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.:	**347-8435**
SRP Section:	**15.04.03 – Control Rod Misoperation (System Malfunction or Operator Error)**
Application Section:	**15.04.03**
Date of RAI Issue:	**12/22/2015**

Question No. 15.04.03-1

REQUIREMENTS AND GUIDANCE

In 10 CFR Part 50 Appendix A, General Design Criterion (GDC) 10 requires the core and associated coolant, control, and protection systems to be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects or anticipated operational occurrences (AOOs). GDC 20 requires, in part, that the protection system be designed to initiate automatically the operation of appropriate systems to ensure that SAFDLs are not exceeded as a result of AOOs. GDC 25 requires the protection system to be designed to ensure that SAFDLs are not exceeded for any single malfunction of the reactivity control systems.

Section 15.4.3 of NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition,” Subsection III, “Review Procedures,” states the following under Item 1: “*For each failure event analyzed, the cases which result in a limiting fuel rod condition should be presented. Initial conditions and parameter values selected for these cases should be justified with a sensitivity analysis or discussion. Conditions of first-order importance for any time in cycle are initial power level and distribution, initial rod configuration, reactivity addition rate, moderator temperature, fuel temperature, and void reactivity coefficients.*”

ISSUE

The applicant presents a four-finger single control element assembly (CEA) drop as the limiting event analyzed in DCD Section 15.4.3. As analyzed, this event does not cause a reactor trip but results in an approach to the specified acceptable fuel design limit (SAFDL) on minimum departure from nucleate boiling ratio (DNBR). DCD Section 4.3.2.5 indicates that the full-strength CEA drop incident is analyzed by selecting the dropped CEA that maximizes the increase in the radial peaking factor and that a conservatively small negative reactivity insertion is used in the event analysis. However the application does not provide supporting information such as an examination of the range of CEA worths and locations. It is therefore not clear that a CEA drop into both a high flux and low flux region has been considered or that cases with a part-strength CEA drop have been examined.

Furthermore, the maximum radial peak distortion following a four-finger CEA drop is assumed to be 1.205. However, the application does not describe the basis for this factor and the uncertainties that are covered by it. According to the audited calculation note related to this event, APR1400-F-A-TM-12004-P, Rev. 0, “CEA Drop Analysis for US-APR1400,” dated August 2012, the distortion factor of 1.205 is a multiplier on the initial integrated radial peaking factor. DCD Table 15.4.3-2 lists the integrated radial peaking factor as 1.37. According to DCD Table 4.3-10, this roughly corresponds to a “P” (part-strength) rodded core configuration at end-of-cycle (EOC) conditions. Consequently, the integrated radial peaking factor following the CEA drop is 1.205*1.37, which is 1.644. However, absent necessary supporting information, the staff can neither confirm which rodded configuration yields the largest peaking factor nor assess the basis for the assumed maximum radial peak distortion factor of 1.205.

In addition, the audited calculation note indicates that, as of August 2012, the 12-finger CEA drop had not been evaluated but will be in future analyses for the core operating limiting supervisory system (COLSS) and the core protection calculator system (CPCS). The calculation note also states that, if a 12-finger CEA drops, the CPCS will appropriately generate a trip if it is necessary because the CPCS conservatively calculates DNBR every 0.05 seconds. The applicant has nevertheless provided no information on its analyses for 12-finger CEA drop events. Absent such information, the staff can neither assess the applicant’s analyses for a range of 12-finger CEA drop events nor verify their implications, if any, for determining the limiting CEA drop event.

INFORMATION NEEDED

Please provide justification that the four-finger single CEA drop is the limiting event for DCD Section 15.4.3. A summary of analysis results using different rodded core configurations, dropped rod types and locations, and different cycle conditions would assist the reviewer in confirming that the event analyzed is the limiting event. Supporting information should include the basis for the maximum radial peak distortion factor of 1.205 as well as a summary of analyses performed for 12-finger CEA drop events.

As appropriate, the applicant should update the DCD and referenced technical reports.

Response – (Rev. 1)

To calculate the most conservative radial peaking factor for the CEA drop analysis, all possible single CEA drop simulations for all combinations of initial CEA configurations (permitted by the Power Dependent Insertion Limit) at different cycle conditions (including BOC, IOC, MOC, and EOC) were performed. In the calculations, the maximum 4-finger CEA drop distortion factor which is 1.2047 was selected as the maximum ratio of post to pre event radial peaking factor as described in Table 1. This factor includes not only | |TS that is caused by the dropped CEA but also the | |TS for operator action time that can be credited for 30 minutes after the drop. The initial rod configurations and dropped CEA information are also described in Table 1. The location of the dropped CEA that yields the largest peaking factor is full core box number [ ]TS, and the maximum case occurs for the [ ]TS inserted CEA configuration. The location of the CEA can be found in DCD Tier 2 Figure 4.3-36.

In case of 4-finger CEA drop event, thermal margin reduction caused by integrated radial peak (Fr) distortion with xenon redistribution effect is preserved as initial thermal margin. To confirm that initial thermal margin is enough to compensate the thermal margin reduction caused by 4-finger CEA drop, a quantitative analysis is performed.

