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.:	**199-8223**
SRP Section:	**03.08.01 – Concrete Containment**
Application Section:	**3.8.1**
Date of RAI Issue:	**09/08/2015**

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 – (Rev. 4)

This response is limited to Regulatory Guide (RG) 1.216, Position 3, “Commission’s Severe Accident Performance Goal”.

For a description of how the application conforms to the guidance of RG 1.216, Position 1, “Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure,” please refer to the revised response to RAI 129-8085, Question No. 03.08.01-5. In the this response, the ultimate pressure capacity (UPC) of the prestressed concrete containment is described. This description includes a discussion regarding the finite element (FE) model, FE analysis method, and the acceptance criteria of RG 1.216, Position 1.

For a description of how the applicant conforms to the guidance of RG 1.216, Position 2, “Combustible Gas Control Inside Containment,” please refer to the response to RAI 199-8223, Question No. 03.08.01-8. In this response, the safety of containment under the combustible gas load (P_s) condition is described. The description includes a discussion regarding the FE model, FE analysis method, and the acceptance criteria in RG 1.216, Position 2. The detailed description of the combustible gas load is also found in the revised response to RAI 129-8085, Question No. 03.08.01-1(c). In order to avoid confusion, the title of Subsection 3.8.1.4.12 in DCD Tier 2 was changed from “Severe Accident Capability” to “Combustible Gas Control Inside Containment” in RAI 199-8223, Question No. 03.08.01-8.

A discussion regarding RG 1.216, Position 3, is as follows.

Based on RG 1.216 Regulatory Position 3.1 a, selection of accident sequences based on a Level 1 probabilistic risk assessment (PRA) study is made. The more likely severe accident sequences to be analyzed for the containment performance are selected using a combination of deterministic and probabilistic approaches. Details regarding the identification of the more likely severe accident challenges are given in response to RAI 433-8363 Question 19-71 Rev.1.

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With regard to Regulatory Position 3.1(c), the development of the finite element models of the containment uses the approach described in Regulatory Position 1 (see RAI 129-8085 Question 03.08.01-5). A similar approach was also discussed in RAI 199-8223 Question 03.08.01-8, which is related to Regulatory Position 2. As the limitations described in Regulatory Position 3.1(c), all of the material properties, based on the enveloped temperature which covers the expected accident temperatures for each severe accident scenario, is conservatively used. In addition, an event which can cause the dynamic pressure transient inside the containment, such as the global hydrogen burning due to flame acceleration and deflagration-to-detonation transition is not expected during the severe accidents. Therefore, the dynamic effects are not included in calculating the response of containment.

Consequently, the MAAP study for the selected more likely severe accident sequences indicates that the pressure build-up inside the containment is bounded by a peak pressure of 110.9 psia (LLOCA) during the 24-hour period following the onset of core damage. A constant temperature of 350°F, which bounds the transient response to a LLOCA, is conservatively employed as the temperature loading.

The maximum pressure and temperature occur after the initial 24-hours of the onset of core damage. These parameters are enveloped by the maximum pressure and temperature, which occur during the initial 24-hour period, as illustrated by the pressure curves of the three sequences (in calculation note 1-035-N389-501, Rev.4). Therefore, the containment is capable of providing a barrier against the uncontrolled release of fission products for the more likely severe accident challenges, in accordance with RG 1.216 Regulatory Position 3.2 a.

Impact on DCD

DCD Tier2, Section 19.2.4.2.2 will be revised, as indicated in the attached markup, for consistency with RAI 432-8377 Question 19-70 Rev. 3.

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 complete reaction of 100 percent of the active fuel cladding with steam. Also, the hydrogen mitigation features are assumed to be unavailable. The hydrogen was then assumed to be burned completely with no heat transfer to heat sinks in the containment with initial containment atmospheric pressure at the highest value possible that would still allow for hydrogen to burn. The maximum pressure load on the containment structure is evaluated to be 7.0 kg/cm^2 (99.8 psia) under the AICC condition. Considering the safety margin of APR1400 containment, for the FLC, the pressure resulting from 100 percent metal water reaction of fuel cladding and resulting from uncontrolled hydrogen burning is determined as 8.7 kg/cm^2 (123.7 psia).

