix 3.8A where the design of representative critical sections of the structures is described.

The evaluation considering the deviations of as-procured or as-built construction to the design is performed with the acceptance criteria described in Subsection 3.8.1.5.

3.8.1.5 Structural Acceptance Criteria

The allowable stresses, strains, forces, displacements and temperatures for the containment structures including the liner are defined based on the requirements given in Article CC-3000 of the ASME Code. When the containment structure is subjected to the load combinations described in Table 3.8-2, the allowable stresses, strains, forces or displacements specified below are not exceeded in order that:

a. The containment is essentially elastic under service load conditions.

b. General yielding of the reinforcing steel does not develop under factored primary load conditions.

c. The leak-tight integrity of the liner is maintained.

The safety of containment under the combustible gas load (P_s) condition, which includes hydrogen generation pressure load due to 100 percent fuel-clad and water interaction (P_{g1}) accompanied by hydrogen burning (P_{g2}), is assessed and demonstrated to comply with the allowable values in ASME CC-3720. In Reg. Guide 1.216, for concrete containments, the acceptance criteria are limited to demonstrating that the liner strains satisfy the Factored Load
Category requirements presented in ASME Code, Section III, Division 2, Subarticle CC-3720.

Under these conditions, the loadings should not produce strains in the containment liner plate in excess of the limits established in ASME CC-3720. Allowable strains for factored loads considering membrane only are 0.005 cm/cm in compression and 0.003 cm/cm in tension. Allowable strains for factored loads considering combined membrane and bending are 0.014 cm/cm in compression and 0.010 cm/cm in tension.

The three-dimensional finite element (FE) model for safety evaluation during the combustible gas load condition is based on the structural analysis model for section design. The FE program is used for the nonlinear analysis of the containment structure. The full FE model includes the entire prestressed concrete containment structure which consists of the concrete wall and dome, the liner plate, rebars, and tendons. The solid and shell elements are used for concrete and liner plate, respectively. In addition, the rebars and tendons are modeled as truss elements. Material nonlinear models for steel and concrete are constructed on the basis of the design code and a few references. For simulating the cracking behavior of concrete, smeared crack model is adopted and the tension stiffening effect and their interaction are also taken into consideration. The steel is assumed to be a linear elasto-plastic model. The stress-strain curves for the reinforcing steel and tendons are based on the ASME code-specified minimum yield strengths. An elastic-plastic and a piece-wise linear stress-strain relationship above yield stress is used for the reinforcing steel and tendons. Based on the results of the analyses, all of the tendons and rebars are still in the elastic stage. At the maximum pressure loading level of the combustible gas load condition, the liner plate strains at the cylindrical wall base, mid-height wall, and penetration regions do not reach the allowable limit strain values.

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Question No. 03.08.01-9

10 CFR Part 50.55a provides the regulatory examination requirements of the prestressed concrete containment. Standard Review Plan (SRP) 3.8.1, Section II.7, provides guidance for testing and examining the preservice, in-service, and repair/replacement requirements of the concrete containment. DCD Tier 2, Section 3.8.1.7, "Testing and Inservice Inspection Requirements," describes the testing and in-service requirements of the containment. The staff reviewed Section 3.8.1.7 and noted that additional information is needed in order to complete the safety review procedure of the testing and in-service inspection of the concrete containment. In accordance with 10 CFR Part 50.55a, and SRP 3.8.1, the applicant is requested to explain the following:

a. DCD Tier 2, Section 3.8.1.7.1, "General Requirements," does not identify whether this containment is considered a prototype containment. DCD Tier 2, Section 3.8.1.7.1, "General Requirements," does not identify whether this containment is considered a prototype containment. It is believed that containment designed to ASME Subsection CC, incorporating new or unique design features not yet confirmed by tests are supposed to be designated as prototype containment. Thus, the applicant is requested to address whether this containment is designated as a prototype design and if not, explain why not. If it is a prototype containment, Section 3.8.1.7.1 of the DCD should be updated accordingly and explain that the additional provisions applicable to prototype containments in ASME Subsection CC, Article CC-6000 are implemented.

b. DCD Tier 2, Section 3.8.1.7 does not identify and discuss the examination requirements of the containment, including the supplemental requirements of 10 CFR 50.55a.DCD Tier 2, Section 3.8.1.7 does not identify and discuss the examination requirements of the containment, including the supplemental requirements of 10 CFR 50.55a. Thus, the applicant is requested to include this information in the DCD.

c. CD Tier 2, Section 3.8.1.7, does not identify and discuss the periodic leakage testing and examination of the containment in accordance with 10 CFR 50, Appendix J.CD Tier 2, Section 3.8.1.7, does not identify and discuss the periodic leakage testing and examination of the containment in accordance with 10 CFR 50, Appendix J. The applicant is requested to provide this information in the DCD.

d. From the information provided in Section 3.8.1.7.2 of the DCD, it is not clear to the staff whether all applicable positions of Regulator Guides (RG) 1.35 and 1.35.1 are performed for the inservice inspection of the tendon systems or whether there are any exceptions. From the information provided in Section 3.8.1.7.2 of the DCD, it is not clear to the staff whether all applicable positions of Regulator Guides (RG) 1.35 and 1.35.1 are performed for the inservice inspection of the tendon systems or whether there are any exceptions. The applicant is requested to provide this information in the DCD.

Response

a. The structural configuration of the reactor containment building (RCB) of the APR1400 is identical, with the exception of wall thickness, with that of Shin-Kori Unit 3, which has been tested and verified as a prototype. Therefore, the RCB of the APR 1400 is classified as a non-prototype containment, according to ASME Section III, Div.2, Subarticle CC-6150.

The 6 inch linear increase in wall thickness may result in different stresses, strains and displacement from Shin-Kori Units 3&4. However, inherent behavioral characteristics are not changed due to the structure's shape and composition being the same as Shin-Kori Units 3 & 4.

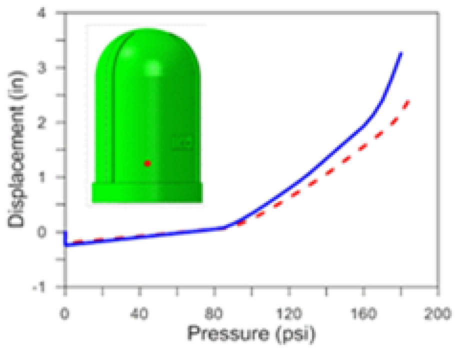
The design parameters, such as compressive strength and elastic modulus of concrete, mix design, cut-off date of material standards, and site conditions affect stress, strain, and displacement. However, these design parameters do not affect inherent structural behaviors. Therefore, those design parameters are not the principle variables used to determine whether the APR1400 RCB is a prototype or not.

As a reference, Regulatory Guide (RG) 1.18, which was withdrawn in 1981, provided the definition of prototype RCB. At present, no regulatory document clearly defines classification criteria to be used to determine if a containment is prototype. Based on RG 1.81, Revision 1 (1972), Appendix A, the following discussion is prepared to demonstrate that the APR1400 RCB is not a prototype. Review items in RG 1.81 demonstrate that changes made in the APR1400 containment should not be considered reasons to classify the RCB as a prototype.

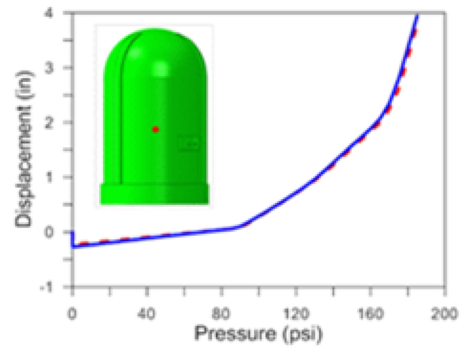
In addition, there is a comparison between APR1400 and Shin-Kori Units 3&4 under ultimate pressure. The static behavior and ultimate pressure capacity (UPC) of the APR1400 RCB under internal pressure is almost the same as those of Shin-Kori Units 3&4. The increased wall thickness affects the ultimate pressure capacity of the RCB, but the behavior of both NPP RCBs is almost the same, as shown in Figure 1.