In case of 12-finger CEA drop, the thermal margin reduction caused by Fr distortion with xenon redistribution effect is significant. If the thermal margin reduction by 12-finger CEA drop is covered by preserved thermal margin, the LCOs have to be excessively limited. Therefore, in case of 12-finger CEA drop, CPCS functionalized to protect the reactor from DNBR or LPD limit violation by applying a predetermined penalty factor to DNBR and LPD calculation in CPC.

CPCS uses two CEACs in each CPC channel to calculate the CEA deviation penalty factors. CEAC scans all CEA positions received from the reed switch position transmitters and calculates the single CEA position-related penalty factors based on any single CEA deviation detected within a CEA subgroup. These 12-finger CEA penalty factors consist of a static penalty factor and xenon penalty factor. Static penalty factors and xenon penalty factor are pre-determined by consideration for static Fr distortion and xenon redistribution. The xenon penalty factor is calculated as a function of elapsed time during which excess deviation exists in the subgroup. If the deviation exceeds a preset dead-band, these penalty factors are applied in the hot pin heat flux and hot channel enthalpy rise as described in Technical Report APR1400-F-C-NR-14003-P, Rev.0, “Functional Design Requirements for a Core Protection Calculator System for APR1400,” which has been already submitted to the NRC.

Figure 1 and Figure 2 show the typical heat flux and DNBR behavior during the 12-finger CEA drop event. In this analysis, the 12-finger CEA drop occurs at 0 seconds and CPC generate reactor trip signal at 0.85 seconds including the processing delay time and reactor trip breaker opening time. And considering the holding coil decay time (0.5 seconds), scram rods begin to drop into the core at 1.35 seconds. Although the DNBR is decreased due to the static Fr distortion within 1 second, the DNBR begins to increase in combination with heat flux decrease by 12-finger CEA drop. After that, the minimum DNBR is maintained above the DNB SAFDL by CPC trip.

In case of both CEAC inoperable condition, CEAC couldn’t generate penalty factor for the CPC DNBR calculation or the LPD calculation when 12-finger CEA drop occurs. In this case, the core has to be protected by the initially preserved thermal margin. For retaining enough thermal margin when both CEAC is inoperable, operators reduce the core power operating limit in accordance with TS LCO 3.2.4 item “b”.

Table 1. Calculation Cases and Cycle Maximum Peaking Factors of 4-Finger CEA Drop

TS

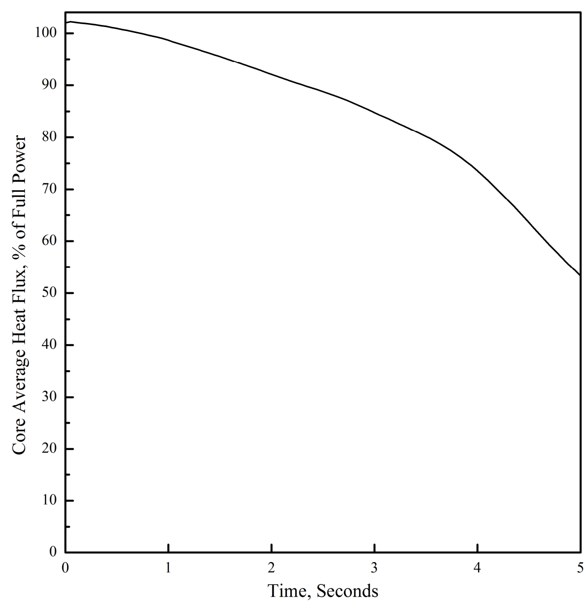

Figure 1. Time vs. Core Average Heat Flux (12-Finger CEA Drop)

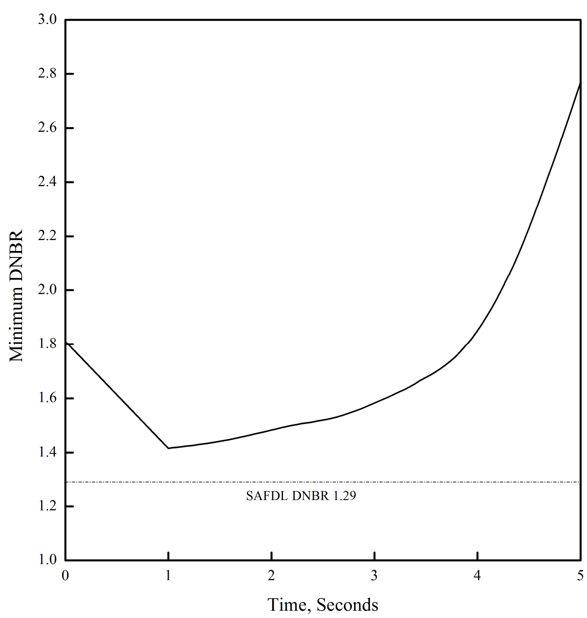

Figure 2. Time vs. DNBR (12-Finger CEA Drop)

Impact on DCD

There is no impact on DCD.

Impact on PRA

There is no impact on PRA.

Impact on Technical Specifications

There is no impact on Technical Specifications.

Impact on Technical/Topical/Environmental Report

There is no impact on any Technical, Topical, or Environmental Report.