SUPPLEMENTAL 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.:	**143-8092**
SRP Section:	**15.06.05 – Loss of Coolant Accidents Resulting Form Spectrum of Postulated Piping Breaks within the Reactor Coolant Pressure Boundary**
Application Section:	**15.06.05**
Date of RAI Issue:	**08/07/2015**

Question No. 15.06.05-1

Core Cooling during Small Break LOCA with Deep Loop Seal Design

General Design Criterion (GDC) 35, "Emergency Core Cooling," in 10 CFR Part 50, Appendix A, mandates the requirements for the emergency core cooling system (ECCS) that need to be satisfied by conforming to the ECCS acceptance criteria for light-water reactors given in 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-water Nuclear Power Reactors." 10CFR50.46(b)(1) identifies the peak cladding temperature (PCT) requirement; and 10CFR50.46(b)(5) requires that after any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time to prevent the core from being uncovered. These requirements, along with 10CFR50.46(a)(1), specify the need to calculate the ECCS cooling performance using an acceptable evaluation model for a number of postulated loss-of-coolant accidents (LOCAs) of different sizes, locations, and other properties sufficient to provide assurance that the most severe LOCAs have been evaluated.

APR1400 DCD Section 15.6.5, "Loss-of-Coolant Accidents Resulting from the Spectrum of Postulated Piping Breaks within the Reactor Coolant Pressure Boundary," and the referenced Technical Report APR1400-F-A-NR-14001-P, "Small Break LOCA Evaluation Model," describe the analysis results of the small-break LOCA (SBLOCA) evaluation and core cooling with a deep loop seal, at a high level. The applicant needs to provide the technical basis to establish that the analysis methodology and applied computer codes conservatively characterize the safety-significant phenomena of loop seal formation and clearing, and peak cladding temperature during a limiting SBLOCA, for both **the initial phase of blowdown and reflood as well as the long term cooling with potential core reheat and secondary cladding temperature rise**. The information is needed to demonstrate that the APR1400 design with a deep loop seal geometry is capable of maintaining core cooling before and after the initial loop seal clearing, and the peak cladding temperature remains within acceptable limits for the most challenging SBLOCA sizes and locations, including cold leg slot breaks.

In addition to providing the technical basis requested above, the applicant is requested to make available to staff any analysis or calculation results that demonstrate meeting the acceptance criteria and update the DCD as appropriate to ensure the analysis method and results are documented.

Response

1. The node model of RCP

The Reactor Coolant Pump (RCP) used for the APR1400 plant is described in the Reference [1]. As shown in the detail insert of the reactor coolant flow region of the pump internals in the Figure 2 of Reference [1], this pump design has a high (almost to the top of the cold leg) exit volute. Therefore, water in the cold legs cannot flow back during blowdown or reflood. However, a high exit volute has not been modeled in the CEFLASH-4AS code for APR1400 plants, this adds conservatism to the modeling by allowing the water in the cold legs to easily flow back to the loop seal region delaying the time for loop seal clearing. For this reason, the delayed loop seal clearing produces the limiting PCT (Peak Cladding Temperature) as a result.

2. The node model of Loop Seal Region

The suction legs or loop seals are modeled with two vertical control volumes (Figure 1) preserving the height and volume in the CEFLASH-4AS code for APR1400 plants.

During the initial portion of the blowdown following a small break, the cold sides of the steam generators and cold legs drain as they are nearest to the break. Upon the loss of two-phase flow, steam is vented from the steam generator side of the loop seals since the steam pressures in the upper plenum, hot legs, and steam generators are sufficient to maintain the normal flow direction.

The path is connected to the bottom of the loop seal region in the CEFLASH-4AS code for APR1400 plants, hence the loop seal clearing will be delayed until the water level reaches the bottom of the two vertical volumes. For this reason, the loop seal model of CEFLASH-4AS produces the limiting PCT (Peak Cladding Temperature).

3. Conclusion

As a result, the loop seal node model and RCP model adopted in CEFLASH-4AS for APR1400 plants under predicts the core coolant levels after loop seal clearing by delaying the clearing process during SBLOCA. Therefore, the CEFLASH-4AS code predicts a more conservative peak clad temperature.

Discussion of deep loop seal clear is provided in Reference [1] which is uploaded in the ERR.

References

1. LTR-TLA-15-037, Rev.0-A, “Evaluation of Core Cooling During Small Break LOCA for APR1400 Design”.

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Figure 1. CEFLASH-4AS DVI Line Break Nodalization

Supplemental Response

Loop Seal Reformation due to ECCS injection during the long term cooling phase of a LOCA can cause suppression of the two-phase mixture level in the reactor core. If this level drops below the top of the active fuel, cladding heatup and oxidation can occur. NRC RAI 8092 requires the PCT caused by Loop Seal Reformation should be below 800℉ in the APR1400 plants. In the previous NRC Public meeting, NRC asked for the results of Loop Seal Reformation calculation using CENPD SBLOCA methodology.

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As shown in Figure 3, loop seal reformation phenomena is occurred when loop seal mixture level reach over the top of loop seal horizontal region. It affects core mixture level decrease.

CEFLASH-4AS Break Spectrum was performed to determine the limiting cases. And Loop seal behavior in CEFLASH-4AS break spectrum is summarized simply as shown in Table 1.

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The limiting cases from break spectrum calculation were selected with below conditions.

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For the 0.044 ft^2 break, core mixture level decrease under the top of core and core uncovery is occurred as shown in dotted-circle region of Figure 4 by loop seal reformation. It causes core reheat while core is uncovered and PARCH/EM code evaluate core reheat temperature.

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Each PARCH/EM input for the selected cases from CEFLASH-4AS is prepared with the following three modifications applied to PARCH/EM base deck. The Pressure, Core Mixture, and Coolant Mass based on CEFLASH-4AS result are applied to PARCH/EM input.

PARCH input for pressure of reactor vessel is assumed higher than CEFLASH-4AS calculation result as shown in Figure 6.

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The maximum core mixture level is 12.5 ft for core uncovery as shown in Figure 6.

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Coolant mass assumed lower than CEFLASH-4AS calculation result for the conservative PCT evaluation as shown in Figure 2.

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Figure 2 Time vs. Coolant Mass (CEFLASH-4AS & PARCH/EM) – 0.044 ft^2 CL break

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As shown in Figure 8, Time vs. PCT result are described and core reheat is occurred by loop seal reformation.

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As a result, the PCTs of limiting cases for loop seal reformation are below 650℉ for the APR1400 and meet the NRC requirement.

Impact on DCD

There is no impact on the 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 Environment Report.