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

July 26, 2018

The Honorable Kristine L. Svinicki
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: REPORT ON THE SAFETY ASPECTS OF THE APR1400 PRESSURIZED-WATER REACTOR

Dear Chairman Svinicki:

During the 655th meeting of the Advisory Committee on Reactor Safeguards, July 11-13, 2018, we completed our review of the Korea Electric Power Corporation (KEPCO), and Korea Hydro & Nuclear Power Company, Ltd., (KHNP) design application of its APR1400 nuclear power plant. This letter report fulfills the requirements of 10 CFR 52.53 and 10 CFR 52.141. During our review, we had the benefit of discussions with representatives of the NRC staff, KEPCO and KHNP and their consultants. We also had the benefit of the documents referenced. Appendix 1 lists the chronology of APR1400 Subcommittee and Full Committee meetings and their subjects.

CONCLUSION

The APR1400 design is mature and robust. There is reasonable assurance that it can be constructed and operated without undue risk to the health and safety of the public.

BACKGROUND

The APR1400 is a pressurized-water reactor, which evolved from the System 80+ design certified in 1997, and codified in 10 CFR Part 52, Appendix B. We reviewed the System 80+ design and recommended that the design be certified in our letter, dated May 11, 1994. The APR1400 includes several features that are designed to further improve safety and operability over that of the System 80+. The APR1400 reference plants are Shin Kori, Units 3 and 4, located in South Korea; Shin Kori 3 began commercial operation in December 2017.

APR1400 Application

KHNP submitted its application to the NRC for certification of the APR1400 design on December 23, 2014. This application was submitted in accordance with 10 CFR Part 52, Subpart B, “Standard Design Certifications.” The NRC formally docketed the application for design certification (Docket No. 052-046) on March 4, 2015. On March 8, 2018, KHNP also requested a design approval in accordance with 10 CFR Part 52, Subpart E, "Standard Design Approvals." The application consists of the APR1400 Design Control Document (DCD), several topical and technical reports, and the APR1400 probabilistic risk assessment (PRA) report.

The DCD information is divided into two parts, denoted as Tier 1 and Tier 2. Tier 1 contains the portion of the generic design-related information that is proposed for approval and certification in the rule, including the inspections, tests, analyses, and acceptance criteria (ITAAC). Tier 2 contains the portion of the generic design-related information that is proposed for approval, but not certification. Tier 2 information includes a description of the design of the facility for a final safety analysis report, as required by 10 CFR 52.47. Subsequently, KHNP supplemented the information in the DCD by providing revisions to the DCD. The applicant submitted the most recent version, Revision 2, on March 8, 2018. The applicant has submitted additional proposed revisions to the DCD to resolve all the confirmatory items from the staff and ACRS-identified issues. It is intended that these revisions be incorporated in Revision 3 of the DCD.

ACRS Review Approach

Our review activities for the APR1400 design certification are listed in Appendix 1. Our reviews did not address security-related issues. During these reviews, we issued nine letters (four interim letters, four letters on topical reports, and one letter on long-term core cooling) identifying issues of concern and areas needing additional discussion.

DISCUSSION

APR1400 Design

The primary system, consisting of two loops, each with a steam generator and two reactor coolant pumps (RCPs), and main components remain the same as those for System 80+. The design has benefited from past operational experience in the area of materials performance. The APR1400 design makes use of advanced steam generator tubing material (alloy 690), high strength materials (alloy 718), and advanced welding alloys, which should improve reliability. The fuel design has been updated to include advanced cladding materials (ZIRLO™) and spacer/mixing grid designs that improve thermal-hydraulic performance.

In addition to updates in the design of the system, KHNP has updated their system performance analytical models and data to ensure adequate margin to regulatory limits. Significant among these updates are models for fuel performance, accident analysis, thermal-hydraulics, long-term core cooling, and large-break loss-of-coolant accident (LOCA) analysis. With respect to fuel performance, the effect of burnup-dependent fuel thermal conductivity degradation has been accounted for through the imposition of temperature penalties.

Safety Enhancement Features

The APR1400 includes advanced design features to enhance safety and operational flexibility. Enhancements include the combination of four trains of safety injection with direct vessel injection, and a unique safety injection tank fluidic device, which optimizes the safety injection flow rate during the initial blowdown and subsequent, long-term, core reflood phase. The performance of the fluidic device was verified via full scale testing. The plant is designed to be "fiber free," which along with experimental verification using conservative conditions, benefits long-term core cooling following a LOCA.

