REVISED 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.:	**129-8085**
SRP Section:	**03.08.01 – Concrete Containment**
Application Section:	**03.08.01**
Date of RAI Issue:	**08/05/2015**

Question No. 03.08.01-2

10 CFR Part 50, Appendix A, 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.4.D discusses the approach for obtaining the concrete creep and concrete shrinkage values for the containment. DCD Tier 2, Section 3.8.1.4.6, "Creep and Shrinkage Analysis," states that the effects of concrete creep, concrete shrinkage, concrete elastic shortening, and tendon steel relaxation are included in the computations for prestress losses in the tendons. The applicant also provided values for these items. DCD Section 3.8.1.4.8 also indicates that the values are based on engineering experience. Based on the above information, it is not clear to the staff as to how the values provided were obtained. SRP 3.8.1, Section II.4.D states that creep and shrinkage values should be established by tests performed on the concrete to be used or from data obtained from completed containments with the same kind of concrete. In accordance with SRP 3.8.1, and Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50, the applicant is requested to address the following:

a. Describe in Section 3.8.1.4.6 of the DCD how the values provided were obtained.

b. DCD Section 3.8.1.4.6 describes the various parameters for prestress tendon losses but does not discuss (1) frictional loses due to curvature of the tendons and (2) slip at the anchorage. These are additional items that are identified in the ASME Code and should also be addressed in Section 3.8.1.4.6 of the DCD.

c. To understand how all of the parameters affect the prestress losses over the life of the plant and to ensure sufficient prestressing in the tendons, the applicant is requested to provide a table for each type of tendon (hoop and vertical), at the start of prestressing and at the end of life (60 years), the following: initial prestress; the actual losses in prestress (in terms of stress or percent) from all of the individual sources; total value of losses; and final prestress.

d. The staff reviewed DCD Section 3.8.1 and noted that the applicant did not provide a description of how concrete cracking is considered in the analysis and design of the concrete containment (containment shell and basemat). The applicant is requested to provide a description of the effects of concrete cracking in Section 3.8.1 of the DCD or provide a technical basis for not considering the effects of concrete cracking.

Response - (Rev. 1)

a. Concrete creep, shrinkage, and tendon relaxation coefficients for prestress losses were established based on engineering experience gained through the construction of Shin-Kori units 3&4. DCD Tier 2, Subsection 3.8.1.4.8 refers to this experience as “experience with similar construction and materials”. These values are to be evaluated and confirmed by certified material test reports (CMTRs) and concrete long-term material testing. Elastic shortening coefficients of concrete are to be computed using the static modulus of elasticity when calculating the losses of prestress. The static modulus of elasticity is also to be evaluated by concrete long-term material testing. DCD Tier 2, Subsection 3.8.1.4.8, 3.8.6 and Table 1.8-2 will be revised as shown in the attachment associated with this response.

b. There are two types of friction losses, wobble friction loss from unintended curvature and curvature friction loss from intended curvature. The two kinds of curvature in tendons induce friction loss of tensile stress. Friction losses are calculated in accordance with CC-3542 of the ASME Code and taken into account in the design of prestressing tendons. The wobble and curvature friction coefficients are determined experimentally and verified by testing while stressing tendons. Description of friction losses in tendons is presented in DCD Tier 2, Subsection 3.8.1.5.1.2. DCD Tier 2, Subsection 3.8.1.4.6 will be revised as shown in the attachment associated with this response.

   Slip at anchorage is also considered in the design of the containment post-tensioning system as described in DCD Tier 2, Subsection 3.8.1.5.2.2. Due to slipping at the anchorage, 5 percent of the maximum stress is lost at the anchor point. Thus, 95 percent of the maximum stress at the anchor point is applied to calculate the tendon stress. The value of 5 percent is provided by the supplier.

c. Tendon stresses at each design point are calculated in accordance with CC-3433 of the ASME Code to consider stress limits and CC-3542 to consider friction loss. Also, stress losses in tendons, such as creep, shrinkage of concrete, and relaxation of prestressing steel, are computed in conformance with tolerance bands in NRC Regulatory Guide 1.35.1. Calculation results are shown in Table 1 for vertical tendons and Table 2 for horizontal (hoop) tendons.

Table 1 Typical Stresses of Vertical Tendons

Stress Point	Stress in Tendon [MPa(ksi)]		Losses of Stress [MPa(ksi)]
	Initial	Final	
Anchor Point	1291.0(187.24)	1007.0(146.06)	Elastic Shortening: 23.9(3.46) Creep: 142.7 (20.70) Shrinkage: 27.8(4.03) Relaxation: 89.6(12.99) Total Loss: 284.0 (41.18)
Spring Line	1372.1(199.00)	1088.1(157.81)	
Dome Apex	1089.9(158.08)	806.0(116.90)	

Table 2 Typical Stresses of Horizontal (hoop) Tendons

Stress Point	Stress in Tendon [MPa(ksi)]		Losses of Stress [MPa(ksi)]
	Initial	Final	
Anchor Point	1291.0(187.24)	914.2(132.60)	Elastic Shortening: 37.5(5.44) Creep: 224.4(32.55) Shrinkage: 27.8(4.03) Relaxation: 87.1(12.63) Total Loss: 376.8(54.65)
Tangent Point	1300.1(188.57)	923.4(133.93)	
Midpoint of Tendon	1080.1(156.66)	703.3(102.01)	

d. Concrete cracking is considered in seismic analysis according to ASCE 43-05 as described in DCD Tier 2, Subsection 3.7.2.8.

