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

July 19, 2016

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

SUBJECT: TOPICAL REPORT WCAP-16996-P, VOLUMES I, II AND III, REVISION 1, "REALISTIC LOSS-OF-COOLANT ACCIDENT EVALUATION METHODOLOGY APPLIED TO THE FULL SPECTRUM OF BREAK SIZES"

Dear Mr. McCree:

During the 635th meeting of the Advisory Committee on Reactor Safeguards (ACRS), July 6-8th, 2016, we reviewed the Westinghouse Electric Corporation (Westinghouse) licensing topical report WCAP-16996-P, Volumes I, II, and III, Revision 1, "Realistic Loss-of-Coolant Accident Evaluation Methodology Applied to the Full Spectrum of Break Sizes" and the NRC staff's draft final safety evaluation report (SER). Our Thermal-Hydraulics Phenomena Subcommittee reviewed this matter in Subcommittee meetings on August 19, 2014, November 4, 2014, June 9, 2015, and April 19, 2016. During these reviews, we had the benefit of discussions with the staff and Westinghouse representatives. We also had the benefit of the referenced documents.

CONCLUSION AND RECOMMENDATIONS

1. The Westinghouse methodology described in WCAP-16996-P is acceptable for meeting the regulatory requirements of 10 CFR 50.46, provided the methodology adheres to the staff's limitations and conditions in the draft final SER and the additional constraint discussed below.

2. The draft final SER limitations and conditions need to be updated to identify clearly all the parameters and assumptions that need to be reviewed in future submittals. These limitations and conditions need to be referenced to the appropriate sections of WCAP-16996-P, Volumes I, II, and III, Revision 1 and the corresponding Westinghouse licensing letters.

BACKGROUND

Westinghouse has developed a methodology to analyze the thermal-hydraulic behavior of a pressurized water reactor (PWR) during a loss of coolant accident (LOCA) for the full range of postulated pipe break sizes; i.e., Region I for small breaks and Region II for intermediate and large breaks. This Full Spectrum LOCA (FSLOCA) methodology is documented in revision 1 of the WCAP-16996-P topical report: Volume I, "WCOBRA/TRAC-TF2 Models and Correlations;" Volume II, "WCOBRA/TRAC-TF2 Assessment;" and Volume III," Full Spectrum LOCA

Uncertainty Methodology and Demonstration Plant Analysis."

The FSLOCA methodology is based on the Westinghouse Evaluation Model, which was only approved for large-break LOCAs (LBLOCAs) and is described in topical report, WCAP-16009-P-A, "Realistic Large-Break LOCA Evaluation Methodology Using the Automated Statistical Treatment of Uncertainty Method (ASTRUM)." The new FSLOCA methodology extends the applicable use of the WCOBRA/TRAC code and analytical methods to include the treatment of small-break LOCAs (SBLOCAs) (i.e., Region I) and intermediate-break LOCAs. Aside from changes in the code suite, the treatment of intermediate-break LOCA and LBLOCA scenarios (i.e., Region II) remains essentially the same as the ASTRUM methodology.

The FSLOCA methodology has attempted to follow the NRC's Code, Scaling, Applicability, and Uncertainty (CSAU) methodology, and has followed Regulatory Guide 1.203. During the staff review, the applicant updated the FSLOCA methodology and incorporated changes that addressed the staff review findings in Revision 1 of WCAP-16996-P. Changes were incorporated into Revision 1 of Volume I, Volume II and Volume III. Subsequently, additional revisions were made to Volume III and approved by the staff. The staff review focused on those portions of WCAP-16996-P related to SBLOCAs. Currently, analyses of SBLOCA are performed using the Westinghouse NOTRUMP SBLOCA Evaluation Model previously approved by the NRC staff and described in topical report WCAP-10079-P-A, "NOTRUMP - A Nodal Transient Small-Break and General Network Code."

