UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

June 15, 2018

Mr. Victor McCree
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: LONG-TERM CORE COOLING FOR THE APR1400

Dear Mr. McCree:

During the 654th meeting of the Advisory Committee on Reactor Safeguards, June 6-7, 2018, we met with representatives of the NRC staff, Korea Electric Power Corporation (KEPCO), and Korea Hydro & Nuclear Power Company, Ltd., (KHNP) to review the adequacy of long-term core cooling (LTCC) as it applies to the APR1400 design certification application. Our APR1400 Subcommittee reviewed this matter during meetings on May 19, 2017 and April 17-18, 2018. We also had the benefit of the referenced documents.

CONCLUSION

The analyses presented by the applicant are adequate to assure long-term core cooling and is sufficient to satisfy the criterion of 10 CFR 50.46(b)(5). The APR1400 design meets the regulatory requirement for long-term core cooling during design basis accidents.

BACKGROUND

On May 8, 2008, the Commission issued a Staff Requirements Memorandum stating, “the ACRS should advise the staff and Commission on the adequacy of the design-basis, long-term core cooling approach for each new reactor design based, as appropriate, on either its review of the design certification or the first license application referencing that reactor design.” The main focus of the Commission’s concern was the ability of the safety systems to provide adequate core cooling over extended time periods when the emergency core cooling system recirculation mode is employed during a design basis accident.

The objective of long-term cooling is to maintain the core at acceptable temperature levels while avoiding the adverse effects of the precipitation of boric acid in the reactor coolant system or recriticality. To ensure that this objective is achieved, the following areas of concern need to be addressed:

- Boric acid precipitation or dilution
- Containment sump performance

- Containment accident pressure credit
- Gas formation
- Blockage of natural circulation
- Post-72 hour core cooling

DISCUSSION

APR1400-F-A-NR-14003-P presented the results of modeling efforts to establish adequacy of LTCC following a loss-of-coolant accident for the APR1400 design. The report provides an overview of the applicable methodology and the description of specific assumptions incorporated into the codes used to analyze long-term cooling, as well as a discussion of the bases for applying these codes and methods to the APR1400 design. Key models were validated using comparisons with approved computer codes.

Boric Acid Precipitation or Dilution

The APR1400 boric acid precipitation analysis is based on a methodology developed by Entergy for the Waterford Unit 3 extended power uprate, which modified the LTCC methodology described in CENPD-254-P-A. The Waterford methodology modified the “mixing volume” to account for time dependent void fraction variation. The evaluation results indicate that simultaneous direct vessel injection and hot leg injection will provide sufficient flushing flow to prevent precipitation.

To assess the effects of boron dilution during emergency core cooling system activation and long-term use, KHNP performed an analysis to determine if recriticality is possible for any long-term core cooling scenario. The initial boron concentration in the lower plenum region was determined to be 4,000 ppm, while the critical boron concentration for recriticality was estimated to be 970 ppm. The minimum boron concentration during natural circulation was estimated to be approximately 1,600 ppm and for the restart of one main coolant pump the minimum concentration was estimated to be approximately 2,300 ppm.

Containment Sump Performance

Sump performance and flow blockage issues are addressed in report APR1400-E-N-NR-14001-P. The APR1400 is designed as a “low fiber plant” to mitigate GSI-191 issues. The combination of this feature with a series of increasingly fine filtration (“trash rack” on the holdup volume tank coupled with the sump strainer for the in-containment refueling water storage tank) assures that flow blockage is minimized and natural circulation maintained. The sump strainer performance was evaluated in accordance with NEI-04-07. The analysis included the following assumptions: 1) no fibrous insulation, 2) reflective metal insulation derived debris contains 75% small fines and 25% large pieces, 3) all particulate, fiber, and other debris reaches the sump strainers, 4) 100 ft^2 of sacrificial strainer surface area is allowed for miscellaneous debris, and 5) 15 lbm of latent fibrous debris. Fibrous debris caused by jet impingement on electrical cables is not expected in the APR1400 due to the use of fiber-free electrical cable insulation.