Impact on DCD

DCD Tier 2, Subsection 3.8.1.4.6, 3.8.1.4.8, 3.8.6 and Table 1.8-2 will be revised, as shown 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.

d. Elastic modulus

1) Containment external concrete wall = 30,441.74 MPa (4.415 × 10^6 psi)

2) Containment internal concrete structure = 30,441.74 MPa (4.415 × 10^6 psi)

3) Containment concrete basemat = 27,789.38 MPa (4.031 × 10^6 psi)

4) Prestressing steel material = 193,053.20 MPa (2.8 × 10^7 psi)

e. Elastic shortening of concrete

1) Vertical direction = 124 × 10^{-6} mm/mm (in/in)

2) Horizontal direction = 194 × 10^{-6} mm/mm (in/in)

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f. Tendon relaxation = 6 %

3.8.1.4.7 Tangential Shear

The design and analysis procedures for tangential shear are in accordance with ASME Section III, Division 2 and NRC RG 1.136.

Tangential shear is resisted by the vertical reinforcement and the horizontal hoop reinforcement in the containment wall.

3.8.1.4.8 Variations in Physical Properties

gained through the construction of Shin-Kori units 3&4 in Korea

In the design and analysis of the containment, consideration is given to the effects of possible variations in the physical properties of materials on the analytical results. The properties used for analysis purposes were established based on engineering experience with similar construction and materials. The values that were used are delineated in Subsection 3.8.1.4.6. Additional reviews of materials and their effects on the analysis and design of the containment will be included in design specification development and materials selection.

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g. Friction coefficients

There are two types of friction losses, wobble friction loss from unintended curvature and curvature friction loss from intended curvature. The two kinds of curvature in tendons induce friction loss of tensile stress. Friction losses are calculated in accordance with CC-3542 of the ASME Code and taken into account in the design of the post-tensioning system. The friction coefficients are determined experimentally and verified by testing while stressing tendons.

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The values are to be evaluated and confirmed by certified material test reports (CMTRs) and concrete long-term material testing. The COL applicant is to perform concrete long-term material testing in a way which verifies physical properties of materials used during the design stage and the characters of long term deformation of concrete (COL 3.8(14)). The test results are to be reviewed by designers.

COL 3.8(7) The COL applicant is to confirm that uneven settlement due to construction sequence of the NI basemat falls within the values specified in Table 2.0-1.

COL 3.8(8) The COL applicant is to provide the necessary measures for foundation settlement monitoring considering site-specific conditions.

COL 3.8(9) The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation and to monitor groundwater chemistry.

COL 3.8.(10) The COL applicant is to provide the following soil information for the APR1400 site: 1) elastic shear modulus and Poisson's ratio of the subsurface soil layers, 2) consolidation properties including data from one-dimensional consolidation tests (initial void ratio, Cc, Ccr, OCR, and complete e-log p curves) and time-versus-consolidation plots, 3) moisture content, Atterberg limits, grain size analyses, and soil classification, 4) construction sequence and loading history, and 5) excavation and dewatering programs.

COL 3.8(14) The COL applicant is to perform concrete long-term material testing in a way which verifies physical properties of materials used during the design stage and the characters of long term deformation of concrete.

3.8.7 References

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission.

2. ASME Section III, Subsection NE, "Class MC Components," The American Society of Mechanical Engineers, the 2007 Edition with the 2008 Addenda.

3. ASME Section III, Division 2, "Code for Concrete Containments," Subsection CC, American Society of Mechanical Engineers, 2001 Edition with 2003 Addenda.

4. Regulatory Guide 1.35, "Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containment," Rev. 3, U.S. Nuclear Regulatory Commission, July 1990.

5. Regulatory Guide 1.35.1, "Determining Prestressing Forces for Inspection of Prestressed Concrete Containments," U.S. Nuclear Regulatory Commission, July 1990.

Table 1.8-2 (5 of 29)

Item No.	Description
COL 3.8(7)	The COL applicant is to confirm that uneven settlement due to construction sequence of the NI basemat falls within the values specified in Table 2.0-1.
COL 3.8(8)	The COL applicant is to provide the necessary measures for foundation settlement monitoring considering site-specific conditions.
COL 3.8(9)	The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation and to monitor groundwater chemistry.
COL 3.8(10)	The COL application is to provide the following soil information for APR1400 site: 1) Elastic shear modulus and Poisson's ratio of the subsurface soil layers, 2) Consolidation properties including data from one-dimensional consolidation tests (initial void ratio, Cc, Ccr, OCR, and complete e-log p curves) and time-versus-consolidation plots, 3) Moisture content, Atterberg limits, grain size analyses, and soil classification, 4) Construction sequence and loading history, and 5) Excavation and dewatering programs.
COL 3.9(1)	The COL applicant is to provide the inspection results for the APR1400 reactor internals classified as non-prototype Category I in accordance with RG 1.20.
COL 3.9(2)	The COL applicant is to provide a summary of the maximum total stress, deformation, and cumulative usage factor values for each of the component operating conditions for ASME Code Class 1 components except for ASME Code Class 1 nine major components. For those values that differ from the allowable limits by less than 10 percent, the contribution of each loading category (e.g., seismic, deadweight, pressure, and thermal) to the total stress is provided for each maximum stress value identified in this range. The COL applicant is to also provide a summary of the maximum total stress and deformation values for each of the component operating conditions for Class 2 and 3 components required to shut down the reactor or mitigate consequences of a postulated piping failure without offsite power (with identification of those values that differ from the allowable limits by less than 10 percent).
COL 3.9(3)	The COL applicant is to identify the site-specific active pumps.
COL 3.9(4)	The COL applicant is to confirm the type of testing and frequency of site-specific pumps subject to IST in accordance with the ASME Code.
COL 3.9(5)	The COL applicant is to confirm the type of testing and frequency of site-specific valves subject to IST in accordance with the ASME Code.
COL 3.9(6)	The COL applicant is to provide a table listing all safety-related components that use snubbers in their support systems.

