U.S. NUCLEAR REGULATORY COMMISSION REGULATORY AUDIT OF CHAPTER 4 (REACTOR) OF THE APR1400 DESIGN CONTROL DOCUMENT

Korea Hydro and Nuclear Power Co., Ltd. (KHNP) and Korea Electric Power Corporation (KEPCO)

APR1400 DESIGN CERTIFICATION
Docket No. 52-046

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Summary:

This audit was held to examine the documents supporting and gain an understanding of the calculations presented in the design control document (DCD) and referenced technical reports as related to the core design, core protection calculator system, (CPCS) and core operating limit supervisory system (COLSS) and confirm that the design calculations performed in support of the Advanced Power Reactor 1400 (APR1400) design certification (DC) application are consistent with the descriptions of the computer codes in DCD Tier 2, Section 15.0.2.

To support the U.S. Nuclear Regulatory Commission (NRC) staff's review of the information in the DCD, as described in Title 10 of the *Code of Federal Regulations* (10 CFR) 52.47, the NRC staff audited information related to the core design, core protection calculator and core operating limit supervisory systems, and associated bases and calculations for the APR1400 DC, as referenced in DCD Tier 2, Sections 4.3, 4.4, and 7.2.

Objectives:

The objectives of this audit were for the staff to: (1) gain an understanding of APR1400 supporting calculations and analyses to reach a reasonable assurance finding and (2) review related documentation and non-docketed information to evaluate conformance with the Standard Review Plan (SRP) or technical guidance.

Observations and Results:

The NRC staff had requested and received a presentation on the details of the Core Protection Calculator System (CPCS), including how it works and relevant inputs factors. KHNP also discussed a document containing responses to the issues outlined in the Audit Plan (ADAMS Accession number ML16019A050). The results from the audit are discussed by issue number as listed in the Audit Plan, as follows:

Core Design Issues:

1. Since the analysis method for large break LOCA differs from that approved for the System 80+ design (due to the use of RELAP5/MOD3.3), the staff would like to understand if the core design process for determining limiting pressure drops and component loads will differ from that described in DCD Section 4.4 (i.e., using only the TORC and CETOP codes).

Staff obtained clarification on Issue 1 regarding core design and limiting pressure drops. KHNP referred in part to the response to RAI 326-8408, Question 04.04-5, which clarified that System 80 reactor flow test data adjusted for conditions of the APR1400, not a code, are used for determining pressure drops. The staff found no further action was necessary.

2. The staff notes that the source of the gadolinium isotopic data used by DIT/ROCS is not clearly identified in the approved code topical reports. To address this concern, the audit will seek to identify the source of the gadolinium isotopic data used by DIT/ROCS. If the source cannot be identified from existing documentation, this should be clearly stated and the DIT multigroup library data for the Gd isotopes should then be examined for consistency with data from later evaluated nuclear data files such as ENDF/B-V.

KHNP did not provide an answer to this issue, so the staff intend to issue an RAI to determine the source of the gadolinium isotopic and get this information on docket.

3. The applicant presents axial core power distributions at various core depletion states assuming only unrodded operation. However, the APR1400 is designed to use regulating rods to control power shapes. The audit will seek clarification on whether the presented unrodded axial power shapes are meant to result in peak core power densities that bound those for cases where regulating rods are partially inserted in the core.

KHNP explained that the COLSS considers thousands of power shapes, some of which include rod insertion. Since the COLSS monitors the peak core power density, the APR1400 considers rodded axial power shapes during operation. Staff found this information to be satisfactory but determined that an explanation tying the power shape consideration to the COLSS needs to be docketed. Staff intend to issue an RAI to get this information on docket.

4. Demonstration of detection of CEA misalignment or drop; the applicant states: "Since the plant protection system (CPCs and CEACs) detects the CEA positions by means of two independent sets of reed switches and uses this information in determining margin to trip, it is not necessary to rely on in-core or ex-core nuclear instrumentation to detect control element misalignment or drop. Thus, this testing is not performed." The audit is to examine if the applicant's justifications are acceptable for not performing: (1) demonstrated CEA positions and misalignment tests and (2) demonstration of the capability of the incore neutron flux instrumentation to detect rod misalignment equal to or less than the Technical Specifications limits for control rod misalignment.