Table 1 Review Results according to RG 1.18 Revision 1 (1972)

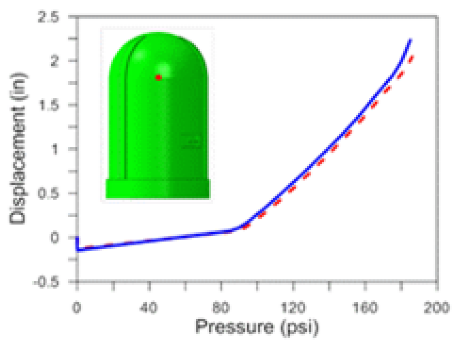
Review Items	SKN 3 Unit	APR1400 Unit	Review Result
A number of buttresses other than six	Three	Same	Non-prototype
Any buttresses in the dome	Three	Same	Non-prototype
A pattern of tendons other than vertical tendons and hoop tendons in the wall, and three groups of tendons oriented at 60 degree in the dome	240 degree	Same	Non-prototype
A prestressed dome with a shape other than ellipsoidal on top	Hemispherical	Same	Non-prototype
A base other than a conventionally reinforced flat slab	RC flat slab	Same	Non-prototype
A general containment shape different than a vertical cylinder	Cylindrical Shell	Same	Non-prototype
Individual tendons with ultimate strength greater than 500 tons	ASTM A416 Grade 270	Same	Non-prototype
An opening larger than 0.2D	Diameter of Equipment hatch & Airlock etc.	Same	Non-prototype
Two openings with a diameter greater than 0.15D separated by a distance less than 0.2D	Diameter of all penetrations	Same	Non-prototype
A connection of the cylindrical wall to the bottom slab or to the top dome by a sliding joint, a hinge, or a combination of hinge and sliding joint	All connections	Same	Non-prototype
An intermediate interior floor connected to the wall	Separation with 2 inch gap	Same	Non-prototype
Any other structural design feature that may decrease the safety margins from that of a containment confirmed by an acceptance test	UPC (Refer to Figure 1)	Margin increased	Non-prototype



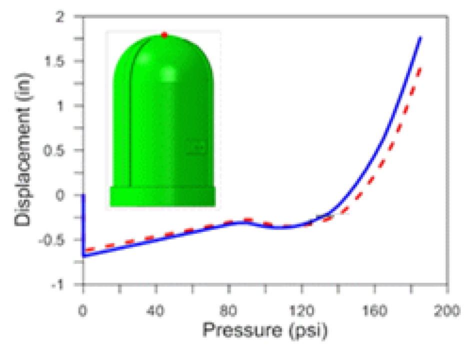
(a) Az. 45˚, EL. 109'



(b) Az. 45˚, Mid height



(c) Az. 45˚, Springline



(d) Dome Apex.

Figure 1 Radial or Vertical Displacements of RCB under Internal Pressure, Nonlinear Analysis Results for UPC Evaluation (Dot line: APR1400, Solid line: SKN34)

b. The structural integrity test (SIT) complies with the requirements of Article CC-6000 of ASME Section III. The in-service inspection (ISI) performed in accordance with the requirements of ASME Section XI, Subsection IWL, RG 1.35, RG 1.35.1 and 10 CFR 50.55a. The examination requirements of the tests will be added to DCD Tier 2, Subsections 3.8.1.7.1.1 and 3.8.1.7.2.1, as shown in the attachment associated with this response.

c. The periodic leakage rate testing of containment is described in DCD Tier 2, Subsection 6.2.6. A brief description will be added to DCD Tier 2, Subsection 3.8.1.7.2.1 as shown in the attachment associated with this response.

d. The in-service inspection (ISI) is performed in accordance with RG 1.35 and 1.35.1 with no exceptions. Applicable regulatory guides will be added to DCD Tier 2, Subsection 3.8.1.7.2.1 as shown in the attachment associated with this response.

Impact on DCD

DCD Tier 2, Subsections 3.8.1.7.1, 3.8.1.7.1.1 and 3.8.1.7.2.1 will be revised as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

and welding procedures are in accordance with Subarticle CC-4530 of ASME Section III, Division 2.

All nondestructive examination procedures are in accordance with Section V of the ASME Code.

3.8.1.7 Testing and Inservice Inspection Requirements

3.8.1.7.1 Structural Integrity Test

The structural integrity test (SIT) is performed in accordance with ASME Section III, Division 2, CC-6000 to verify the structural integrity of the containment. The test is performed after the containment is complete, including the liner, concrete structures, all electrical and piping penetrations, equipment hatch, personnel airlocks, and post-tensioning.

The pressure will be brought up to 115 percent of the containment design pressure in approximately five or more equal increments. At each pressure level, the pressure will be held constant for 1 hour prior to measuring the deflections.

~~Under the test pressure level, the crack pattern for all cracks larger than 0.254 mm (0.01 in) and longer than 150 mm (6 in) will be mapped at the locations required by the ASME Code.~~

3.8.1.7.1.1 General Requirements

Prior to operating the plant, the SIT is performed to demonstrate the structural acceptability of the primary containment.

At each pressure level, the pressure will be held constant for 1 hour to allow for the pressure and containment response to stabilize and to survey the exterior surface of the primary containment. Internal and external temperature measurements will be taken.

Pre- and post-test inspections will be performed to confirm that the concrete, liner plate, and interior structures were not damaged during the SIT.

Under each test pressure level, the crack patterns are measured in accordance with Subarticle CC-6225 of ASME Section III, Division 2. All cracks larger than 0.254 mm (0.01 in) and longer than 150 mm (6 in) will be mapped at the locations required in Subarticle CC-6350 of ASME Section III, Division 2.
Displacement of the containment is measured and evaluated in conformance with Subarticle CC-6223 and CC-6360 of ASME Section III, Division 2.

elevation. This criterion may be waived if the residual displacements within 24 hours are not greater than 10 percent.

Test results and conclusions will be documented in a separate report.

3.8.1.7.2 Inservice Surveillance

, NRC RG 1.35, NRC RG 1.35.1, and 10 CFR 50.55a

3.8.1.7.2.1 General Requirements

During the plant life, the in-service inspection of the containment is performed in accordance with the requirements of the ASME Section XI, Subsection IWL. The inservice inspection includes a visual examination of the concrete exterior surface for cracking, spalling, or grease leakage; a visual inspection of the tendon anchorage assembly of sampled tendons; a tendon lift-off test to discover damaged or broken tendon wires and to provide reasonable assurance of an acceptable prestress level during the plant life.

The containment is designed to allow access to the post-tensioning systems during in-service inspections.

The visual examination is performed for accessible areas in accordance with Subarticle IWL-2510 of ASME, Section XI. When conditions exist in accessible areas that could indicated the presence of, or result in, degradation to inaccessible ares, the acceptability of inaccessible ares will be evaluated to meet the requirements of 10 CFR 50.55a.
The examination of the post-tensioning system, including sample selection, tendon force and elongation measurements, and examination of anchorage areas meets the requirements of Subarticle IWL-2520 of ASME, Section XI.

3.8.1.7.2.2 Predic

The prediction of th

The prediction of tendon lift-off forces is determined based on the estimated prestress losses at the time of test. As a minimum, the following sources of prestress loss are considered:

a. Elastic shortening taking into consideration the sequence of stressing of the tendon

b. Creep and shrinkage of concrete

c. Stress relaxation in tendon

d. Reduction of wire cross section due to corrosion, if any

The containment leakage tests comply with 10 CFR 50, Appendix J and are performed in accordance with NEI 94-01 and ANSI/ANS 56.8. Type A, B, and C tests are described in Section 6.2.6.