COL 3.8(14) The COL applicant is to perform concrete long-term material testing in a way which verifies physical properties of materials used during the design stage and the characters of long term deformation of concrete.

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APR1400 Design Certification

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

Docket No. 52-046

RAI No.:	**129-8085**
SRP Section:	**03.08.01 –Concrete Containment**
Application Section:	**03.08.01**
Date of RAI Issue:	**08/05/2015**

Question No. 03.08.01-5

10CFR Part 50, Appendix A, GDC 16, "Containment Design," requires concrete containment to act as a leak-tight membrane to prevent the uncontrolled release of radioactive effluents to the environment. DCD Section 3.8.1.4.11, "Ultimate Pressure Capacity," states that the ultimate pressure capacity (UPC) of the containment is evaluated based on the design results of the structure. The applicant further states that the analysis for the UPC is performed considering material nonlinear behaviors for the reinforced concrete containment.

In reviewing DCD Section 3.8.1.4.11 of the application, the staff noted that additional information is needed to better understand the applicant's approach for determining the UPC of the containment. Standard Review Plan (SRP) 3.8.1, Section II.4.K discusses the regulatory criteria for determining the internal pressure capacity of the containment. SRP 3.8.1 states that the design and analysis procedure for the UPC of the containment is acceptable if performed in accordance with Regulatory Guide (RG) 1.216, "Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure."

In accordance with SRP 3.8.1, and GDC 16, the applicant is requested to provide a detailed description of the approach used to calculate the UPC of the containment identified in Section 3.8.1.4.11 of the DCD and explain how this approach compares to that described in Regulatory Position 1 of the RG 1.216.

Response - (Rev. 1)

The ultimate pressure capacity (UPC) of the prestressed concrete containment, which is for assessment of the safety margin above the design-basis accident pressure, is evaluated based on the design results (rebar arrangements) of the structure. A full three-dimensional finite element model is developed for the analysis of the concrete containment. 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, the smeared crack model is adopted and the tension stiffening effect and their interaction are also taken into consideration.

The tensile strength of concrete is not considered in the concrete model. The reinforcement in concrete structures is provided by means of rebars. With this modeling approach, the concrete behavior is considered independently of the rebars. Therefore, in the concrete modeling, tension stiffening is required in the smeared crack model to simulate load transfer across cracks through the rebar to consider the effects of the reinforcement interaction with concrete.

The steel is assumed to be a linear elasto-plastic material. 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. In the initial state of the nonlinear analysis, the containment structure is subject to dead and prestressing loads. During the UPC analysis, the internal pressure is monotonically increased until a specified failure criterion is reached. The pressure corresponding to failure criterion of the liner, rebar, and tendons is recorded. The pressure at which the first failure criterion is reached is determined to be the ultimate pressure capacity of the prestressed concrete containment.

Origionally, SRP 3.8.1 (Rev.3), which was issued in May 2010, was used to establish the criteria used to determine the UPC. The UPC was determined based on attaining a maximum global membrane strain away from discontinuities of 0.8 percent. This strain limit was applicable to all materials which contribute to resisting the internal pressure (i.e., tendons, rebars, and liner). When the UPC was evaluated based on SRP 3.8.1 (Rev.3), the UPC of the containment was a pressure of 1.269 MPa (184 psi), as currently described in Section 3.8.1.4.11 of the DCD.

Since the original analysis was performed, SRP 3.8.1 (Rev.3) was revised to Rev.4, which was issued in September 2013. In the revised SRP, it states that the design and analysis procedures for UPC are acceptable if performed in accordance with RG 1.216, which was issued in August 2010. RG 1.216 states that the UPC can be estimated based on satisfying both of the following strain limits: (1) a total tensile average strain in tendons away from discontinuities of 0.8 percent, which includes the strains in the tendons before pressurization (typically about 0.4 percent) and the additional straining from pressurization; and (2) a global free-field strain for the other materials that contribute to resist the internal pressure (i.e., liner, if considered, and rebars) of 0.4 percent. In addition, the additional failure modes, such as concrete shear and concrete crushing, which may occur near discontinuities should be considered.

In accordance with RG 1.216, the ultimate pressure capacity of the containment is a pressure of 1.089 MPa (158 psi), at which the maximum strain of the liner plate is approximately 0.4 percent. It is noted that this UPC pressure is the lowest pressure from the acceptance criteria in RG 1.216, and is determined to occur near the upper portion of the equipment hatch. At this ultimate pressure level, the maximum strains of the rebars and tendons do not reach the allowable limit strain values. In addition, with regard to the punching shear (local failure of concrete) at the near discontinuities such as equipment hatch, the shear capacity of shear rebars exceed the shear force corresponding to the ultimate pressure level. However, the concrete shear strength is neglected.

The COL applicant is to provide the detailed design results and evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, electrical and piping penetrations (COL 3.8(11)).