Insert Description A at this location.

(Delete) Recall 'Results'

19.2.4.2.2 Containment Pressurization ~~Results~~

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~~Figure 19.2.3-21 shows the containment pressure response for a large-break LOCA that results in the highest containment pressure at 24 hours following the onset of core damage. For this scenario, the containment pressure does not reach 8.7 kg/cm^2 (123.7 psia) for 24 hours after the onset of core damage.~~

19.2.4.2.3 Emergency Containment Spray Backup System Performance

For a provision against a beyond-design-basis accident where either two SC pumps and two CS pumps or the IRWST is unavailable, the ECSBS is provided as an alternative to the CSS.

The ECSBS is designed to protect the containment integrity against overpressure and prevent the uncontrollable release of radioactive materials into the environment. The emergency containment spray flow path is from external water sources (the reactor makeup water tank, demineralized water storage tank, fresh water tank, or the raw water tank), through the fire protection system line via the diesel-driven fire pump, to the ECSBS line emergency connection located at ground level near the auxiliary building.

The ECSBS flow rate provides sufficient heat removal to prevent containment pressure from exceeding 8.7 kg/cm^2 (123.7 psia). In order to evaluate the performance of ECSBS, analysis is performed using the MAAP code.

Sequences are analyzed assuming that ECSBS operation began 24 hours after the onset of core damage. Figure 19.2.3-21 shows the containment pressure response following the

Description A

As described in NRC RG 1.216 (Reference 6) Regulatory Position 3, the containment should maintain its role as a reliable, leak-tight barrier for approximately 24 hours following the onset of core damage, under the more likely severe accident challenges.

Based on RG 1.216 Regulatory Position 3.1 a, selection of accident sequences based on a Level 1 probabilistic risk assessment (PRA) study is made. The more likely severe accident sequences to be analyzed for the containment performance are selected using a combination of deterministic and probabilistic approaches. The top ten dominant sequences which account for 87.6% of the cumulative core damage frequency (CDF) are selected from the Level 1 PRA results. Accident initiators of station blackout (SBO), large break LOCA (LBLOCA), small break LOCA (SBLOCA), total loss of feedwater (TLOFW), and steam generator tube rupture (SGTR) are selected for dominant sequences from the deterministic approach. These selected sequences from probabilistic and deterministic approaches account for more than 90 % of the cumulative CDF. Regarding RG 1.216 Regulatory Position 3.1 b, the selected sequences are analyzed with cavity flooding system (CFS) and emergency containment spray backup system (ECSBS) availability by using MAAP computer code.

With regard to Regulatory Position 3.1 c, the development of the finite element models of the containment uses the similar approach described in DCD Section 3.8.1.4.11 and 3.8.1.4.12. As the limitations described in Regulatory Position 3.1 c, all of the material properties, based on the enveloped temperature which covers the expected accident temperatures for each severe accident scenario, is conservatively used. In addition, an event which can cause the dynamic pressure transient inside the containment, such as the global hydrogen burning due to flame acceleration and deflagration-to-detonation transition is not expected during the severe accidents. Therefore, the dynamic effects are not included in calculating the response of containment. Based on the results of the analyses, during the severe accident sequences, the liner plate strains at the cylindrical wall base, mid-height wall, and penetration regions do not reach the allowable limit strain values of membrane only load and combined membrane and bending load.

The maximum pressure and temperature occur after the initial 24 hours of the onset of core damage. These parameters are enveloped by the maximum pressure and temperature, which occur during the initial 24-hour period. Therefore, the containment is capable of providing a barrier against the uncontrolled release of fission products for the more likely severe accident challenges, in accordance with RG 1.216 Regulatory Position 3.2 a.