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Question No. 03.08.01-10

According to 10 CFR 52.47(a)(23), applications for light-water reactor (LWR) designs shall include a description and analysis of design features for the prevention and mitigation of severe accidents. Standard Review Plan (SRP) 3.8.1, Section II.4.K and Regulatory Guide (RG) 1.216, “Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure,” provide guidance for demonstrating the structural integrity of the containment in accordance with the requirements in 10 CFR 52.47(a)(23). In accordance with RG 1.206 and RG 1.216, the description of the evaluation for containment pressure integrity under the more likely severe accident challenges is normally described in Section 19 of the applicant’s DCD. DCD Section 19.2.3.1.2, “Containment Pressure Limits” states that the containment structural integrity evaluation is described in Subsection 3.8.1.4.12.

The staff reviewed Section 3.8.1.4.12, “Severe Accident Capability,” of the DCD and noted that additional information is needed in order for the staff to complete its safety review of the containment. The staff noted that information such as a description of the severe accidents that are being evaluated, the loads that are selected, the mathematical models that are being used, analysis approach and results are not included in the application. Regulatory Guide 1.216, Position 3, “Commission’s Severe Accident Performance Goal,” describes the methods acceptable for demonstrating that the containment can maintain its role as a reliable, leak-tight barrier for approximately 24 hours following the onset of core damage. In accordance with 52.47(a)(23), SRP 3.8.1 and RG 1.216, the applicant is requested to provide a description of its severe accident analysis approach in Section 3.8.1.4.12 of the DCD, and explain how it compares to the approach described in Regulatory Guide 1.216, Position 3.

Response

The severe accident evaluation is described in DCD Tier 2, Subsection 19.2. The safety of containment under severe accident conditions is assessed and demonstrated to comply with the criteria set forth in ASME CC-3720. The containment should maintain its role as a reliable, leak-tight barrier (for example, by ensuring that containment stresses do not exceed the Factored

Load Category requirement for concrete containments) approximately 24 hours following the onset of core damage under the more likely severe accident challenges and, following this period, the containment should continue to provide a barrier against the uncontrolled release of fission products. In Reg. Guide 1.216 and SRP 3.8.1, for concrete containments, the acceptance criteria are limited to demonstrating that the liner strains satisfy the Factored Load Category requirements presented in ASME Section III, Division 2, Subarticle CC-3720.

The containment structure should be designed against the loading produced by the inadvertent full actuation of a post-accident inerting hydrogen control system, excluding seismic or design basis accident loadings. Under these conditions, the loadings should not produce strains in the containment liner plate in excess of the limits established in ASME CC-3720. Allowable strains for factored loads considering membrane only are 0.005 in compression and 0.003 in tension. Allowable strains for factored loads considering combined membrane and bending are 0.014 in compression and 0.010 in tension.

Impact on DCD

There is no impact on the DCD. The response to RAI 199-8223, Question 03.08.01-8 provides changes to the DCD section discussed in this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

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Question No. 03.08.01-11

Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50, provide the regulatory requirements for the design of the concrete containment. Standard Review Plan (SRP) 3.8.1, Section II discusses the applicable codes, standards and specifications, regulatory requirements, and regulatory guides applicable to the design of the concrete containment.

The containment structure, including the basemat directly beneath the containment is integral with the auxiliary building (AB) basemat. The staff noted that Section 3.8.1 of the DCD Tier 2 does not describe the jurisdictional boundary for design of the containment in accordance with ASME Section III, Division 2, Subsection CC. In accordance with Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50, and SRP 3.8.1, the applicant is requested to identify the jurisdictional boundary of the containment for design in accordance with ASME Section III, Division 2 Code, and describe what aspects of the design incorporates additional design requirements beyond the portion of the containment foundation directly beneath containment shell. In addition, the applicant is requested to update Section 3.8.1 of the DCD Tier 2 accordingly.

Response

APR1400 has a mat foundation of reinforced concrete referred to as nuclear island (NI) common basemat for the reactor containment building (RCB) and the auxiliary building (AB) areas. The NI common basemat has variable thickness according to the arrangement of structures, systems, and components. The thickness of the AB foundation is 10 feet, and that of the RCB varies from 23 feet to 33 feet, except for the portions of tendon gallery and reactor cavity area.

The design basis of the RCB and AB foundations conform to the requirement of ASME Section III, Division 2, Subsection CC and ACI 349 codes, respectively. The boundary of jurisdiction between the ASME and the ACI codes is as shown in Figure 1. The common basemat is divided into two parts by code jurisdiction at the thickness transition interface, and it is a logical choice based on the physical configuration and functional requirements of the basemat.

In the APR1400 design, the anchoring of the containment shell reinforcement is limited within the ASME code boundary as shown in Figures 3.8A-16 and 3.8A-17 of the DCD, and this is in accordance with the ASME code interpretation III-2-83-01.

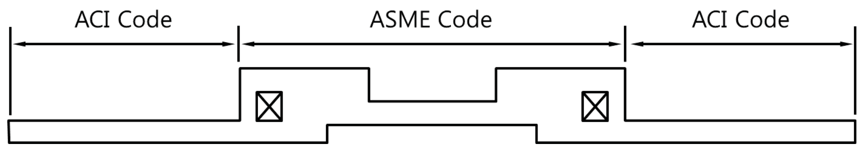


Figure 1 Jurisdictional Boundary for Design of Common Basemat

As the design criteria for the two portions of the basemat are different, the application of loads for the basemat is also divided into two parts. Figure 2 represents the application of loads based on the different code criteria. As shown in Figure 2, the load combinations provided by the ASME and the ACI codes are used in the analysis and design of the RCB and AB foundations, respectively. At the interface between the two codes, a greater amount of reinforcement required by either code is used, and the reinforcement of the RCB foundation is developed into the AB foundation as shown in Figures 3.8A-16 and 3.8A-17 of the DCD.

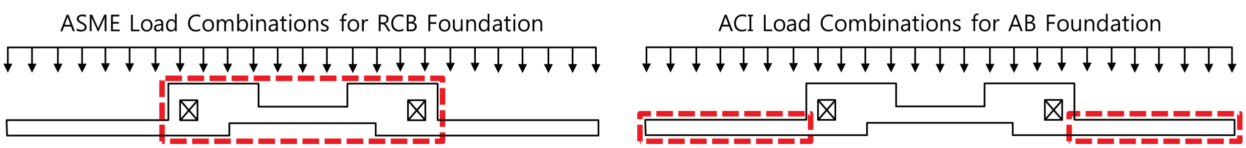


Figure 2 Application of Loads based on Code Criteria

Impact on DCD

DCD Tier 2, Subsection 3.8.1.1.2 will be revised as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

The general configuration and dimensions of the containment structure are shown in Figures 3.8-1 and 3.8-2. Local areas at the equipment hatch and two personnel airlock areas are thickened as shown in Figure 3.8-3.

The containment has the following dimensions:

a. Inside diameter of containment: 45.72 m (150 ft)

b. Inside height of containment: 76.66 m (251.5 ft) from the top of base slab to the ceiling of dome apex

c. Thickness of containment wall: 1.37 m (4 ft 6 in)

d. Dome thickness: 1.22 m (4 ft)

3.8.1.1.2 Foundation Basemat

A description of the foundation basemat is given in Subsection 3.8.5.

Appendix 3.8A shows the reinforcement details of the intersection where the containment wall intersects with nuclear island (NI) common foundation basemat.