Impact on DCD

DCD Tier 2, Table 1.8-2 and Sections 3.8.1.4.11, 3.8.6, and 19.3.2.3.3 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

Technical report "Evaluations and Design Enhancements to Incorporate Lessons Learned from Fukushima Dai-Ichi Nuclear Accident" (APR1400-E-P-NR-14005-P/NP, Rev. 0), Sections 5.1.2.3.3.3, 5.1.2.3.4.6, 5.1.2.5.3, and Figures 5-4 and 5-5 will be revised, as indicated in the attachment associated with this response.

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.~~

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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

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The ultimate pressure capacity (UPC) of the prestressed concrete containment, which is for assessment of the safety margin above the design-basis accident pressure, is evaluated based on the design results (rebar arrangements) of the structure. A full three-dimensional finite element model is developed for the analysis of the concrete containment. 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, the smeared crack model is adopted and the tension stiffening effect and their interaction are also taken into consideration. The tensile strength of concrete does not considered in the concrete model. The reinforcement in concrete structures is provided by means of rebars, with this modeling approach, the concrete behavior is considered independently of the rebars. Therefore, in the concrete modeling, the tension stiffening is required in the smeared crack model to simulate load transfer across cracks through the rebar which consider the effects of the reinforcement interaction with concrete. 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. In the initial state of the nonlinear analysis, the containment structure is subject to dead and prestressing loads. During the UPC analysis, the internal pressure is monotonically increased until a specified failure criterion is reached. The pressure corresponding to failure criterion of the liner, rebar, and tendons is recorded. The pressure at which the first failure criterion is reached is determined to be the ultimate pressure capacity of the prestressed concrete containment.

The design and analysis procedures for determining the UPC are performed in accordance with RG 1.216, and is estimated based on satisfying both of the following strain limits: (1) a total tensile average strain in tendons away from discontinuities of 0.8 percent, which includes the strains in the tendons before pressurization (typically about 0.4 percent) and the additional straining from pressurization; and (2) a global free-field strain for the other materials that contribute to resist the internal pressure (i.e., liner, if considered, and rebars) of 0.4 percent.
The ultimate pressure capacity of the containment is a pressure of 1.089 MPa (158 psi), at which the maximum strain of the liner plate is approximately 0.4 percent. It is noted that this UPC pressure is the lowest pressure from the acceptance criteria in RG 1.216, and is determined to occur near the upper portion of the equipment hatch. In addition, the additional failure modes, such as concrete shear and concrete crushing, which may occur near discontinuities should be considered.

The COL applicant is to provide the detailed design results and evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, electrical and pipe penetrations (COL 3.8(11)).

COL 3.8(7) The COL applicant is to confirm that uneven settlement due to construction sequence of the NI basemat falls within the values specified in Table 2.0-1.

COL 3.8(8) The COL applicant is to provide the necessary measures for foundation settlement monitoring considering site-specific conditions.

COL 3.8(9) The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation and to monitor groundwater chemistry.

COL 3.8.(10) The COL applicant is to provide the following soil information for the APR1400 site: 1) elastic shear modulus and Poisson's ratio of the subsurface soil layers, 2) consolidation properties including data from one-dimensional consolidation tests (initial void ratio, Cc, Ccr, OCR, and complete e-log p curves) and time-versus-consolidation plots, 3) moisture content, Atterberg limits, grain size analyses, and soil classification, 4) construction sequence and loading history, and 5) excavation and dewatering programs.

COL 3.8(11) The COL applicant is to provide the detailed design results and evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, electrical and piping penetration.

3.8.7 References

1. 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” U.S. Nuclear Regulatory Commission.

2. ASME Section III, Subsection NE, “Class MC Components,” The American Society of Mechanical Engineers, the 2007 Edition with the 2008 Addenda.

3. ASME Section III, Division 2, “Code for Concrete Containments,” Subsection CC, American Society of Mechanical Engineers, 2001 Edition with 2003 Addenda.

4. Regulatory Guide 1.35, “Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containment,” Rev. 3, U.S. Nuclear Regulatory Commission, July 1990.

5. Regulatory Guide 1.35.1, “Determining Prestressing Forces for Inspection of Prestressed Concrete Containments,” U.S. Nuclear Regulatory Commission, July 1990.

Table 1.8-2 (5 of 29)

Item No.	Description
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COL 3.9(1)	The COL applicant is to provide the inspection results for the APR1400 reactor internals classified as non-prototype Category I in accordance with RG 1.20.
COL 3.9(2)	The COL applicant is to provide a summary of the maximum total stress, deformation, and cumulative usage factor values for each of the component operating conditions for ASME Code Class 1 components except for ASME Code Class 1 nine major components. For those values that differ from the allowable limits by less than 10 percent, the contribution of each loading category (e.g., seismic, deadweight, pressure, and thermal) to the total stress is provided for each maximum stress value identified in this range. The COL applicant is to also provide a summary of the maximum total stress and deformation values for each of the component operating conditions for Class 2 and 3 components required to shut down the reactor or mitigate consequences of a postulated piping failure without offsite power (with identification of those values that differ from the allowable limits by less than 10 percent).
COL 3.9(3)	The COL applicant is to identify the site-specific active pumps.
COL 3.9(4)	The COL applicant is to confirm the type of testing and frequency of site-specific pumps subject to IST in accordance with the ASME Code.
COL 3.9(5)	The COL applicant is to confirm the type of testing and frequency of site-specific valves subject to IST in accordance with the ASME Code.
COL 3.9(6)	The COL applicant is to provide a table listing all safety-related components that use snubbers in their support systems.