Regarding Issue 4, the staff heard an oral discussion by KHNP that clarified that the CPCS, which uses safety-grade reed switch position transmitters, detects CEA misalignment. The non-safety-grade incore detectors are not used to detect CEA misalignment. KHNP requested that an RAI be issued to provide a further written answer, if necessary. NRC staff will evaluate the need to issue an RAI.

Core Protection Calculator System (CPCS) Issues:

1. DCD Section 4.3.3.1.1.4 describes the use of a fixed source MCNP (Monte Carlo, N-particle) code adjoint calculation to determine the shape annealing functions, while CENPD-170-P identifies the DOT/DORT codes for this purpose. What methodology is to be used for the APR1400 to synthesize the power shapes, and what deviations are taken from the CENPD-170-P methodology?

Regarding Issue 1, KHNP stated that MCNP is used to determine the Shape Annealing Functions (SAF). KHNP also showed the staff a report where the use of MCNP had been validated. Since MCNP has not been approved for use in this way before, the staff plans to issue an RAI asking how MCNP is used and verified in support of the CPCS.

2. CENPD-170-P specifies a number of analytical methods and computer codes, so will these same codes be utilized for the APR1400, and if so, have these codes been reviewed and approved by the NRC?

On Issue 2, staff identified a reference, CEN-310-P-A ("CPC and Methodology Changes for the CPC Improvement Program," CEN-310-P-A, April 1986), that must be checked for prior NRC review and approval of the analytical methods and codes of concern.

3. APR1400-F-C-NR-14001-P, Rev. 0, "CPC Setpoint Analysis Methodology for APR1400," states that the CPC calculations are verified using a large number of power distributions at BOC, MOC, and EOC, but it does not describe how the CPC constants (e.g., Fxy and Fq) are calculated, especially when new fuels are introduced (i.e., mixed cores). For mixed cores, how will multiple DNBR uncertainties be implemented in the CPC algorithms?

Staff received clarification on Issue 3 during the audit. The CPC constants are based on measurements and/or cycle maximum values, which are verified during startup testing by comparing measured data against calculations for the particular startup condition. The constants are adjusted upwards if the startup benchmark shows non-conservatisms.. For mixed cores, the larger value of DNBR calculated for two fuel types is selected, and an additional mixed core penalty factor is imposed on DNBR uncertainty. The staff was satisfied with the explanation and determined that no additional action was necessary.

4. The CPC power distribution uncertainties are evaluated based on core simulator 3D power distributions for a variety of conditions. Are design basis AOO events included in the database of power shapes?

Staff received clarification on Issue 4 during the audit. Although power shapes are not generated explicitly for AOOs and design basis events, some are generated at core conditions that are representative of AOO and design basis event conditions. The staff was satisfied with the explanation and determined that no additional action was necessary.

5. Describe the setpoint calculation process for reloads. Define what calculations are performed generically for each fuel type, and which are cycle-specific. Identify the codes used and provide a reference to the approval SER.

On Issue 5, KHNP explained the reload analysis process. It is divided into non as-built and as-built analyses and therefore takes into account plant-specific information. The non as-built analyses are performed for each fuel type. All calculations are cycle-specific and are therefore

performed for each cycle. The staff understood the explanations but determined that the CEFAST code, which is used as part of the as-built analyses to generate and validate CPC constants, should be verified for previous NRC approval.

6. For the core average axial power distribution, CENPD-170 discusses conversion of ex-core detector responses to peripheral core power at three core rings and then to 20-node axial shape using up to eight algorithm constants (α1 through α8). These are apparently pre-calculated to represent flat-, saddle-, top-, or bottom-peaked axial shapes for beginning-of-life (BOL) and end-of-life (EOL) conditions. The CPC uses some degree of pattern recognition on the 3-ring axial power distribution to determine which of the four power shape types are present and then uses a cubic spline fit to data. The applicant should explain how the constants are developed, whether they are cycle-dependent or burnup-dependent within one cycle, and how they will be verified against plant data.