Next Page

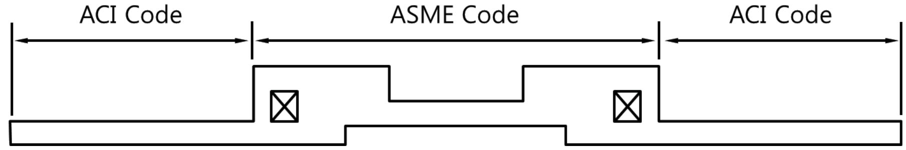
3.8.1.1.3 Containment Shell

3.8.1.1.3.1 General

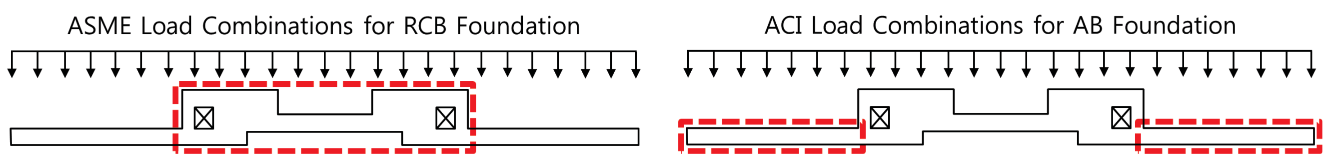
The cylindrical containment shell has a constant thickness of 1.37 m (4 ft 6 in) from the top of the foundation basemat to the springline. The shell is thickened locally around the equipment hatch, two personnel airlocks, feedwater, and main steam line penetrations. The containment reinforcing consists primarily of hoop and meridional steel. Prestressing tendons are also arranged in hoop and meridional directions. The tendons in the meridional directions extend over the dome to form an inverted "U" shape.

The design basis of the NI common basemat under the RCB and the AB conform to the requirement of ASME Section III, Division 2, Subsection CC and ACI 349, respectively. The boundary of jurisdiction between the ASME and the ACI codes is shown in Figure 3.8-26. The jurisdictional boundary is placed at the thickness transition interface due to the physical configuration and functional requirements of the basemat. The anchoring of the containment shell reinforcement is limited within the ASME code boundary as shown in Figures 3.8A-16 and 3.8A-17.

As the design criteria for the two portions of the basemat are different, the application of loads is also divided into two parts, as shown in Figure 3.8-26. The load combinations provided by the ASME and the ACI codes are used in the analysis and design of the RCB and AB foundations, respectively. At the interface between the ASME and ACI codes, a greater amount of reinforcement required by either code is used, and the reinforcement of the RCB foundation is developed into the AB foundation as shown in Figures 3.8A-16 and 3.8A-17.



Jurisdictional Boundary for Design of Common Basemat



Application of Loads based on Code Criteria

Figure 3.8-26 Code Jurisdiction Boundary of Common Basemat

Figure Added

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**199-8223**
SRP Section:	**03.08.01 – Concrete Containment**
Application Section:	**03.08.01**
Date of RAI Issue:	**09/08/2015**

Question No. 03.08.01-12

Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50, provide the regulatory requirements for the design of the concrete containment. Standard Review Plan (SRP) 3.8.1, Section II.5.A discusses the allowable limits for stresses and strains for the design of concrete containments with emphasis on the extent of compliance with Article CC-3000 of Section III, Division 2, of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code.

In DCD Section 3.8.1.5, “Structural Acceptance Criteria,” the applicant indicated that the allowable stresses, strains, forces, displacements and temperatures for the containment structure including the liner are defined based on the requirements given in Article CC-3000 of the ASME Code. The applicant’s structural acceptance criteria approach does not seem to be in accordance with SRP Section 3.8.1 II which indicates that the specified allowable limits are acceptable if they are in accordance with Subsection CC-3000 of the ASME Code, with additional guidance provided by Regulatory Guides 1.136 and 1.216 which are referenced in the SRP. Also, the staff noted that the specific acceptance criteria for service level load conditions and factored load conditions listed in Sections 3.8.1.5.1 and 3.8.1.5.2 of the DCD Tier 2 respectively are not complete.

In accordance with Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50 and SRP 3.8.1, the applicant is requested to describe in Sections 3.8.1.5.1 and 3.8.1.5.2 that the acceptance criteria identified in these two sections are supplemented by other provisions in Subsection CC-3000 of the ASME Code, with additional guidance provided by RGs 1.136 and 1.216.

Response

The structural acceptance criteria, such as allowable stresses, strains, forces, displacements and temperature, are determined in accordance with Article CC-3000 of the ASME Code, and NRC RGs 1.136 and 1.216.

The allowable stress and strain of the liner plate under severe accident conditions follows Subarticle CC-3720 of the ASME Code, in accordance with NRC RGs 1.136 and 1.216, as indicated in DCD Tier 2, Subsection 3.8.1.4.12.

Moreover, RG 1.136 Regulatory Position 5.C provides supplemental requirements for tangential shear. However, the supplemental requirements for tangential shear are not applied to the containment of the APR 1400 since there are no supplemental requirements for new prestressed concrete containments.

To clarify the description of the applicable acceptance criteria, DCD Tier 2, Subsection 3.8.1.5 will be revised as shown in the attachment associated with this response.

Impact on DCD

DCD Tier 2, Subsection 3.8.1.5 will be revised as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

liner plate strains at the cylindrical wall base, mid-height wall, and penetration regions do not reach the limit strain of the allowable values.

3.8.1.4.13 Design Summary Report

A design summary report for the containment structures is presented in Appendix 3.8A where the design of representative critical sections of the structures is described.

The evaluation considering the deviations of as-procured or as-built construction to the design is performed with the acceptance criteria described in Subsection 3.8.1.5.

3.8.1.5 Structural Acceptance Criteria

The allowable stresses, strains, forces, displacements and temperatures for the containment structures including the liner are defined based on the requirements given in Article CC-3000 of the ASME Code. When the containment structure is subjected to the load combinations described in Table 3.8-2, the allowable stresses, strains, forces or displacements specified below are not exceeded in order that:

, and NRC RG 1.136 and 1.216

a. The containment is essentially elastic under service load conditions.

b. General yielding of the reinforcing steel does not develop under factored primary load conditions.

c. The leak-tight integrity of the liner is maintained.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**199-8223**
SRP Section:	**03.08.01 – Concrete Containment**
Application Section:	**03.08.01**
Date of RAI Issue:	**09/08/2015**

Question No. 03.08.01-13

Appendix A to 10 CFR Part 50, General Design Criteria (GDC) 1, 2, 4, 16 and 50, provide the regulatory requirements for the design of the concrete containment. Standard Review Plan (SRP) 3.8.1, Section II specifies the materials for construction of concrete containments with emphasis on the extent of compliance with Article CC-2000 of Section III, Division 2, of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, with additional guidance provided in Regulatory Guide 1.136.

DCD Section 3.8.1.5.1.2, “Prestressing System,” identifies the material for the prestressing elements and in the case of the anchorage components, refers to the tendon manufacturer’s respective material specifications. However, the staff was unable to find the manufacture’s specifications for the bearing plates, anchor head assemblies, and the wedges which are part of the anchorage system Per Appendix A to 10 CFR Part 50, GDC 1, 2, 4, 16 and 50; and SRP 3.8.1, the applicant is requested to identify what manufacture tendon system is used for the design of APR1400, and if the information is not publicly available, provide the manufacturer’s technical literature on this type of tendon system, including their anchorage system.

Response

The post-tensioning system of the containment is VSL E6-42 multi-strand system using a wedge block with wedge type anchors. VSL E6-42 multi-strand system uses the same anchorage system as VSL E6-43 which is identified in the VSL data sheet available to the public. The multi-strand system employs 0.6 inch diameter, seven wire, low relaxation strand manufactured in accordance with ASTM A416, Grade 270, as described in DCD Tier 2, Appendix 3.8A, Subsection 3.8A.1.2.4.