COL 3.8(11) The COL applicant is to provide the detailed design results and evaluation of the ultimate pressure capacity of penetrations, including the equipment hatch, personnel airlocks, electrical and piping penetration.

event. The technical report (Reference 5) provides the containment pressure and temperature analyses response for the full-power case with the assumed RCP seal leakage, and confirms that, during the course of the event for all phases, containment integrity is maintained.

Loss of RHR during mid-loop operation in Mode 5 is additionally assumed for the evaluation of containment capability. In this event, steam is assumed to be released from the RCS to the containment through the pressurizer manway due to the boiling of reactor coolant following the loss of RHR. The ECSBS is assumed to start spraying water into the containment atmosphere via a FLEX pump when the containment pressure reaches the UPC value of ~~12.9 kg/cm² (184 psia)~~ 11.11 kg/cm2 (158 psi). After the initial operation, the ECSBS is assumed to be intermittently operated for 2 hours whenever the containment pressure reaches the UPC value. GOTHIC analyses are performed to confirm that the containment pressure and the temperature can be controlled within the UPC limit with the ECSBS operation following the loss of RHR in mode 5.

19.3.2.3.4 Supporting Systems

To mitigate the BDBEE, the following supporting systems have also been evaluated in Reference 5:

a. Electrical system (ac power and dc power)

b. Emergency lighting

c. Communication system

d. Water sources

e. Fuel oil

The design approach meets the NEI 12-06 in meeting the N+1 approach for the FLEX equipment, and primary and alternative connection points for fluids and electrical items. Regarding the storage of robust FLEX equipment and commodities, the N+1 philosophy has been adopted for the storage housing. Reference 5 describes the requirements in detail and the necessary design changes for APR1400 to meet the industry regulations. The

In Phase 3, the primary side feedwater sources and fuel oil for the mobile GTGs are refilled from offsite resources. If the SCS is successfully restored after the 4.16 kV GTG is connected, the plant can be brought to and maintained at the cold shutdown using the SCS instead of the RCS feed-and-bleed operation.

The specific storage location, mobilization, and other details for the FLEX pumps and mobile GTGs are COL items.

5.1.2.3.3.3 Phase 3: Coping with Both Installed Plant Equipment and Offsite Resources in Addition to Onsite Equipment (after 72 hours)

In Phase 3, the 4.16 kV mobile GTG, fuel, and cooling water are available from offsite for long-term coping for the event. The 4.16 kV mobile GTG is used to restore Train A or Train B of 4.16 kV Class 1E power system. If the SCS is operable when the 4.16 kV Class 1E power is restored, the plant is cooled down to and maintained at cold shutdown by resuming the SCS operation. If not, the operator keeps the plant at the same safe shutdown state as in Phase 2, using the primary FLEX pump for RCS inventory makeup. The primary makeup water source and fuel oil for the mobile GTGs are refilled using offsite resources. In this operation mode, containment pressure increases consistently from the beginning of the event due to the mass and energy released from the RCS, but it can be maintained below ultimate pressure capacity (UPC) by operating the emergency containment spray backup subsystem (ECSBS) intermittently after reaching UPC ~~at around 3.5 days following the event~~ (see Figure 5-4). Details for the offsite resources will be provided by the COL applicant.

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5.1.2.3.4 Supporting Analysis for Core Cooling

Supporting analyses have been performed using RELAP5/Mod 3.3 to confirm the APR1400 core cooling capability to cope with the BDBEE, ELAP concurrent with LUHS, according to the FLEX strategies. Specifically, the coping capability is evaluated for the following operation modes:

- Full-power operation
- Low-power operations and shutdown conditions with SGs available
- Shutdown conditions with SGs not available

Among the above operation modes, the full-power operation is selected as a representative case for the modes 1 through 4 (power operation, startup, hot standby, and hot shutdown), and mode 5 (cold shutdown) operation with SGs available. Mid-loop operation is selected as a representative case for the mode 5 and 6 operation with SGs not available. In the full-power operation case, the RCP seal leakage is assumed to be 94.64 L/min (25 gpm) per RCP.

5.1.2.3.4.1 Acceptance Criteria

The following acceptance criteria based on the NEI 12-06, Section 3.2.1 (Reference 8) are applied to the supporting analysis for the operational strategy for core cooling during the BDBEE:

- Core cooling is maintained.
- No fuel failures occur.

The fulfillment of above criteria is determined by evaluating RCS key parameters, such as RCS and SG pressures, RCS temperature, and collapsed levels in the reactor vessel, core, and SG.

176.67 °C (350 °F) (hot shutdown) and 54.44 °C (130 °F) (cold shutdown), while the SGs are still available. If the ELAP concurrent with LUHS occurs during these operation modes, the RCS is heated up and pressurized for a period due to the loss of the SCS. If the RCS temperature is initially below the maximum RCS temperature requiring the LTOP, i.e., 136.11 °C (277 °F), the RCS pressure can be maintained below the LTOP limiting pressure of 43.94 kg/cm^{2}A (625 psia), because the LTOP relief valve installed in the SCS automatically opens at the opening setpoint (38.51 kg/cm^{2}A [530 psig]). Once the RCS temperature reaches the LTOP disable temperature (136.11 °C [277 °F]), the operator isolates the RCS from the SCS by manually closing the SCS isolation valves. The operator action for isolation of the SCS is finished before the RCS temperature exceeds the SCS entry temperature (176.67 °C [350 °F]). After that, the RCS overpressurization can be protected by POSRVs. After closing the SCS isolation valves, the RCS temperature and pressure continue to increase, and eventually return to the hot standby condition. The full-power FLEX strategy can be also applied after the plant returns to hot standby.