Instrumentation & Control

The DCD and Safety I&C System technical report provide a detailed description of how the digital instrumentation and control (DI&C) system architecture meets the fundamental design principles of independence, redundancy, predictability and repeatability, diversity and defense-in-depth, and control of access.

The APR 1400 digital safety I&C system architecture is based on the NRC-approved Common Q computing platform which uses microprocessors. This platform is used in each division of the reactor trip and engineered safeguards systems. To provide redundancy, each of these systems has four divisions with no communication between them other than the final voting computing units which receive trip signals from each division for two of four voting. To ensure independence, each division voting unit incorporates an independent, hardware-based watchdog timer to produce a trip or alarm if the voting unit locks up. Diversity and defense-in-depth is provided through an independent diverse protection system which uses a non-software-based field programmable gate array-based logic controller to develop reactor and safeguards trip functions. The Common Q platform requires a central processing unit (CPU) load limit to not adversely affect the deterministic behavior and response time of the system. However, because of its more complex algorithms, the core protection calculator system requires a higher load limit. To avoid adversely affecting the deterministic behavior and response time of the system with a higher CPU load, the programming restrictions listed in the Common Q platform supplemental information in support of the APR1400 Design Certification are applied and are incorporated as ITAAC items. Control of access from external sources to in-plant systems and networks is ensured by the use of hardware-based, unidirectional data diodes, which allow data communication from in-plant to external recipients, but blocks external electronic access. The above design features ensure that the overall APR1400 architecture meets the DI&C fundamental design principles.

Probabilistic Risk Assessment

The APR1400 design certification application included a PRA in accordance with regulatory requirements. The scope of the APR1400 PRA includes a Level 1 and Level 2 PRA for internal events, internal flooding and fire for both at-power and low power/shutdown conditions, and for external events at-power.

A seismic margins analysis was performed, but the risk from seismic events was not quantified – there are no estimates of core damage frequency or large release frequency. Because the approach was based on conservatively selected high confidence of low probability of failure values, no meaningful information on contributors to risk was obtained. The approach provides confidence that the plant has margin with respect to seismic events. The scope is sufficient for the discussion of risk insights and results, and for severe accident evaluation during the design phase.

Our review found that this PRA was acceptable for design certification purposes. The estimated frequencies of core damage and large releases provide confidence that the APR1400 design meets the Commission’s Safety Goal Policy Statement as elaborated in Regulatory Guides 1.174 and 1.200. The PRA was an integral part of the APR1400 design process, and risk insights influenced a number of design changes throughout the review. This integrated risk perspective was an important contribution to achieving the estimated low risk.

However, the current PRA needs to be improved before initial fuel load. It is important that any future use of the PRA results during the combined license and startup processes, such as risk-informed applications, should be carefully examined and supplemented by more complete analysis.

The part of the APR1400 PRA that includes at-power Level 1 internal events and internal flooding, and Level 2 large release frequency was peer reviewed against the PRA standard. Not all peer review findings have been dispositioned. Scope limitations, varying levels of modeling detail, and lack of specificity with respect to as-built, as-operated plant conditions (including operator training and emergency procedures) limit direct use of the current PRA for risk-informed applications.

Specific examples of issues needing further refinement before the final PRA is completed are provided here to alert future applicants and reviewers. The potential impacts of loss of cooling for the RCP motors should be addressed in the RCP seal LOCA analysis; the impact of loss of heating, ventilation, and air conditioning needs to be addressed and documented in more detail; and loss of offsite power recoveries, including required operator actions and equipment, need to be evaluated for different time periods.

The combined license applicant will decide whether to invoke in-vessel retention through external reactor vessel cooling. Therefore, KHNP did not take credit for this optional accident management strategy. If this option is selected, the combined license applicant will not only need to address this associated combined license item, but will also need to consider the impact on plant response using the PRA.

SUMMARY

We agree with the staff’s resolution of all the open items for the APR1400 in regard to specific safety issues. The APR1400 design is mature and robust. There is reasonable assurance that it can be constructed and operated without undue risk to the health and safety of the public.

Sincerely,

/RA/

Michael Corradini
Chairman

REFERENCES

1. Korea Electric Power Corporation and Korea Hydro & Nuclear Power Company, Ltd., “APR1400 Design Control Document Tier 2,” Revision 2, March 8, 2018 (ML18079A487).