Impact on DCD

There is no impact on DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**199-8223**
SRP Section:	**03.08.01 – Concrete Containment**
Application Section:	**03.08.01**
Date of RAI Issue:	**09/08/2015**

Question No. 03.08.01-14

Appendix A to 10 CFR Part 50, General Design Criteria (GDC) 1, 2, 4, 16 and 50, provide the regulatory requirements for the design of the concrete containment. Standard Review Plan (SRP) 3.8.1, Section II specifies the procedures used for design and analysis of the concrete containment with emphasis on the extent of compliance with Article CC-3300 of Section III, Division 2, of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, with additional guidance provided in Regulatory Guide 1.136.

DCD Tier 2, Section 3.8.1.4.5.2, “Thermal Stress Analysis,” discusses the thermal analysis of the containment and Section 3.8A.1.4.1.3.2 discusses the effects of temperature variations during normal operating and accident conditions. However, these sections do not provide the design temperatures used for normal and accident conditions. Per Appendix A to 10 CFR Part 50, GDC 1, 2, 4, 16 and 50; and SRP 3.8.1, the applicant is requested to include in the DCD the ambient temperatures inside and outside containment considered for design during normal and accident conditions. In addition, for variation of temperature through the containment thickness, provide the results of the thermal analysis showing the gradient for the various cases (normal loading and accident loading over time), and identify which ones have been used in the design of the containment.

Response

The temperatures inside and outside containment during normal and accident conditions which are considered for temperature load will be discussed in DCD Tier 2, Subsection 3.8A.1.4.1.3.3, as indicated in the attachment associated with this response.

The temperature transients result in a nonlinear temperature distribution within the concrete; results presented in this response are taken from the transient heat transfer analysis. Figure 1 shows typical temperature profiles adjacent to the liner plate after a design basis accident, and Figure 2 shows the typical temperature profiles of the containment wall, which is exposed to the atmosphere.

Deformation and stress contours for temperature loads are plotted in Figures 3 through 6, below. The most critical case among all of temperature load cases is the accident condition combined with winter ambient temperature, however all cases are evaluated.

The most critical case for the structural design is determined as convergent temperature thru the full thickness, and the time is 100,000 sec. As shown in Figure 2, the temperature gradients at 10,000 seconds and 100,000 seconds are considerable compared to the others. For the thermal stress analysis, the stress contours at 10,000 seconds and 100,000 seconds are plotted in Figure 7. The stress results differ slightly, but the differences are not significant for structural design.

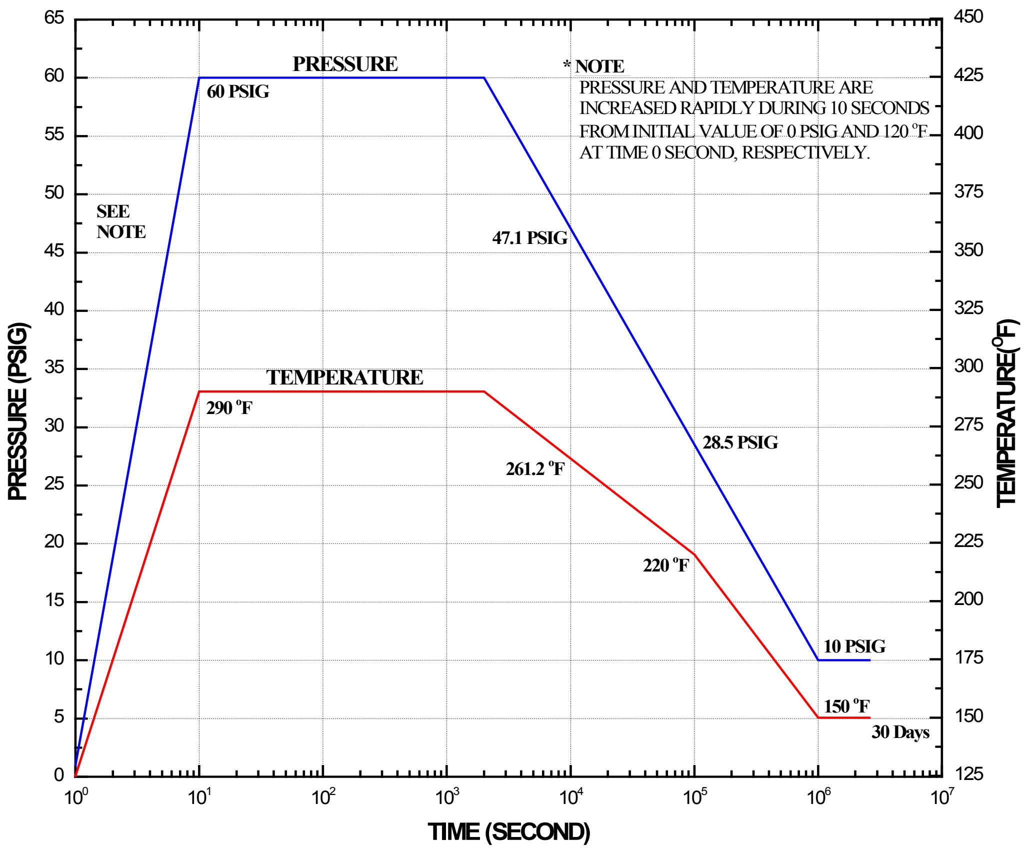
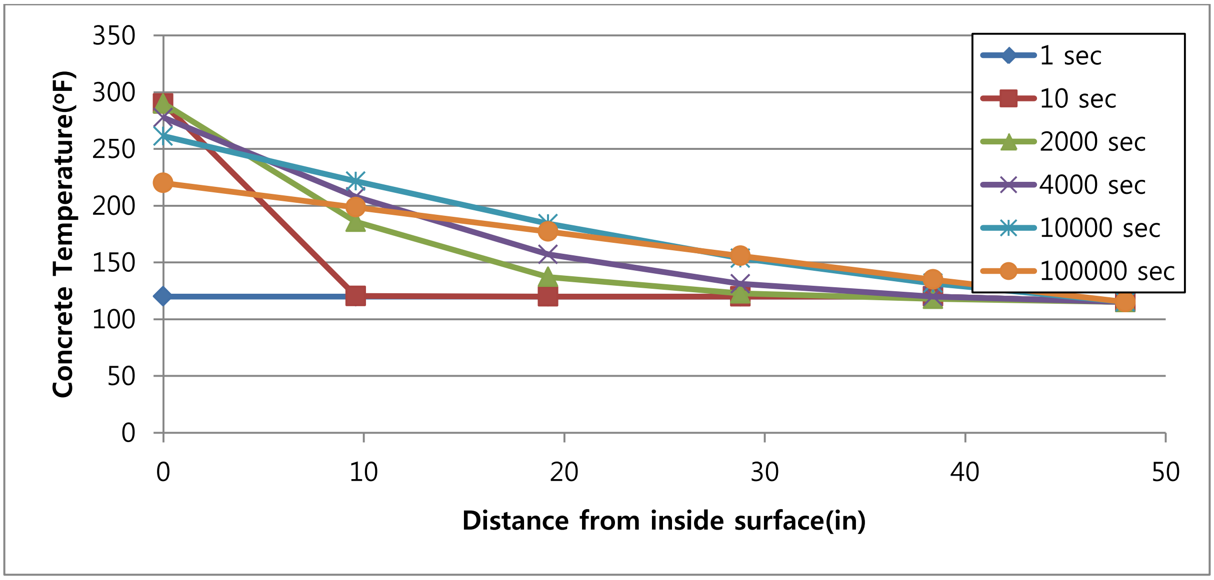
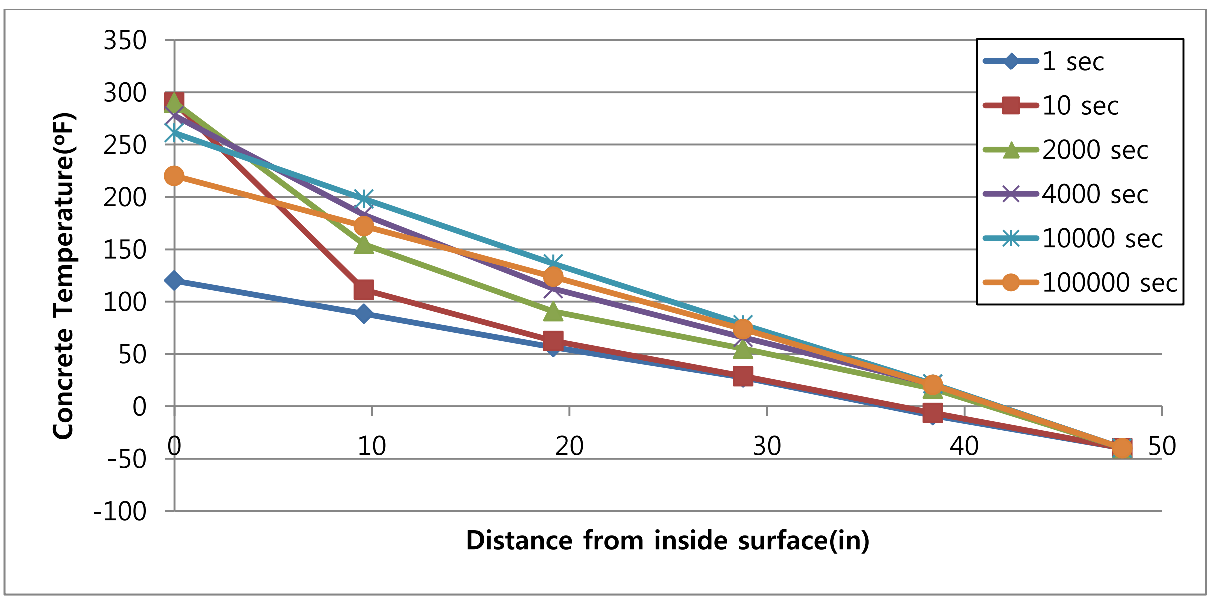