5.1.2.3.4.6 Analysis Results and Conclusion for Shutdown Conditions with SGs not Available

Mid-loop operation is selected as a representative case for the analysis of the mode 5 and 6 operation with SGs not available. The FLEX strategy for the mid-loop operation consists the following three phases as described in Subsection 5.1.2.3.3.

Phase 1 0 to 3 hours

Phase 2 3 to 72 hours

Phase 3 Indefinite time period following Phase 2

Based on the analysis result for the mid-loop operation case, which is the most limiting case of the shutdown operation with SGs not available, it is concluded that the decay heat can be removed by RCS inventory boiling during Phase 1. The Phase 1 period can be extended to about 4 hours, using gravity feed from two SITs, even though the Phase 1 period is determined to be 3 hours in the timeline of the FLEX strategy. In Phase 2, the plant can be maintained at cold shutdown by the RCS feed-and-bleed operation using the FLEX pump. The Phase 2 feed-and-bleed operation using an onsite water source is assumed to last for 72 hours in the timeline of the mid-loop operation FLEX strategy, but the capacity of the RWT is sufficient to extend the period of Phase 2 up to 6.4 days even if the water source is shared with SFP cooling (see Table B-3 in Appendix B). Hence, the operator has sufficient time margin for preparation of Phase 3. In Phase 3, the primary side feedwater sources and fuel oil for the mobile GTGs are refilled from offsite resources. If SCS is successfully restored after the 4.16 kV GTG is connected, the plant can be brought to and maintained at the cold shutdown using SCS instead of the RCS feed-and-bleed operation.

In this operation mode, containment pressure increases consistently from the beginning of the event due to the mass and energy released from the RCS, but it can be maintained below UPC by operating the ECSBS intermittently after reaching UPC ~~at around 3.5 days following the event~~ (see Figure 5-4).

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5.1.2.4 SFP Cooling

This subsection outlines the operational strategy to maintain the SFP water level at a safe condition throughout the BDBEE. The APR1400 SFP conditions are analyzed for a number of postulated scenarios for the ELAP event. The scenario with ELAP following a seismic event is found to be the most limiting case due to the higher SFP inventory loss.

5.1.2.4.1 Strategy for SFP Cooling

Based on the supporting analyses (see Subsection 5.1.2.4.2) to determine the bulk SFP heatup time and boiloff rate, for a worst-case full core offload, these analyses concluded the following:

a. Normally closed motor-operated valve (MOV) (fail as-is)

b. Air-operated valve (AOV) (fail closed)

c. Check valve inside containment (automatic isolation)

5.1.2.5.2 Containment Capability during Full-Power Operation

The containment design incorporates a prestressed concrete containment with a steel liner to house the nuclear steam supply system. The containment and associated systems are designed to safely withstand environmental conditions that may be expected to occur during the life of the plant, including both short-term and long-term effects following a design basis accident (DBA) and beyond DBA.

During a BDBEE, no major pipe break is postulated inside the containment, but RCP seal leakage is assumed to be at a leak rate of 94.64 L/min (25 gpm) per RCP, a total of 378.5 L/min (100 gpm) for four RCPs. The containment pressure and temperature analyses are performed using the GOTHIC (Version 8.0) computer program. The containment pressure reaches the design pressure of 5.25 kg/cm^2 A (74.7 psia) in about 63 days from the beginning of the event. The design temperature of 143 °C (290 °F) is not exceeded until 71 days following the event. Figure 5-3 provides the containment pressure and temperature responses with the assumed RCP seal leakage. Therefore, containment integrity is maintained following full-power events through all phases.

5.1.2.5.3 Containment Capability during Mode 5 Operation

Loss of residual heat removal (RHR) during mid-loop operation in mode 5 is additionally assumed for the evaluation of containment capability. In the RCS mid-loop operation, SG nozzle dams are installed on the steam generator plena and the pressurizer manway remains opened. In this event, steam is assumed to be released from the RCS to the containment through the pressurizer manway due to the boiling of reactor coolant following the loss of RHR.

Due to the mass and energy released from the RCS, containment pressure increases consistently from the beginning of the event, but it can be maintained below UPC by operating the ECSBS intermittently after reaching UPC ~~at around 83 hours~~ [Deleted]. The ECSBS is assumed to start spraying water into the containment atmosphere via a FLEX pump when the containment pressure reaches the UPC value of ~~12.9 kg/cm^2 A (184 psia)~~ [11.11 kg/cm^2 (158 psi)]. After the initial operation, the ECSBS is assumed to be intermittently operated for 2 hours whenever the containment pressure reaches the UPC value. The FLEX pump provides the flow rate of 2,839 L/min (750 gpm) and the differential pressure of at least 2.8 kg/cm^2 (40 psi) at the ECSBS nozzle. The external water source for ECSBS operation is the RWT.