2. Advisory Committee on Reactor Safeguards, “Report on the Safety Aspects of the ASEA Brown Boveri - Combustion Engineering Application for Certification of the System 80+ Standard Plant Design,” May 11, 1994 (ML16217A355).

3. Advisory Committee on Reactor Safeguards, “Interim Letter: Chapters 2, 5, 8, 10, and 11 of the NRC Staff’s Safety Evaluation Report with Open Items Related to the Certification of the APR1400 Design,” February 21, 2017 (ML17052A307).

4. Advisory Committee on Reactor Safeguards, “Interim Letter: Chapters 3, 4, 9, and 15 of the NRC Staff’s Safety Evaluation Report with Open Items Related to the Certification of the APR1400 Design,” July 26, 2017 (ML17206A234).

5. Advisory Committee on Reactor Safeguards, “Interim Letter: Chapters 6, 12, 13, 14, 16, 17, and 19 of the NRC Staff’s Safety Evaluation Report with Open Items Related to the Certification of the APR1400 Design,” June 21, 2017 (ML17171A033).

6. Advisory Committee on Reactor Safeguards, “Interim Letter: Chapters 7 and 18 of the NRC Staff’s Safety Evaluation Report with Open Items Related to the Certification of the APR1400 Design,” September 25, 2017 (ML17265A792).

7. Advisory Committee on Reactor Safeguards, “Safety Evaluation of APR1400 Topical Report, ‘Fluidic Device Design for the APR1400’,” February 21, 2017 (ML17052A311).

8. Advisory Committee on Reactor Safeguards, “Safety Evaluation of APR1400 Topical Report, ‘KCE-1 Critical Heat Flux Correlation for PLUS7 Thermal Design’,” February 23, 2017 (ML17053A159).

9. Advisory Committee on Reactor Safeguards, “Safety Evaluation for Topical Report APR1400-F-M-TR-13001-P, Revision 1, ‘PLUS7 Fuel Design for the APR1400’,” March 26, 2018 (ML18074A379).

10. Advisory Committee on Reactor Safeguards, “Safety Evaluation for Topical Report APR1400-F-A-TR-12004- P, Revision 1, ‘Realistic Evaluation Methodology for Large-Break Loss of Coolant Accident of the APR1400’,” June 15, 2018 (ML18166A269).

11. Advisory Committee on Reactor Safeguards, “Long-Term Core Cooling for the APR1400,” June 15, 2018 (ML18166A293).

12. U.S. Nuclear Regulatory Commission, 51 FR 30028, “Safety Goals for the Operations of Nuclear Plants,” August 21, 1986 (ML051580401).

13. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.174, “An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis,” Revision 3, January 2018 (ML17317A256).

14. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.200, “An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities,” Revision 2, March 2009 (ML090410014).

APPENDIX 1

CHRONOLOGY OF THE ACRS REVIEW OF THE KHNP APPLICATION FOR THE APR1400 DESIGN CERTIFICATION

The extensive ACRS review of the APR1400 design and its interactions with representatives of the NRC staff and KHNP are discussed in the minutes and transcripts of the following ACRS meetings.

ACRS MEETING/DATES	SUBJECT
APR1400 Subcommittee 4/20-21/2016	Overview of the APR1400 design
APR1400 Subcommittee 9/21-22/2016	APR1400 Design Certification: Chapters 2 (excluding 2.3) and 5 of the DCD and the NRC SER with Open Items
APR1400 Subcommittee 10/4/2016	APR1400 Design Certification: Chapters 2.3, 10 and 11 of the DCD and the NRC SER with Open Items
APR1400 Subcommittee 11/29/2016	APR1400 Design Certification: Chapter 8 of the DCD and the NRC SER with Open Items
APR1400 Subcommittee 12/14/2016	APR1400 Design Certification: Topical Reports “KCE-1 Critical Heat Flux Correlation for PLUS 7 Thermal Design” and “Fluidic Device Design for the APR1400,” and the NRC SER
APR1400 Subcommittee 2/8/2017	APR1400 Design Certification: Chapter 4 of the DCD and the NRC SER with Open Items
640th ACRS Meeting 2/9/2017	APR1400 Design Certification: (1) Chapters 2, 5, 8, 10 and 11 of the DCD and the NRC SER with Open Items; and (2) Topical Reports “KCE-1 Critical Heat Flux Correlation for PLUS 7 Thermal Design” and “Fluidic Device Design for the APR1400,” and the NRC SER
APR1400 Subcommittee 2/24/2017	APR1400 Design Certification: Chapter 12 of the DCD and the NRC SER with Open Items
APR1400 Subcommittee 3/21-22/2017	APR1400 Design Certification: Chapters 6, 13 and 16 of the DCD and the NRC SER with Open Items