Figure 1 Containment Pressure and Temperature Profile after Design Basis Accident

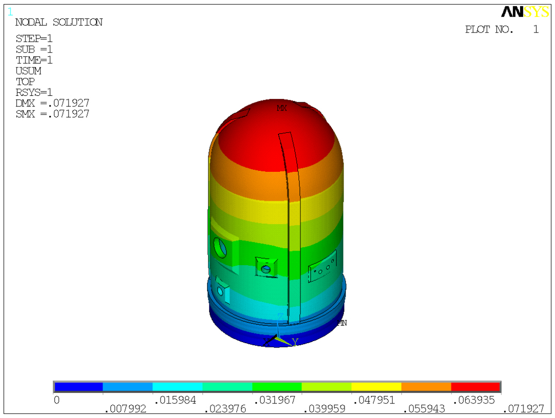


(A) Accident-Summer

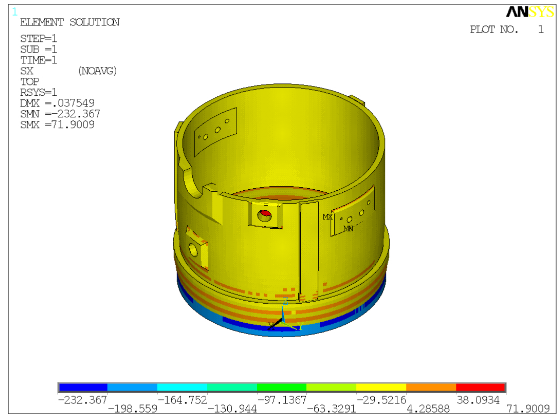


(B) Accident – Winter

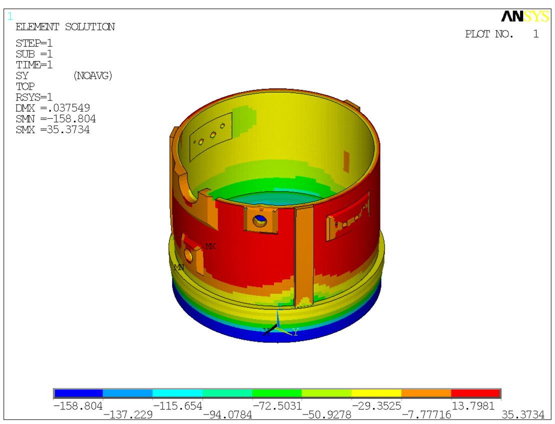
Figure 2 Temperature Profile through the Thickness



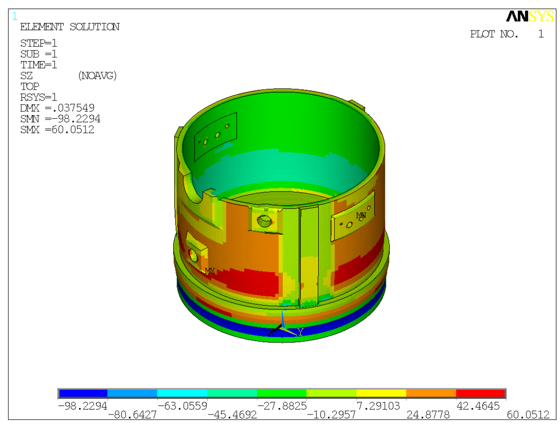
(A) Displacement



(B) Stress Contour - σ_{rr}

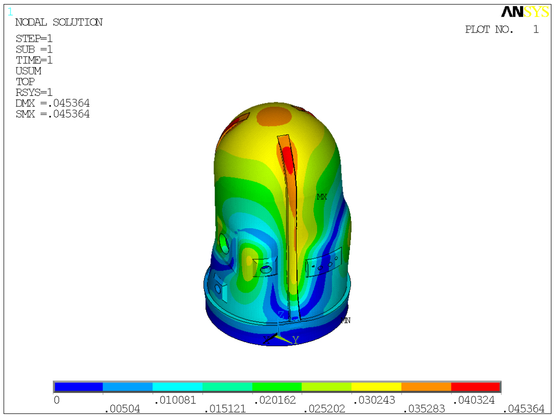


(C) Stress Contour - $\sigma_{\theta\theta}$

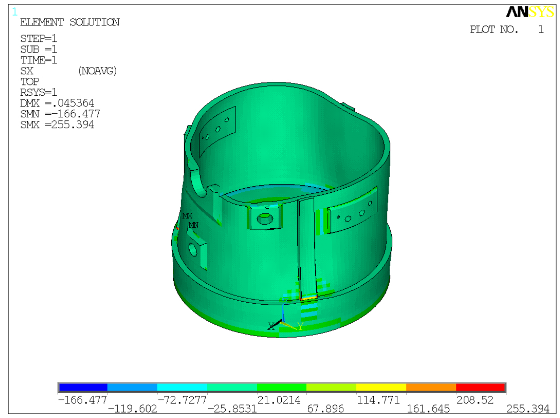


(D) Stress Contour - σ_{zz}

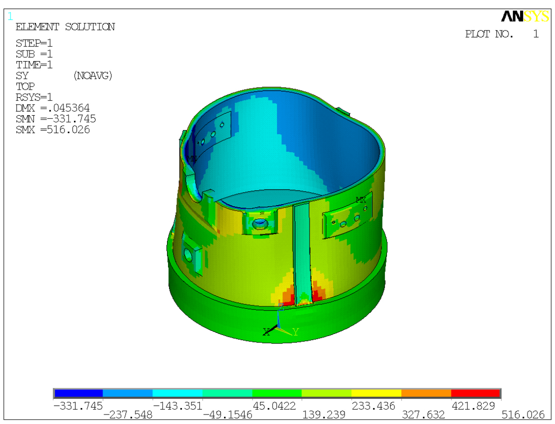
Figure 3 Deformation and Stress Contour for Temperature Load (Operating, Summer)