GOTHIC analyses are performed for evaluation of the containment pressure and temperature responses following loss of RHR in mode 5. Figure 5-4 shows that the containment pressure reaches the UPC value in about ~~3.5 days~~ [77 hours] without ECSBS operation, but with the intermittent operation of ECSBS, containment pressure can be maintained within the UPC limit. Figure 5-5 shows that the containment temperature is maintained well below ~~185 °C (365 °F)~~ [182 °C (359 °F)], which is less than the upper limit temperature of 196 °C (385 °F) for ensuring the operability of RCS sensors.

5.1.2.6 Support Systems

5.1.2.6.1 Electrical Systems

This subsection describes the electrical strategies to support the FLEX items described above for NTTF 4.1 and 4.2.

As stated earlier, the BDBEE causes the unit to lose all ac power. The initial condition is assumed to be

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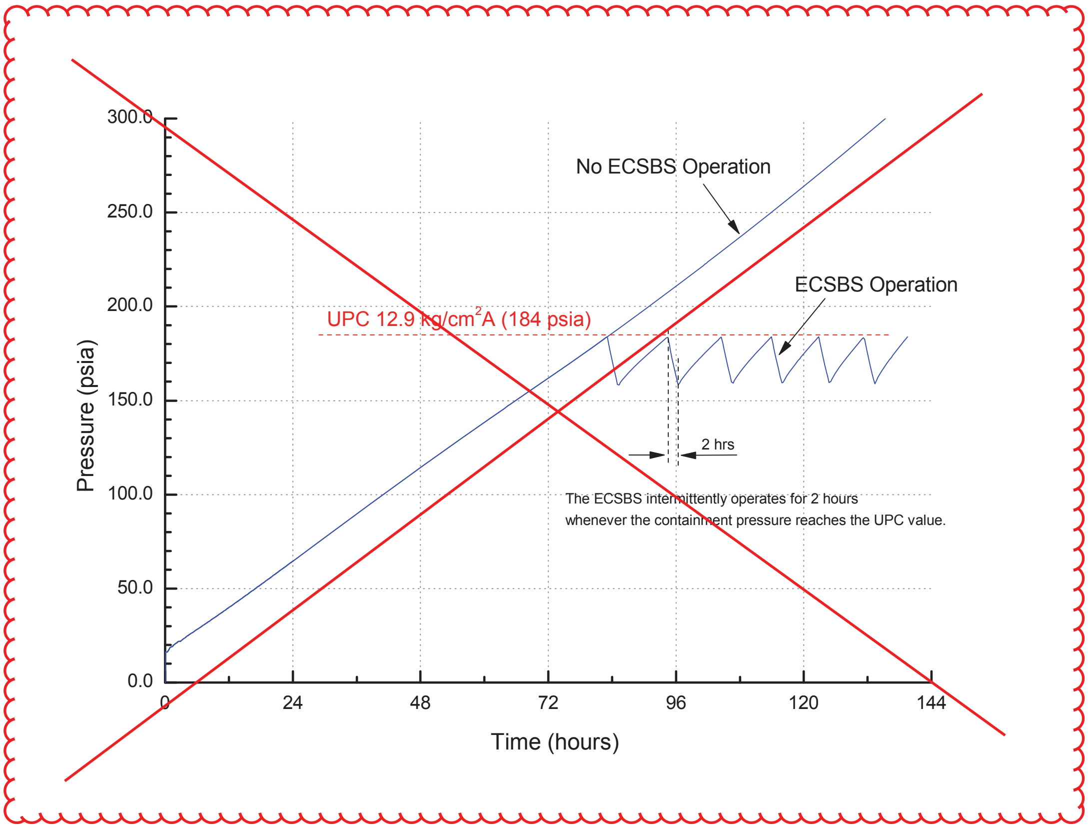

Figure 5-4 Containment Pressure for Loss of RHR (Mode 5)

A

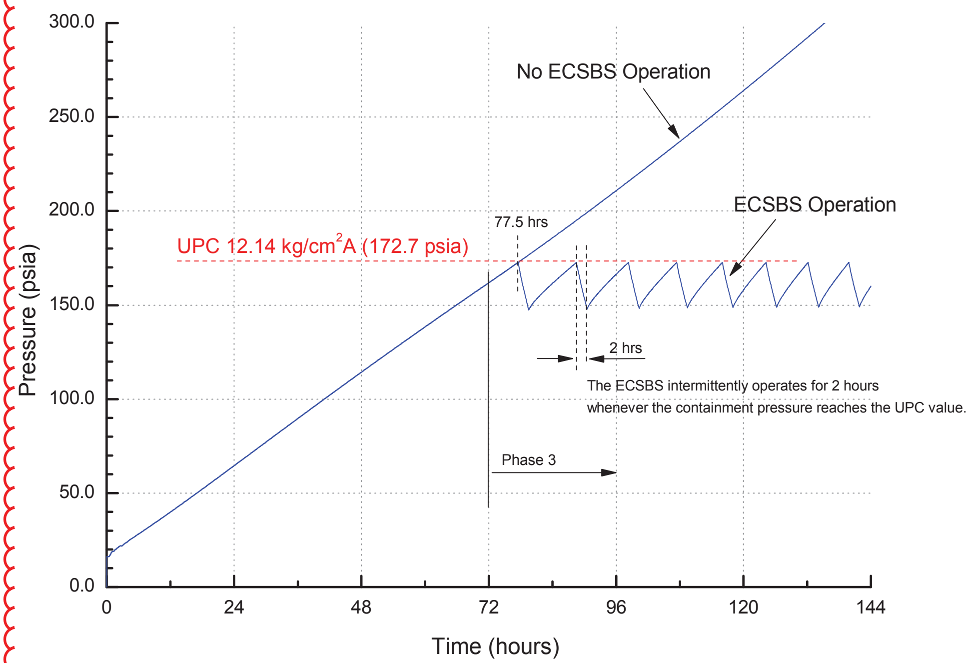

Figure 5-4 Containment Pressure for Loss of RHR (Mode 5)