ACRS MEETING/DATES	**SUBJECT**
APR1400 Subcommittee 4/5/2017	APR1400 Design Certification: Chapter14 (excluding 14.3) of the DCD and the NRC SER with Open Items
APR1400 Subcommittee 4/19-20/2017	APR1400 Design Certification: Chapters 17 and 19 of the DCD and the NRC SER with Open Items
APR1400 Subcommittee 5/18-19/2017	APR1400 Design Certification: Chapters 9 (excluding 9.1.2) and 15 (including adequacy of long-term cooling) of the DCD and the NRC SER with Open Items
APR1400 Subcommittee 6/5/2017	APR1400 Design Certification: Chapter 3 of the DCD and the NRC SER with Open Items
644th ACRS Meeting 6/7/2017	APR1400 Design Certification: Chapters 6, 12, 13, 14 (excluding 14.3), 16, 17 and 19 of the DCD and the NRC SER with Open Items
APR1400 Subcommittee 6/20-21/2017	APR1400 Design Certification: Chapters 7 and 18 of the DCD and the NRC SER with Open Items
645th ACRS Meeting 7/12/2017	APR1400 Design Certification: Chapters 3, 4, 9 (excluding 9.1.2) and 15 (including adequacy of long-term cooling) of the DCD and the NRC SER with Open Items
646th ACRS Meeting 9/7/2017	APR1400 Design Certification: Chapters 7 and 18 of the DCD and the NRC SER with Open Items
APR1400 Subcommittee 10/17/2017	APR1400 Design Certification: Chapters 8 and 10 of the updated DCD and the NRC SER with No Open Items
APR1400 Subcommittee 11/14/2017	APR1400 Design Certification: Chapters 2 (excluding 2.5), 5, 11 and 12 of the updated DCD and the NRC SER with No Open Items
APR1400 Subcommittee 12/6/2017	APR1400 Design Certification: Updated APR1400 PRA information briefing
APR1400 Subcommittee 1/24/2018	APR1400 Design Certification: (1) Chapters 4, 14 (excluding 14.3), 16 and 18 of the updated DCD and the NRC SER with No Open Items; and (2) Topical Report "PLUS7 Fuel Design for the APR1400" and the NRC SER

ACRS MEETING/DATES	**SUBJECT**
APR1400 Subcommittee 2/21/2018	APR1400 Design Certification: Chapters 9, 19.3, 19.4 and 19.5 of the updated DCD and the NRC SER with No Open Items
651st ACRS Meeting 3/10/2018	APR1400 Design Certification: Topical Report "PLUS7 Fuel Design for the APR1400" and the NRC SER
APR1400 Subcommittee 4/17-18/2018	APR1400 Design Certification: (1) Chapters 2.5, 3, 7 and 15 of the updated DCD and the NRC SER with No Open Items, (2) Topical Report "Realistic Evaluation Methodology for Large-Break Loss of Coolant Accident of the APR1400 and the NRC SER, and (3) adequacy of long-term cooling
653rd ACRS Meeting 5/3/2018	APR1400 Design Certification: Topical Report "Realistic Evaluation Methodology for Large-Break Loss of Coolant Accident of the APR1400" and the NRC SER
APR1400 Subcommittee 6/5/2018	APR1400 Design Certification: Chapters 17 and 19 of the updated DCD and the NRC SER with No Open Items
654th ACRS Meeting 6/6/2018	APR1400 Design Certification: (1) Topical Report "Realistic Evaluation Methodology for Large-Break Loss of Coolant Accident of the APR1400" and the NRC SER and (2) adequacy of long-term cooling
APR1400 Subcommittee 6/19/2018	APR1400 Design Certification: Chapters 6, 13 and 14.3 of the updated DCD and the NRC SER with No Open Items
655th ACRS Meeting 7/11/2018	APR1400 Design Certification: Report on the Safety Aspects of the APR1400 Pressurized Water Reactor