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.:	**17-7917**
SRP Section:	**15.04.06 – Inadvertent Decrease in Boron Concentration in the Reactor Coolant (PWR)**
Application Section:	**15.4.6**
Date of RAI Issue:	**05/26/2015**

Question No. 15.04.06-1

10 CFR Part 50 Appendix A, GDC 10 requires that the reactor core and associated coolant, control and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded. For an inadvertent reactor coolant system (RCS) boron dilution event, KHNP needs to demonstrate that the system (in this case the alarms and operator response times) has appropriate design margin to assure the SAFDLs are not violated for anticipated operational occurrences (AOOs). The SRP 15.4.6 acceptance criteria for operator action times are 30 minutes during refueling and 15 minutes for all other modes of operation. DCD Section 15.4.6.3.1 calculates the time to criticality assuming complete mixing of the RCS. In Modes 4 and 5 when all reactor coolant pumps (RCPs) are idle and with one shutdown cooling (SDC) train in service (Technical Specifications 3.4.6, 3.4.7 and 3.4.8) the flow rate may not be sufficient to assume complete RCS mixing. Provide a justification that the complete mixing model is conservative including any potential effects of incomplete lower plenum mixing and the corresponding effect on the time to criticality.

Also, demonstrate that the source range detectors, which provide input to the boron dilution alarm system (BDAS) alarm, can sense any postulated incomplete mixing and still preserve adequate operator action times (e.g., 15 minutes in Modes 1 through 5) and update the DCD as appropriate.

Response

The CFX code has been used to determine the degree of the lower plenum mixing during an inadvertent reactor coolant system boron dilution event. Computational fluid dynamics (CFD) has been shown to adequately predict dilution in the comparison report of NEA/CSNI/R(2000)22, March 2001, “International Standard Problem (ISP) No. 43, Rapid Boron-Dilution Transient Tests for Code Verification” and CFX also has been benchmarked against ISP-43 in this report.

Based on the ISP-43 comparison report, the boron mixing simulation of APR1400 lower plenum was performed using ANSYS CFX Version 15.0. The major numerical methodology for the ISP-43 and APR1400 plant calculation is summarized in Table 1. Geometry and mesh of the numerical model of the APR1400 reactor vessel are shown in Figure 1, 2 and 3. For this simulation, downcomer, cold-leg, DVI nozzle, flow skirt, lower support structure, and lower support structure bottom plate are precisely modeled. For mesh configuration, the total number of elements is [ ]TS and the first layer thickness is [ ]TS.

For this analysis, it was conservatively assumed that the shutdown cooling system is not operated and only 180gpm cold and deborated water is injected into the RCS from the charging line.

Initial conditions and boundary conditions are summarized below:

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Including the thermal mixing, the boron transport was calculated in this simulation by using the multicomponent fluid model of the CFX code.

The purpose of this simulation is to compare between average boron concentration and minimum boron concentration at the exit of the lower plenum to understand the degree of mixing in the lower plenum. The average and minimum values of boron concentration at the exit of the lower plenum are summarized in Table 2 and a cross-sectional view of the boron concentration distribution at the exit of the lower plenum is shown in Figure 4. As shown in Table 2 and Figure 4, the deborated water is well mixed through the downcomer, flow-skirt and lower plenum and the boron concentration at the core inlet is fairly flat. And the results of the APR1400 boron mixing evaluation using CFX code, show complete mixing is occurring at the exit of the lower plenum.

Based on the results of the CFD simulation of the APR1400 plant with conservative conditions for boron dilution, the assumption of complete mixing inside the RCS is reasonable for the condition that all RCPs are idle with operation of one train of the shutdown cooling system.

The boron dilution alarm system (BDAS) utilizes the ex-core neutron flux monitoring system (ENFMS) startup channel neutron flux signals to detect a possible inadvertent boron dilution event while in Modes 3 through 6. The BDAS has two separate channels to provide reasonable assurance of detection and alarming of the event. When neutron flux signals increase during Modes 3 through 6 to equal or greater than the calculated alarm setpoint, alarm signals are generated. So it can be possible for the alarm to activate during any postulated incomplete mixing event.

Table 1. Comparison of the numerical methodology for the ISP-43 comparison report and APR1400 plant calculation

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Table 2. Average boron concentration and minimum boron concentration after 30 minutes from the start of deborated water injection through charging line.

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Figure 1. Geometrical model for the fluid region in the APR1400 reactor vessel- (Lower Plenum and Flow Skirt)

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Figure 2. Mesh configuration for the fluid region in the APR1400 reactor vessel
(Lower Plenum and Flow Skirt)

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(a) Top view

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(b) Side view

Figure 3. 3D analysis model and boundary conditions

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Figure 4. Boron concentration distribution at the exit of the lower plenum

Impact on DCD

There is no impact to 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 Environmental Report.