# RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**APR1400 Design Certification**

**Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD**

**Docket No. 52-046**

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| **RAI No.:** | **345-8433** |
| **SRP Section:** | **15.04.01 – Uncontrolled Control Rod Assembly Withdrawal from a Subcritical or Low Power Startup Condition** |
| **Application Section:** | **15.4.1-3** |
| **Date of RAI Issue:** | **12/22/2015** |

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## Question No. 15.04.01-1

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 15.4.1 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 4: "The input to the neutron kinetics analysis model should be examined to assure that the input is appropriately conservative both for the state of the reactor and for the particular way it is used in the analysis…."

ISSUE

Section 15.4 of the DCD includes the following three AOO events: (1) "Uncontrolled Control Element Assembly Withdrawal from a Subcritical or Low-Power Startup Condition" [15.4.1], (2) "Uncontrolled Control Element Assembly Withdrawal at Power [15.4.2], and (3) "Control Element Assembly Misoperation" [15.4.3]. Each event is analyzed using reactivity feedback coefficients for fuel temperature and moderator temperature in combination with kinetics parameters that include effective delayed neutron fractions, neutron lifetimes, and decay constants for delayed neutron precursors. However, the applied kinetics parameters are not described within the respective DCD sections, nor does the DCD incorporate or cite references that detail the respective calculations. The applicant has nevertheless made available three related calculation notes for audit by the NRC staff. The audited calculation notes, which are dated July and August 2012, include appendices containing earlier pre-submittal drafts of the respective DCD sections.

The calculation note for the CEA misoperation event (15.4.3) indicates the conservative use of the most strongly negative reactivity feedback coefficients, which occur at EOC, in combination with the minimum delayed neutron fraction, which likewise occurs at EOC, and notes that minimizing the delayed neutron fraction conservatively maximizes the limiting heat flux increase in that event (Audit Reference 3). For the two CEA withdrawal events (15.4.1 and 15.4.2), the applicant assumes the least negative fuel temperature coefficient and the most positive moderator temperature coefficient, both of which occur at beginning of cycle (BOC) conditions.

Although not stated as such, the analysis appears to use EOC kinetics parameters like those used in the CEA misoperation event (Audit References 1 and 2).

In general, the staff is concerned that the reviewed submittal and audited calculation notes do not adequately describe the assumed kinetics parameters and do not provide supporting information to show that the applied parameters yield appropriately conservative analysis predictions for the respective events.

INFORMATION NEEDED

Please describe and provide the basis for the kinetics parameters (delayed neutron fractions, neutron lifetimes, decay constants) used for the respective events in DCD Sections 15.4.1-3. This should include justification for using the same EOC kinetics parameters for both BOC and EOC conditions and a discussion of how the assumption of a higher delayed neutron fraction would affect the peak linear heat generation rate (PLHGR) and the departure from nucleate boiling ratio (DNBR) in relation to the respective SAFDLs. The justification should show the assumed kinetics parameters to be appropriately conservative for each of the three events. If supporting sensitivity cases were run with different sets of kinetics parameters, please provide a discussion of those results.

As appropriate, update the DCD or the docketed technical reports to enable the staff to make a finding based on the docketed information.

<u>Audit References</u>

1. APR1400-F-A-TM-12037-P, Rev. 0, “Bank CEA Withdrawal from Subcritical or Low Power Analysis for US-APR1400,” July 2012

2. APR1400-F-A-TM-12036-P, Rev. 0, “Bank CEA Withdrawal at Power Analysis for US-APR1400,” July 2012

3. APR1400-F-A-TM-12004-P, Rev. 0, “CEA Drop Analysis for US-APR1400,” August 2012

## Response

A lower delayed neutron fraction (i.e., EOC) maximizes the power "spike" occurring during the CEA bank withdrawal event. This leads to a higher PLHGR value. Prompt neutron lifetimes and decay constants are consistent with the delayed neutron fraction (i.e., EOC). These effects can be seen in the PLHGR case for the CEA bank withdrawal event from a subcritical or low-power startup condition (DCD sections 15.4.1), but are negligible in the PLHGR case for the CEA bank withdrawal event at power (DCD sections 15.4.2).

For the DNBR case, a slower rate of increasing the power with the BOC kinetics parameters causes a long period of time before reaching the reactor trip setpoint and higher maximum core average heat flux after trip than with a faster rate of increasing the power with the EOC kinetics parameters. This leads to a lower minimum DNBR. There is a large safety margin to the DNBR SAFDL in the CEA bank withdrawal event from a subcritical or low-power startup condition (DCD sections 15.4.1). And the DNBR difference is small in relation to the margin for the DNBR SAFDL in the CEA bank withdrawal event at power (DCD sections 15.4.2).

The least negative fuel temperature coefficient and the most positive moderator temperature coefficient, both of which occur at BOC conditions, are assumed in the analyses of the PLHGR case in the CEA bank withdrawal events because of the cycle bounding approach between BOC and EOC.

For the single CEA drop event (DCD sections 15.4.3), a lower delayed neutron fraction (i.e., EOC) gives a faster response for core fission power since the delayed neutron precursor concentration is lower. Impact on the transient results of the single CEA drop event, however, are negligible since a PLHGR and a minimum DNBR occur in the quasi-steady state condition.

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**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 Reports**

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