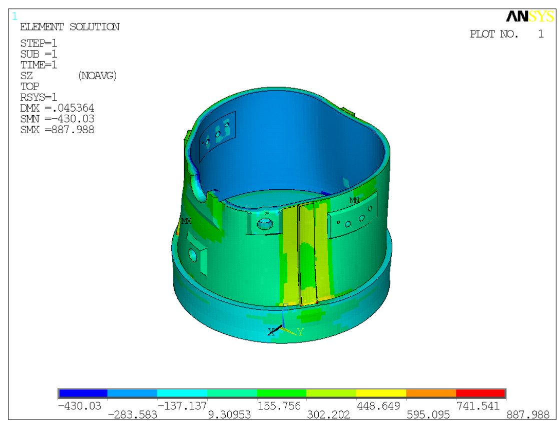
(A) Displacement



(B) Stress Contour - σ_{rr}

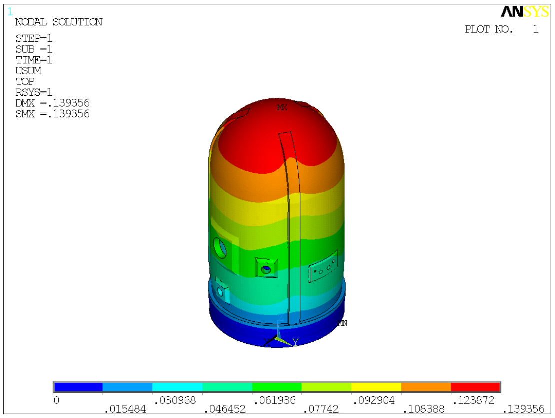


(C) Stress Contour - $\sigma_{\theta\theta}$

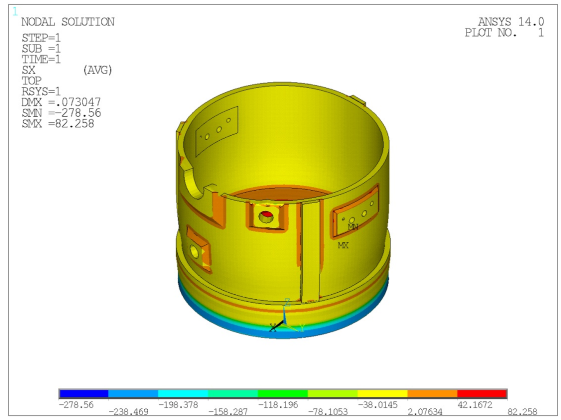


(D) Stress Contour - σ_{zz}

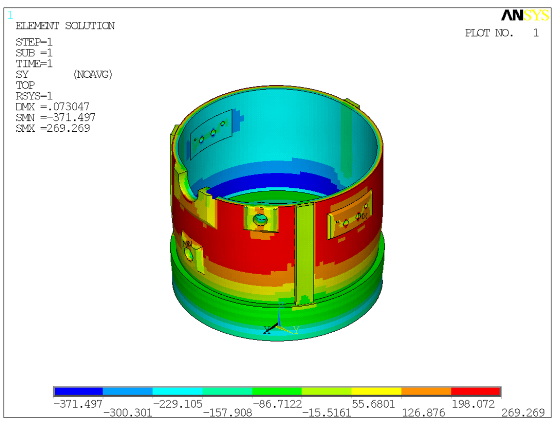
Figure 4 Deformation and Stress Contour for Temperature Load (Operating, Winter)



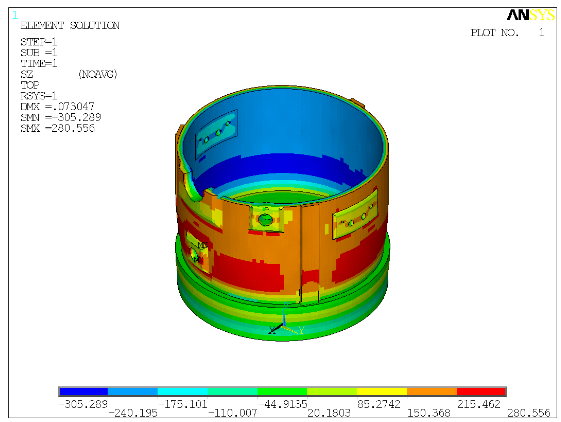
(A) Displacement



(B) Stress Contour - σ_{rr}

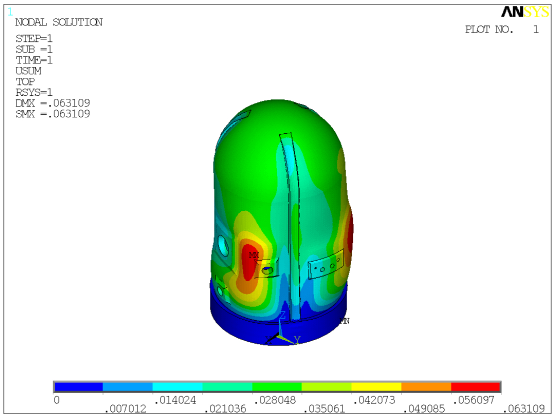


(C) Stress Contour - $\sigma_{\theta\theta}$

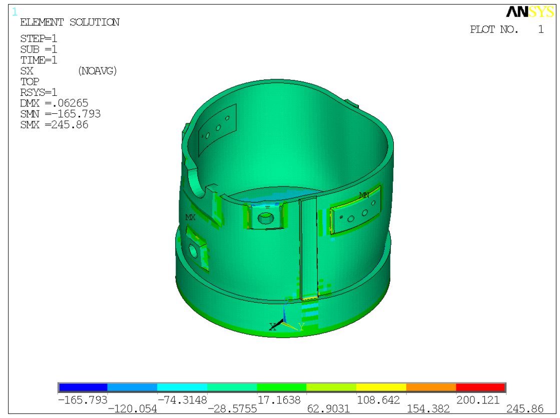


(D) Stress Contour - σ_{zz}

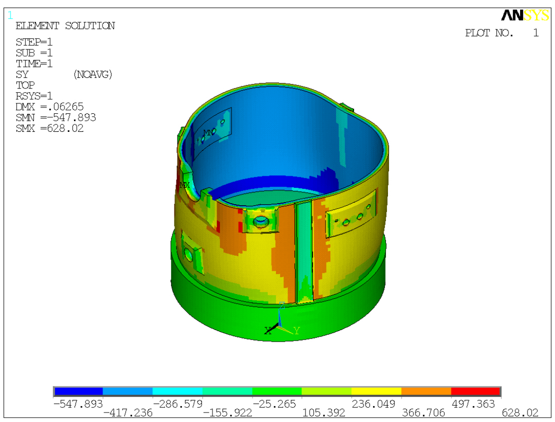
Figure 5 Deformation and Stress Contour for Temperature Load (Accident, Summer)



