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

February 21, 2017

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

SUBJECT: SAFETY EVALUATION OF TOPICAL REPORT, "FLUIDIC DEVICE DESIGN FOR THE APR1400"

Dear Mr. McCree:

During the 640th meeting of the Advisory Committee on Reactor Safeguards, February 9-11, 2017, we met with representatives of the NRC staff, Korea Electric Power Corporation and Korea Hydro & Nuclear Power Company, Ltd. (KHNP) to review the topical report, "Fluidic Device Design for the APR1400," and the associated staff Advanced Topical Report Safety Evaluation. This topical report was submitted by KHNP in support of APR1400 design certification. Our APR1400 Subcommittee reviewed this topical report and the other referenced documents during a meeting on December 14, 2016.

CONCLUSION

The safety injection tank fluidic device design, testing, and evaluation are acceptable and conform to the specified design and performance requirements.

BACKGROUND

The primary function of the emergency core cooling system (ECCS) is to provide water to limit core temperature rise during a loss of coolant accident (LOCA). During the refill stage of a LOCA, the safety injection tank (SIT) passively discharges water into the reactor coolant system once pressure has fallen below a specified level. The SIT with a fluidic device (SIT-FD) differs from current designs. It incorporates an internal fluidic device to provide passive flow control and long-term water injection; i.e., high water flow rate initially during refill for short times, followed by a lower flow rate for longer times during reflood. The SIT passively switches its flow rate from high-flow injection to low-flow injection after the water level in the tank drops below the top of a standpipe in the SIT. During a large-break LOCA, the SIT-FD passive injection extends water flow for a longer period of time, reduces inventory loss to bypass flow out the break, and allows more time to start the safety injection system pumps.

DISCUSSION

The topical report describes the SIT-FD design, its principles of operation, and important design features, as well as full-scale experiments confirming its performance. The staff's safety evaluation considered design, testing, and evaluation of uncertainties. The staff will consider the performance of the SIT-FD as part of the ECCS evaluation during the APR1400 design certification review.

SIT-FD Design

The APR1400 includes four SIT-FDs connected to the reactor coolant system via direct vessel injection nozzles. Each SIT-FD consists of a tank partially filled with borated water and pressurized with nitrogen, and a fluidic device inside the tank at its exit. The fluidic device structure allows for water flow in two parallel flow paths to the tank exit. One flow path has a small flow resistance and allows a high water flow rate through a standpipe and supply nozzles into the vortex chamber. The other flow path has a large flow resistance caused by small tangential flow control nozzles that create a lower water flow rate into the vortex chamber.

The design requirement for the total pressure loss coefficient of the SIT-FD injection flow path for the high flow phase is calculated based on the refill injection rate requirement, the SIT initial pressure, and the reactor coolant system depressurization transient. The design requirement for the allowable ranges of the total pressure loss coefficient of the SIT-FD injection flow path for the low flow phase is calculated based on the requirements of the minimum flow rate and injection duration to keep the downcomer filled with water and to preclude boil-off uncovering the core until the safety injection system pump injection begins.

SIT-FD Testing

Experiments were performed to confirm the principle and performance of the SIT-FD, the two-stage injection flow control, and the insensitivity of the pressure loss coefficients to the initial pressure, standpipe height, and expected manufacturing tolerances. Four series of full-scale performance verification tests were conducted at the Valve Performance Evaluation Rig (VAPER) test facility at the Korea Atomic Energy Research Institute to confirm the operational principles of the fluidic device, and examine the performance of the SIT-FD design. The four-test series involved 13 experiments to demonstrate flow behavior and test reproducibility by varying the initial pressure, standpipe height, fluidic device nozzle manufacturing tolerances, as well as its tangential angle. The results confirmed that flow performance is insensitive to these variations. Since these were full-scale experiments, no scaling analysis was required.

The staff evaluated the full scale testing results and confirmed the performance during high and low flow injection phases. Based on discussions with the staff, KHNP performed a computational fluid dynamic analysis that qualitatively confirmed vortex formation inside the fluidic device, as well as cavitation effects, which were accounted for in the VAPER testing program during high and low flow injection phases. The design requirements of the SIT-FD are satisfied by the full-scale experimental test results and associated computational results by KHNP.

Effect of Dissolved Gases

In the APR1400, the SIT water inventory is in contact with pressurized nitrogen. Over time, nitrogen will dissolve and saturate the liquid phase. As water flows through the fluidic device, pressure drops allowing dissolved nitrogen to come out of solution increasing the resistance to flow. The VAPER tests used compressed air as the cover gas, but there was not an effort to assure in the tests that the water was saturated with dissolved gas.

To evaluate the effect of dissolved nitrogen gas on the SIT-FD flow, KHNP provided a bounding estimate of nitrogen released from solution during the entire injection period. Based on the review of KHNP's calculation, the staff found that the results are acceptable because the effect of nitrogen release on flow and the pressure loss coefficient is negligible.

Uncertainty Analysis

The total uncertainty of the pressure loss coefficient developed from the full-scale testing of the fluidic device was computed by systematically evaluating uncertainty contributions from parameters including, but not limited to, water injection flow rate and pipe cross sectional area. The uncertainties were analyzed at a 95% confidence level. The staff reviewed and accepted the KHNP uncertainty analysis and confirmed that the specified requirements are met by the test results plus uncertainty.

SUMMARY

The SIT-FD design, testing, and evaluation are acceptable and conform to the specified design and performance requirements. Approval of the complete APR1400 ECCS design requirements, which are intended by the applicant to comply with General Design Criterion 35 and 10 CFR 50.46(b), should be contingent upon staff review of KNHP's full spectrum LOCA evaluations.

Sincerely,

/RA/

Dennis C. Bley
Chairman

REFERENCES

1. Korea Electric Power Corporation & Korea Hydro & Nuclear Power Co., Ltd., Topical Report APR1400-Z-M-TR-12003-P, "Fluidic Device Design for the APR 1400," December 2012 (ML13018A194).

2. U.S. Nuclear Regulatory Commission, “Advanced Power Reactor 1400, Advanced Topical Report Safety Evaluations for the ‘KCE-1 Critical Heat Flux Correlation for Plus7 Thermal Design’ and the ‘Fluidic Device Design for the APR1400’,” October 25, 2016 (ML16230A224).

3. U. S. Nuclear Regulatory Commission, Advanced Topical Report Safety Evaluation, “Advanced Topical Report Safety Evaluation (ATRSE) by the Office of New Reactors of Topical Report APR1400-Z-M-TR-12002-P, Revision 0, ‘Fluidic Device Design for the APR1400’ Korea Hydro & Nuclear Power Co., Ltd. Project No. PROJ0782,” February 26, 2016 (ML16278A625).

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