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

May 2, 2013

Mr. R.W. Borchardt
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: WCAP-17116-P, "WESTINGHOUSE BWR ECCS EVALUATION MODEL: SUPPLEMENT 5- APPLICATION TO ABWR"

Dear Mr. Borchardt:

During the 603rd meeting of the Advisory Committee on Reactor Safeguards on April 11-12, 2013, we reviewed the licensing topical report (LTR), WCAP-17116-P, "Westinghouse BWR ECCS Evaluation Model: Supplement 5- Application to ABWR," and the associated NRC staff safety evaluation. On March 5, 2013, this matter was also reviewed in a joint meeting of our Thermal-Hydraulics Phenomena; ABWR; and Materials, Metallurgy, and Reactor Fuels Subcommittees. During these meetings, we had the benefit of discussions with representatives of the NRC Staff, Westinghouse, and the Nuclear Innovation North America LLC. We also had the benefit of the documents referenced.

RECOMMENDATION

The Westinghouse BWR ECCS Evaluation Model-Supplement 5 LTR (WCAP-17116-P) should be approved for application to Advanced Boiling Water Reactor (ABWR) designs, subject to the conditions and limitations imposed by the staff.

BACKGROUND

Westinghouse is requesting approval of several topical reports that extend existing BWR methods to ABWR designs in support of fuel license amendments that would be submitted after a combined license is issued. Of these, WCAP-17116-P deals with application of the Westinghouse BWR Appendix K methodology to ABWR Emergency Core Cooling System (ECCS) - loss of coolant accident (LOCA) evaluations.

The BWR ECCS methodology in the WCAP-17116-P is based on analyses performed with the thermal-hydraulics code, GOBLIN, coupled to the fuel heat up code, CHACHA-3D. GOBLIN, the first version of which was approved by the NRC in 1989, is based on a one-dimensional drift flux model and assumes thermal equilibrium between the phases. For the proposed ABWR application, GOBLIN analyzes core thermal-hydraulic behavior with hot sub-channels placed in parallel with average sub-channels into which the rest of the core is lumped. CHACHA-3D is a one dimensional code that uses GOBLIN inputs to calculate various fuel parameters of interest in a core axial plane. The methodology is based on assumptions in conformance with those required for Appendix K evaluation models and has been approved for use in the U.S. for BWR 2 to 6 plant designs.

With regard to the proposed application to ABWRs, no code changes have been made to either GOBLIN or CHACHA-3D. Unlike the BWR 2 to 6 plants which have external recirculation loops and pumps, ABWRs incorporate reactor internal pumps (RIPs). In LOCAs with simultaneous loss of offsite power (LOOP), the RIPs coast down faster than external recirculation pumps. The WCAP-17116-P methodology must be evaluated for these more rapid pump coastdowns and associated dryout conditions.

Because the ABWR design eliminates the potential for large pipe breaks below the active fuel level, prolonged periods of core uncovery during blowdown and reflood are not expected. Nonetheless, the capability of the WCAP-17116-P methodology to conservatively predict minimum coolant inventory and core uncovery phenomena in ABWRs during the pump coastdown phase prior to ECCS initiation requires evaluation.

DISCUSSION

The WCAP-17116-P methodology incorporates the conservatisms inherent in Appendix K based evaluation models. Of particular interest for ABWR LOCA/LOOP scenarios are conservatisms in decay heat level, initial hot assembly power, and no clad rewetting after initiation of dryout. All 10 RIPs are assumed to simultaneously coast down with a time constant well below one second.

To elucidate the applicability of the Westinghouse evaluation model to ABWRs, calculations have been done for several large breaks which are all above the active fuel. These include main steamline, feedwater line, residual heat removal suction line, and high pressure core flooder (HPCF) line breaks. In addition, small (0.02 ft^2) breaks such as the bottom drain line break, which is well below the fuel, were evaluated. The staff evaluated selected predictions of the WCAP-17116-P methodology by performing confirmatory analyses. These analyses used the two-fluid thermal-hydraulics code, TRACE, which allows for both mechanical and thermal nonequilibrium between the phases, in contrast to the drift flux (mixture type) model in GOBLIN. Because TRACE is a best estimate code, some input parameters were adjusted to better reflect the Appendix K approach.

In both sets of calculations, the peak clad temperatures (PCTs) occurred during the coast down of all RIPs and before ECCS actuation. PCT was highest for the lowest initial core flow and fastest turbine valve closures. No core uncovery was calculated during this period.

The phenomena that most influence the early fuel temperature transient appear to be the initial energy stored in the fuel and the time at which dryout occurs. Temperatures fall after reaching PCT as the decay heat generation rate falls below the post-dryout heat transfer rate. The break size has little direct effect on clad temperatures, which are primarily affected by dryout caused by loss of flow due to RIP coastdown.