Containment Accident Pressure Credit

Containment accident pressure credit has been addressed using the GOTHIC containment model with conservative assumptions based on SECY-11-0014. The credit is small and only required for the limited time when the in-containment refueling water storage tank temperature is greater than 212°F.

Prototype testing demonstrated no gas ingestion due to vortexing or flashing would occur. In addition, the occurrence of flashing in the debris bed is minimized by assuring that the hydrostatic pressure due to strainer submergence is greater than the pressure drop across the debris bed.

In-vessel debris effects were analyzed in accordance with the methodology described in WCAP-16406-P. The peak clad temperature due to deposition of the maximum allowable debris and a crud thickness of 0.050 inches was calculated to be below the 800°F limit.

SUMMARY

The analyses presented by the applicant is adequate to assure LTCC and is sufficient to satisfy the criterion of 10 CFR 50.46(b)(5). The APR1400 design meets the regulatory requirement for LTCC during design basis accidents.

Sincerely,

/RA/

Michael Corradini
Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission, Staff Requirements Memorandum M080430C, "Staff Requirements - Periodic Briefing on New Reactor Issues, 1:00 P.M., Wednesday, April 30, 2008, Commissioners' Conference Room, One White Flint North, Rockville, Maryland (Open to Public Attendance)," May 8, 2008 (ML081290255).

2. Korea Electric Power Corporation and Korea Hydro & Nuclear Power Company, Ltd., APR1400-F-A-NR-14003-P, “Post-LOCA Long Term Cooling Evaluation Model,” Revision 1, March 2017 (ML17114A525).

3. Entergy, W3F1-2005-0012, “Supplement to Amendment Request NPF-38-249 Extended Power Uprate Waterford Steam Electric Station, Unit 3 Docket No. 50-382 License No. NPF-38,” February 16, 2005 (ML050490396).

4. Combustion Engineering, CENPD-254-P-A, “Post-LOCA Long Term Cooling Evaluation Model," June 1980 (ML15358A220).

5. Korea Electric Power Corporation and Korea Hydro & Nuclear Power Company, Ltd., APR1400-E-N-NR-14001-P, “Design Features to Address GSI-191,” Revision 3, February 2018 (ML18057B530).

6. Nuclear Energy Institute, NEI-04-07, Volume 1, “Pressurized Water Reactor Sump Performance Evaluation Methodology,” December 31, 2004 (ML050550138).

7. Nuclear Energy Institute, NEI-04-07, Volume 2, “Pressurized Water Reactor Sump Performance Evaluation Methodology: Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Revision 0,” December 6, 2004 (ML050550156).

8. U.S. Nuclear Regulatory Commission, SECY-11-0014, “Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance In Postulated Accidents,” January 31, 2011 (ML102780586).

9. Westinghouse, WCAP-16406-P, “Evaluation of Downstream Sump Debris Effects in Support of GSI-191,” June 2005 (ML052160184).

10. Korea Electric Power Corporation and Korea Hydro & Nuclear Power Company, Ltd., “Korea Electric Power Corporation and Korea Hydro & Nuclear Power Co., Ltd Application for Design Certification of the APR1400 Standard Design,” Revision 1, August 6, 2017 (ML17096A325).

REFERENCES

1. U.S. Nuclear Regulatory Commission, Staff Requirements Memorandum M080430C, "Staff Requirements - Periodic Briefing on New Reactor Issues, 1:00 P.M., Wednesday, April 30, 2008, Commissioners' Conference Room, One White Flint North, Rockville, Maryland (Open to Public Attendance)," May 8, 2008 (ML081290255).

2. Korea Electric Power Corporation and Korea Hydro & Nuclear Power Company, Ltd., APR1400-F-A-NR-14003-P, "Post-LOCA Long Term Cooling Evaluation Model," Revision 1, March 2017 (ML17114A525).

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6. Nuclear Energy Institute, NEI-04-07, Volume 1, "Pressurized Water Reactor Sump Performance Evaluation Methodology," December 31, 2004 (ML050550138).

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