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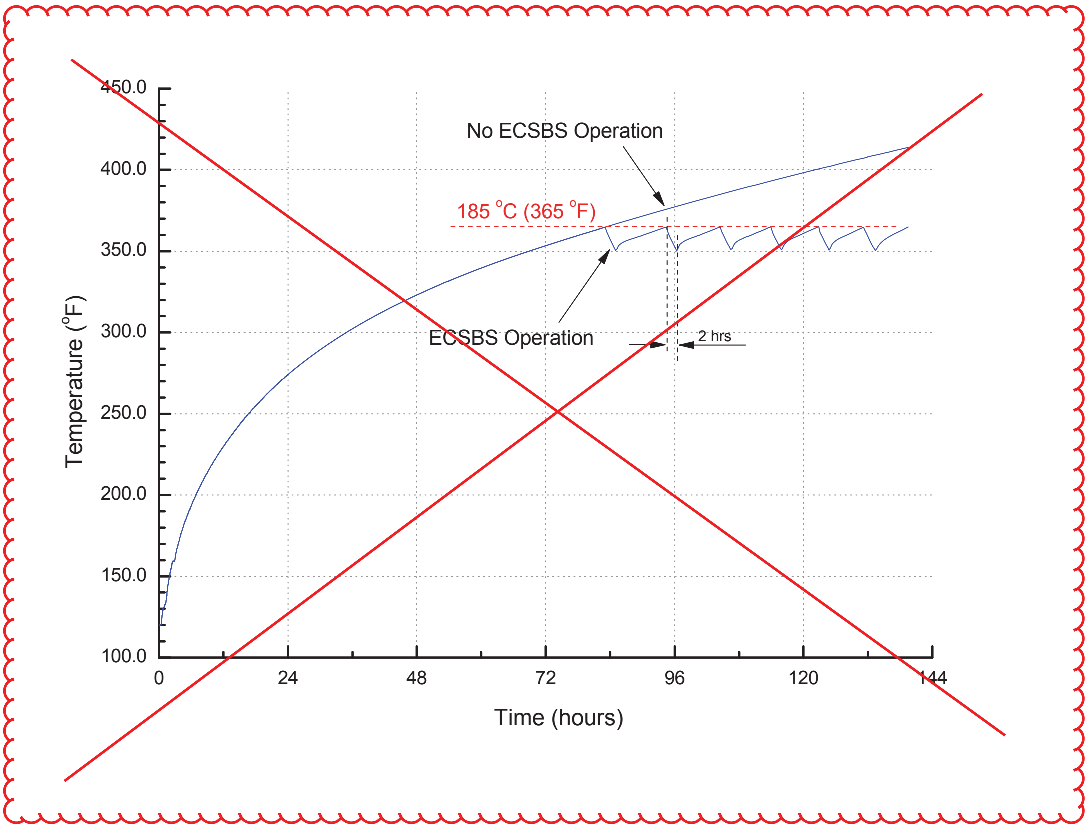

Figure 5-5 Containment Temperature for Loss of RHR (Mode 5)

B

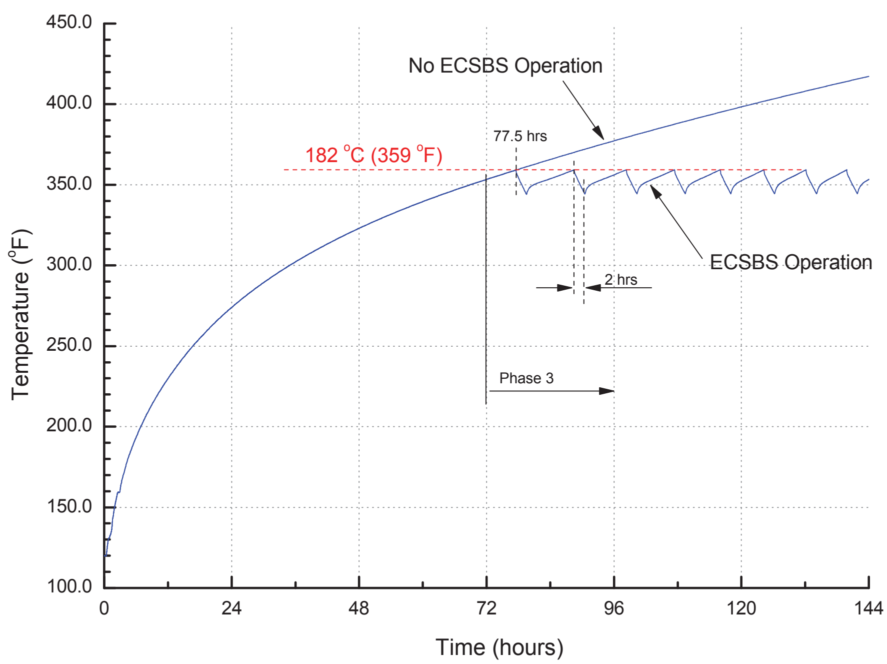

Figure 5-5 Containment Temperature for Loss of RHR (Mode 5)