GOBLIN, with the proprietary Westinghouse dryout correlation and with fine enough nodalization, has been well validated against transient flow and power data taken with full-length 24-rod sub-bundles in the FRIGG facility. Based on these comparisons and provided that sufficient (> 25) core nodes are used, the GOBLIN dryout predictions appear to be reliable. The TRACE dryout correlation is from the open literature and has not been tested in the rapid flow and power transients calculated in ABWR LOCA/LOOP scenarios.

In spite of these differences in dryout correlations and some differences in the calculated initial conditions, the TRACE clad temperature transients are similar to those in the WCAP-17116-P predictions. TRACE calculates lower PCT but this should not be considered as arising solely from conservatisms in the WCAP-17116-P methodology. Rather, the lower PCT in TRACE may be due to prediction of lower initial fuel temperatures and the use of a different dryout correlation. However, given the large margins to all LOCA acceptance criteria in both sets of calculations, the differences between them appear to be minor and support approval of the WCAP-17116-P methodology to ABWRs.

Actuation of ECCS occurs after the time at which PCT is calculated, according to analyses by both the WCAP-17116-P methodology and TRACE. As all potential large breaks are above the active fuel, the minimum coolant inventory in the system occurs well after ECCS initiation and is lowest for the feedwater line break in the WCAP-17116-P calculations. No core uncovery is calculated except for the HPCF line break where a brief period (~100 seconds) of uncovery for the lower power assemblies is calculated at about 300 seconds into the transient. While good mixing of emergency coolant is expected in this case, a bounding calculation was also done by Westinghouse to clarify the effects of incomplete mixing, which could lead to less level swell and a lower two-phase level. These calculations indicated some increase in the uncovery time and the clad temperature (~660 ºF). Nonetheless, the temperatures were still well below the PCT obtained in the pump coastdown period, which in turn exhibit large margins to the Appendix K acceptance criteria. Even the brief period of uncovery at the top of the lower power assemblies could be a result of the Appendix K assumptions. The TRACE predictions, which are closer to ‘best’ estimates, indicate no period of core uncovery at all. Further, the coolant inventory behavior for the various scenarios in the TRACE study follow similar trends to those seen in the WCAP-17116-P calculations. This confirms the applicability of the WCAP-17116-P methodology to ABWRs after ECCS actuation.

The WCAP-17116P methodology has been validated against the FRIGG transient dryout experiments, and confirmed by TRACE calculations for PCT and minimum coolant inventory. For the ABWR, the WCAP-17116-P methodology calculates large margins to Appendix K acceptance criteria. The Westinghouse BWR ECCS Evaluation Model-Supplement 5 licensing topical report, (WCAP-17116-P) should be approved for application to ABWR designs, subject to the conditions and limitations imposed by the staff.

Sincerely,

/RA/

J. Sam Armijo
Chairman

REFERENCES

1. WCAP-17116-P, Revision 0**,** "Westinghouse BWR ECCS Evaluation Model: Supplement 5-Application to the ABWR," September 2009 (ML092810301) (Proprietary).

2. Final Safety Evaluation by the Office of New Reactors Licensing Topical Report WCAP-17116-P, "Westinghouse BWR ECCS Evaluation Model: Supplement 5-Application to the ABWR," Westinghouse Electric Company Project No. 0772 (ML13032A156) (Proprietary).

3. Standard Review Plan, (SRP) Section 15.0.2, "Review of Transient and Accident Analysis Methods," U.S. NRC, March 2007.

4. P. Sawant, et al., "Technical Evaluation Report of the Westinghouse BWR ECCS Evaluation Model: Supplement 5 – Application to ABWR," Energy Research, Inc. (ERI)/U.S. Nuclear Regulatory Commission (NRC) 11-207, March 2012 (ML12353A627) (Proprietary).

5. Summary Report for February 15-17, 2011 Audit, Licensing Topical Report WCAP-17116P, "Westinghouse Boiling Water Reactor Emergency Core Cooling System Evaluation Model: Supplement 5-Application to the Advanced Boiling Water Reactor," June 28, 2011 (ML111810561), (OUO Sensitive Internal Information, Proprietary).

6. Scott Krepel, NRC/RES, TRAC/RELAP Simulations of Toshiba ABWR LOCA Analyses, August 23, 2012 (Proprietary).

7. ERI/NRC 12-210, TRACE Calculation Notebook: Toshiba-ABWR (ML12263A176) (Proprietary), September 2012.

8. Letter from S. Head to the NRC Document Control Desk, "South Texas Project Units 3 and 4 Docket No. PROJ0772 Supplement 1 - Responses to Request for Additional Information, U7-C-NINA-NRC-110052, April 18, 2011 (Proprietary), (ML1111A207).

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