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RAI 199-8223 - Question 3.8.1-10_Rev.3

RAI 199-8223 - Question 3.8.1-10_Rev.4

Description B

Based on RG 1.216 Regulatory Position 3.1 a, selection of accident sequences based on a Level 1 probabilistic risk assessment (PRA) study is made. The more likely severe accident sequences to be analyzed for the containment performance are selected using a combination of deterministic and probabilistic approaches. The represent sequences which can account for more than 90 % of the cumulative core damage frequency (CDF) are selected from the Level 1 PRA results. ~~In addition to the probabilistic approach,~~ deterministic sequences based on dominant accident initiators such as station blackout (SBO), and large break LOCA (LBLOCA), small break LOCA (SBLOCA), total loss of feedwater (TLOFW), and steam generator tube rupture (SGTR) are constructed in order to achieve a conservative accident progression.

Regarding RG 1.216 Regulatory Position 3.1 b, the selected sequences are analyzed with cavity flooding system (CFS) and emergency containment spray backup system (ECSBS) availability by using MAAP computer code. The bounding pressures and temperatures profile are then employed in the static finite element study of the containment. For the selected more likely accident sequences the highest peak pressure ~~[110.9 psia]~~ (110.9 psia) shown in Figure 19.2.3-21 does not reach the severe accident load for FLC ~~[~~8.7 kg/cm^2 (123.7 psia)~~]~~, for 24 hours after the onset of core damage.

With regard to RG 1.216 Regulatory Position 3.1 c, the three-dimensional finite element (FE) model for safety evaluation under severe accident is constructed based on the design results (rebar arrangements) of the structure. The finite element models of the containment uses the similar approach described in DCD Section 3.8.1.4.11 and 3.8.1.4.12. As the limitations described in RG 1.216 Regulatory Position 3.1 c, all of the material properties, based on the enveloped temperature which covers the expected accident temperatures for each severe accident scenario, is conservatively used. The full FE model includes the entire prestressed concrete containment structure which consists of the concrete wall and dome, liner plate, rebars, and tendons. The solid and shell elements are used for concrete and liner plate, respectively, and the rebars and tendons were modeled as truss elements. Also, the large, operating-type penetrations such as equipment hatch, personnel airlock, and main steam penetration are considered in the full FE model. An event which can cause the dynamic pressure transient inside the containment, such as the global hydrogen burning due to flame acceleration and deflagration-to-detonation transition is not expected during the severe accidents. Therefore, the dynamic effects are not included in calculating the response of containment. FE study using ABAQUS code predicts the maximum strain of liner plate considering at the cylindrical wall base, mid-height wall, and penetration regions is ~~[~~-9.128E-4~~]~~[SRI] and ~~[~~8.428E-4~~]~~[SRI] for compression and tension, respectively at LLOCA scenario. At the LOFW scenario, the maximum strain of liner plate considering at the cylindrical wall base, mid-height wall, and penetration regions is ~~[~~-9.128E-4~~]~~[SRI] and ~~[~~7.051E-4~~]~~[SRI] for compression and tension, respectively. At the SBO scenario, the maximum strain of liner plate considering at the cylindrical wall base, mid-height wall, and penetration regions is ~~[~~-9.128E-4~~]~~[SRI] and ~~[~~6.680E-4~~]~~[SRI] for compression and tension, respectively. Based on the results of the analyses, the crack penetration of concrete of containment does not occur, and all of the tendons and rebars are still in the elastic stage. Allowable strains established in ASME Code, Section III, Division 2, Subarticle CC-3720 for factored loads considering membrane only are 0.005 in compression and 0.003 in tension.

Allowable strains for factored loads considering membrane and bending are 0.014 in compression and 0.010 in tension. Based on the results of the analyses, during the severe accident sequences, the liner plate strains at the cylindrical wall base, mid-height wall, and penetration regions do not reach the allowable limit strain values of membrane only load and combined membrane and bending load.

The pressures and temperatures that occur after the initial 24 hours of the onset of core damage are enveloped by the maximum pressure and temperature, which occur during the initial 24-hour period. Therefore, the containment is capable of providing a barrier against the uncontrolled release of fission products for the more likely severe accident challenges, in accordance with RG 1.216 Regulatory Position 3.2 a.