On Issue 6, KHNP explained that the algorithm constants are cycle-dependent, are not burnup dependent, and are determined from plant startup test data. Staff determined that the information presented should be on the docket and will issue an RAI regarding power shape constants.

7. For the radial power distribution, planar radial peaking factors and axial augmentation factors are used to define the hot pin power as a function of the CEA configuration (both normal and abnormal). No detail is provided on the method used to define these. The applicant should explain how the planar radial peaking factors will be calculated, whether cycle- or burnup dependent, what codes are used in the calculations, and whether the codes have been approved.

Staff received clarification on Issue 7 during the audit. The ROCS computer code estimates the maximum planar radial peaking factor, which is initially installed in the CPCS with an additional penalty. The planar radial peaking factor is measured and compared to the estimated value at a specific burnup, and if the measured value is greater than the calculated value, the CPCS maximum planar radial peaking factor is adjusted by the ratio of the measured to calculated values. The staff was satisfied with the explanation and determined that no additional action was necessary.

8. Explain how the axial augmentation factors are calculated, whether cycle- or burnup-dependent, what codes are used, and whether the codes have been approved.

On Issue 8, KHNP stated the axial augmentation factors were deleted because the effects were demonstrated to be insignificant and that this was approved by NRC in the CEN-310-P-A report. The staff will take an action item to check the information in CEN-310-P-A.

9. Explain whether the CPC constants will be adjusted during a cycle to reduce conservatism, and if so, how the changes are verified.

KHNP explained that the CPC constants are pre-calculated with additional uncertainty until measured values of the constants can be input. Therefore, they may be adjusted after the reactor startup tests and are not adjusted at any other time during the cycle. The resolution of Issue 9 is related to that of Issue 6, for which an RAI will be issued.

10. Explain where in the safety analysis is the time delay that the core protection calculator (CPC) will utilize before reverting to the "predetermined penalty factor" (PF), as discussed in the

response to RAI 274-8277 (ADAMS Accession Number ML15363A340; Question 07.01-37), that will be a large value to ensure a core protection calculator (CPC) initiated departure from nucleate boiling ratio (DNBR) reactor trip and/or a local power density (LPD) reactor trip, explained, defined, and captured, within the design basis event's "sequence of events."

KHNP explained at the audit that there is actually no time delay considered in the Chapter 15 safety analysis, and that there is no design basis event that assumes CEA misoperation concurrent with both CEAC failure. NRC pointed out that a statement that was included in the response to RAI 274-8277 Question 07.01-37 regarding a time delay is apparently incorrect. NRC staff will issue a follow-up RAI for clarification.

11. Based on the definition of a "pre-determined penalty factor" (PF) added to the APR1400 FSAR, Tier 2, Table 7.2-7, mark-ups (FSAR mark-up page# 7.2-71), as provided in the response to RAI # 274-8277 (ML15363A340; Question# 07.01-38), explain how the predetermined PF will be guaranteed to be large enough during the entire fuel lifecycle to ensure that a CPC initiated reactor trip is reached.

KHNP stated that a predetermined penalty factor of 8.0 is applied when both CEACs are inoperable, and that this value is large enough to initiate a reactor trip under any credible circumstances that could challenge safety limits. Staff has further questions on the provenance and determination of the penalty factor and will issue RAIs on this topic.

Core Operating Limit Supervisory System (COLSS) Issues

1. The staff SER for the System 80+ refers to topical reports CENPD-169 and CEN-312 for the detailed description of the COLSS. The staff reviewers would like to understand if these documents could be considered part of the design basis for the APR1400. If so, please make these documents available in the Electronic Reading Room.

On COLSS Issue 1, the discussion led the staff to determine that the CEN-312, "Overview Description of the Core Operating Limit Supervisory System (COLSS)," report should be considered part of the licensing basis, and staff intends to issue an RAI requesting it.

Conclusions:

The NRC staff received a presentation and discussion of the issues related to core design and the core protection calculator and core operating limit supervisory systems, which clarified several issues staff had identified. Staff will issue RAIs to close gaps in the information currently on the docket and to allow KHNP to answer some questions which they were not able to answer during the audit.