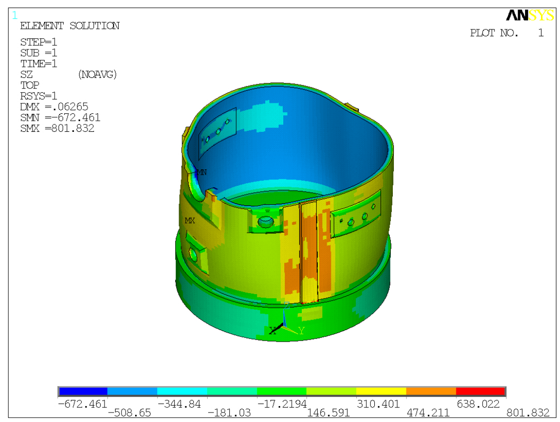
(A) Displacement



(B) Stress Contour - σ_{rr}

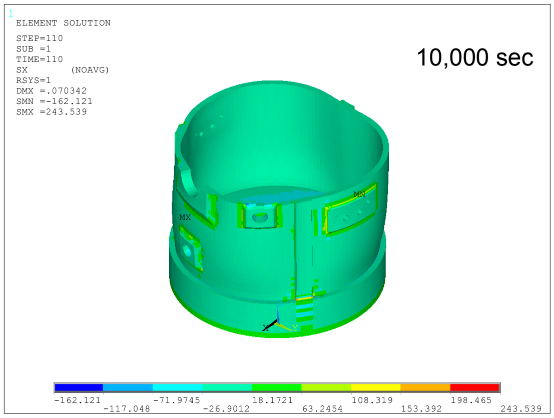


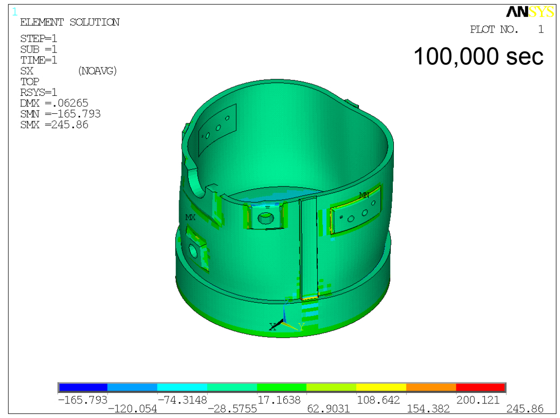
(C) Stress Contour - $\sigma_{\theta\theta}$



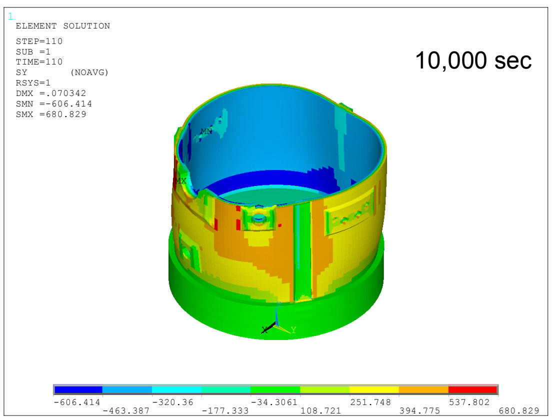
(D) Stress Contour - σ_{zz}

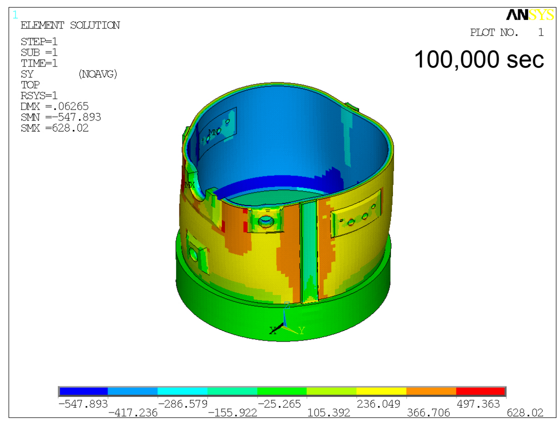
Figure 6 Deformation and Stress Contour for Temperature Load (Accident, Winter)



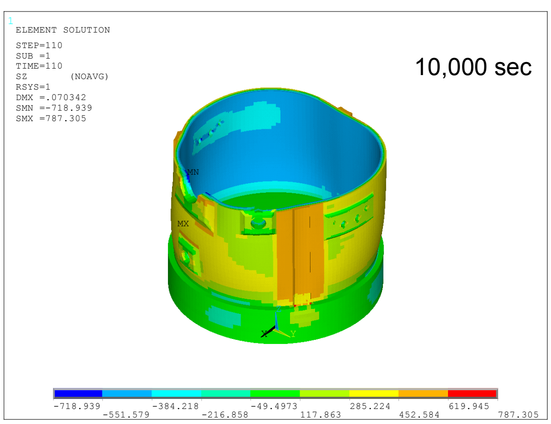


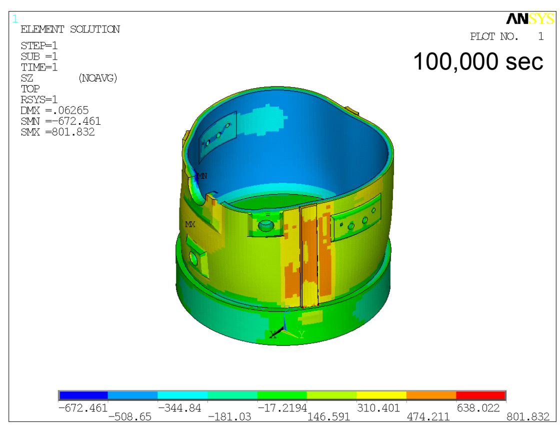
(A) Stress Contour - σ_{rr}





(B) Stress Contour - $\sigma_{\theta\theta}$





(C) Stress Contour - σ_{zz}

Figure 7 Comparison of Stress Contours for Temperature Load (Accident, Winter) – 10,000 sec vs 100,000 sec

Impact on DCD

DCD Section 3.8A.1.4.1.3.3 will be revised, as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

Internal Pressure

The design basis accident (DBA) pressure of 413.7 kPa (60 psig) is applied to the inside surface of the containment wall and dome. The structural integrity test pressure is 1.15 times the design pressure. External or internal events such as containment spray actuation can induce a negative pressure on the containment. Therefore, the containment is designed for a negative pressure of 27.6 kPa (4 psig). To consider the pressure, which acts on the equipment hatch cover and attached doors in personnel airlocks, additional point loads are applied through reference nodes, which are located at the center of the penetration holes and inside surface of concrete wall. These reference nodes control and transfer the pressure loads to the surface of the corresponding cylindrical sleeve using the RBE3 command in the ANSYS program.

Prestress

The prestress is divided into two cases. The initial prestress is used for service categories to maximize the concrete compressive stress. For factored categories, the final (effective) prestress is considered to maximize the tensile stress of the reinforcing steels. The prestress lo

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Operating Temperature
- Inside (Liner Plate) : 120.0 ˚F
- Outside (exposed area) : 115.0 ˚F / −40.0 ˚F (Summer / Winter)
- Outside (enclosed area) : 104.0 ˚F / 50 ˚F (Max. / Min.)

Accident Temperature
- Inside (Liner Plate) : 290.0 ˚F
- Outside (exposed area) : 115.0 ˚F / −40.0 ˚F (Summer / Winter)
- Outside (enclosed area) : 104.0 ˚F / 50 ˚F (Max. / Min.)

Temperature Load

The thermal effect considers temperature variations during normal operating and accident conditions combined with the worst temperature condition (summer/winter) on the outside of the containment wall and dome. During normal operation, the containment is subject to a steady-state temperature condition. The linear gradient from the steady-state heat transfer analysis is applied to the stress analysis model. The containment is subject to a rapid temperature transient in the event of a loss-of-coolant accident (LOCA). The temperature transients result in a nonlinear temperature distribution within the concrete, which comes from the results of the transient heat transfer analysis.