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.:	**430-8455**
SRP Section:	**15.06.05 – Loss of Coolant Accidents Resulting From Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary**
Application Section:	**15.6.5.2 and 15.6.5.3**
Date of RAI Issue:	**03/07/2016**

Question No. 15.06.05-22

REGULATORY BASIS

Title 10 of the Code of Federal Regulations, Part 50, Appendix A, General Design Criterion (GDC) 28—Reactivity limits requires that the reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to assure that the effects of postulated reactivity accidents can neither (1) result in damage to the reactor coolant pressure boundary greater than limited local yielding nor (2) sufficiently disturb the core, its support structures or other reactor pressure vessel internals to impair significantly the capability to cool the core. These postulated reactivity accidents shall include consideration of rod ejection (unless prevented by positive means), rod dropout, steam line rupture, changes in reactor coolant temperature and pressure, and cold water addition.

DESCRIPTION OF ISSUE

Generic Safety Issue (GSI) 185 (Control of Recriticality Following SBLOCAs) concerns the potential return to criticality following a small break LOCA due to insertion of unborated water in the core as a result of restoration of natural circulation or restart of a reactor coolant pump. The unborated water results from condensed steam from the steam generator tubes collecting in the loopseal piping. As noted in DCD, Tier 2 Table 15.0-12, GSI-185 was resolved, and consequently, no analysis was performed for the APR1400. The basis for closure was an analysis performed for an operating B&W plant which was determined to be bounding for Westinghouse and C-E plants (including the System 80+) due to unique B&W plant loopseal arrangement relative to the core.

REQUEST

Because of the higher reactor power of the APR1400 compared with the System 80+ and larger heat transfer surface area, as well as differences in loopseal volume, the staff cannot make the same qualitative conclusion for the APR1400 without an analysis. Therefore, demonstrate by analysis that a return to criticality cannot occur following a SBLOCA.

Response

ABB-CE performed Boron Dilution Analysis using CENPD methodology for System80+ and acquired the approval from the US NRC. KHNP performed Boron Dilution Analysis using the same CENPD methodology for the KNGR SSAR (APR1400 NPP) and acquired the approval from the KINS. When it comes to the RCS geometry, APR1400 is almost same as the System80+ (see the Table 15.06.05-22-1).

According to the System80+ Reactor Vessel Boron Mixing following a Small Break (Reference 1), it is assumed that the largest possible volume of unborated water is fully filled instead of performing SBLOCA analyses in order to estimate the limited volume amount of unborated water slug as a conservative approach. Therefore, the reactor power differences between the APR1400 and System 80+ caused by the heat transfer surface area of the steam generator are not related to the volume amount of unborated water slug (see the Figure 15.06.05-22-1).

As you can see the Figure 15.06.05-22-1, provided below, the assumed unborated water slug is the sum of volumes of a loop seal, a RCP and a half of the cold leg. If it is assumed that this volume will be exceeded at the level of the centerline of the cold leg, the highly borated water in the downcomer annulus will enter the loop seals through the RCP and cold leg, and then will mix with unborated water in the loop seal region. Therefore, the volume of assumed unborated water is the maximum amount of condensate that can occur for the long term after an SBLOCA. Also, the volumes of coolant (borated water) are very important to predict the results of boron dilution.

As it is shown in Table 15.06.05-22-1, the assumed unborated water slug for the APR1400 is less than the System80+, by about 6%, and also the borated water volume for the reactor vessel of the System80+ is almost the same as the APR1400. In addition, the geometry of the reactor vessel is almost same between System80+ and the APR1400. Therefore, the results of System80+ boron dilution analysis are also applicable for the APR1400.

The Generic Issue No. 185, “Control of recriticality following Small-break LOCAs in PWRs” was issued by NRR on July 7, 2000 and then Generic Safety Issue 185 was closed by NRR, Sep 23, 2005. According to the closure documentation, it is concluded that “boron dilution with restart of natural circulation is not a significant event at all Westinghouse, Combustion Engineering, and Framatome B&W reactors.” And also it is concluded that “boron dilution with restart of an RCP is not a significant event at Westinghouse and Combustion Engineering reactors”. APR1400 plant has geometry same as System80+ in terms of boron mixing phenomena. Therefore, the closure documentation of GSI-185 is also applicable for the APR1400.

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Figure 15.06.05-22-2 Assumption of unborated water volume

Table 15.06.05-22-1. Comparison of system component volumes between System80+ and APR1400

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The reactor coolant enters the inlet nozzles of the reactor vessel, flows downward between the reactor vessel wall and the core support barrel, and passes through the flow skirt section where the flow distribution is equalized, and into the lower plenum. The coolant then flows upward through the core, removing heat from the fuel rods. Generally, the temperature of unborated water slug is higher than the temperature of downcomer inventory due to the cold ECCS water by SIP or SIT. After initiating natural circulation or restarting one RCP, the unborated water slug in the loop seal region start to mix with inventory of pump discharge leg volume and then move into downcomer region. The cold unborated water slug cannot easily penetrate the cold downcomer inventory caused by the buoyancy effect. Therefore, mixing is occurring actively in this region. But mixing in this region is not considering in the mixing calculation conservatively.

The flow skirt is used to reduce inequalities in core inlet flow distributions and to prevent formation of large vortices in the lower plenum. The flow skirt is supported by nine equally spaced machined sections that are welded to the bottom head of the reactor vessel. The flow holes are designed on the lower support structure bottom plate and the flow skirt to function as an orifice that stabilizes the flow and contributes to the uniform flow distribution at the core inlet. The flow skirt is a perforated plate installed at the entrance to the lower plenum from the downcomer. Due to the design feature, this equipment promotes flow mixing significantly to distribute flow from the downcomer to the core uniformly. Therefore, assumption of fully mixing in the lower plenum region is reasonable for mixing calculation. The detail information of flowskirt is described in section 3.9.5.1.3 of DCD.

- **Natural Circulation case**

According to the PKL test, the natural circulation phenomena does not occur simultaneously in the four loop. And also, the boron concentration of unborated slug volume is higher than 50 ppm. Actually, the unborated water will mix actively in the cold leg region, downcomer region, and flow skirt. Here, it may be assumed that unborated water will be mixed completely with borated water in the lower plenum region instead of no mixing assumption in the cold leg region, downcomer region, and flow skirt region. The delivered unborated water can be mixed completely in the reactor vessel region.

The unborated water is mixed to the borated water in reactor vessel passing through flow skirt and lower plenum structure. The downcomer region is excluded conservatively in this calculation.

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- **RCP restart case**

The unborated water is mixed to the borated water in reactor vessel passing through flow skirt and lower plenum structure. The downcomer region is excluded conservatively in this calculation.

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In conclusion, the core remains subcritical when boron dilution accident occurred during small break LOCA. The analysis results have shown that the minimum boron concentration is higher than the critical boron concentration from the mixing calculation. Therefore, it is demonstrated that the core remains subcritical and adequately cooled for the APR1400.

Reference

1. 00000-FS-C-209, System80+ Reactor Vessel Boron Mixing Following a Small Break LOCA Assuming Restart of One RCP, C.B. Martin, 4/5/94
2. APR1400 Nuclear Engineering Data (FS-DD012, NE-DD012, ME-DD210)

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.