DISCUSSION

Regulatory Scope

The staff review focused on the applicability of the FSLOCA Evaluation Model for performing best estimate analyses for the entire LOCA spectrum in Westinghouse designed three-loop and four-loop PWR plants. Once the methodology is approved for these plant types, the applicant plans to seek approval for Westinghouse two-loop plants with upper plenum injection and Combustion Engineering designs. The FSLOCA Evaluation Model is intended to be applicable to Westinghouse PWRs with dry containments, as well as ice-condenser containments.

The proposed FSLOCA methodology must satisfy the regulatory requirements set forth in 10 CFR 50.46. Additional guidance is provided by Regulatory Guides 1.157 and 1.203, and NUREG/CR-5249. The staff concluded that the FSLOCA methodology followed the evaluation model development and assessment process, as described in Regulatory Guide 1.203. The staff also concluded that the FSLOCA quality assurance requirements and documentation requirements were fulfilled. The WCOBRA/TRAC-TF2 code satisfied the general purpose computer program requirements for three-loop and four-loop Westinghouse PWRs. It is not applicable to long-term cooling over a period of days, since it lacks boric acid precipitation models. We concur.

Phenomena Description

The LOCA scenario postulates an instantaneous rupture of a reactor coolant pipe in combination with the most limiting single failure in the emergency core cooling system (ECCS). Given actuation setpoints and safety system designs of the ECCS, a typical break spectrum analysis produces a characteristic peak cladding temperature (PCT) versus pipe break area that goes through a maximum for small breaks (typically < 1.0 ft^2), and increases again to another maximum for large pipe break areas. The PCT is one of three figures of merit that are tracked to

assure adequate core cooling. The other two are the cladding maximum local oxidation (MLO) and the cladding core-wide oxidation (CWO). The PCT is typically a good indicator of the trend for all three figures of merit.

Small pipe breaks are more limiting than large breaks for certain PWRs. During small pipe break accidents, the reactor coolant system depressurizes slowly. The reactor pressure remains above the accumulator setpoint (typically 600 psia) for up to an hour. During this time, the core uncovers; i.e., the two-phase liquid level falls below the top of active fuel. Because of the high decay heat shortly after shutdown, core uncovery can cause a significant increase in the PCT. It is important to note that for some PWR plants, the PCT can increase by as much as 100°F, when the break area changes by as little as 0.005 ft^2 in this region; e.g., the PCT at a 0.055 ft^2 break is considerably higher than the PCTs at both 0.05 ft^2 and 0.06 ft^2 breaks. In some cases, the two-phase mixture level in the core can recede slowly to levels near the core mid-plane before the accumulator discharges, thus, causing the PCT, MLO, and CWO to increase. Thus, it is important that FSLOCA plant applications identify the region in which the limiting break size occurs.

Evaluations of long-term core uncovery LOCAs emphasize the importance of models that predict the two-phase mixture level, within the reactor core. Clearly, with the core potentially becoming uncovered for a period of an hour or more, small changes in the core two-phase mixture level during such periods can result in large PCT changes. Therefore, modeling of two-phase level swell is perhaps one of the more important phenomena governing the SBLOCA response. It is necessary to have models capable of predicting the key phenomenological behavior governing the two-phase level response in the vessel (i.e., upper plenum, core, and lower plenum), as these models will determine the depth and duration of any potential core uncovery. Calculations with models governing the SBLOCA response are sensitive to two-phase phenomena that have inherent uncertainties such as interfacial drag that affects two-phase level swell in the core, loop seal dynamics, condensation during ECCS injection, core bypass effects, steam heat transfer above the two-phase level, and steam generator condensation and liquid hold-up. The interaction of these models determines the core two-phase mixture level in the reactor vessel that directly affects the magnitude of the PCT, MLO, and CWO.

SBLOCA Analysis Approach

In the draft final SER, the staff has approved an approach with limitations and conditions for the WCOBRA/TRAC-TF2 code simulations. The analysis would first identify the limiting break area for the SBLOCA spectrum in Region I, by systematically examining a range of break areas (< 1 ft^2) using a set of limiting two-phase model parameters and initial conditions that create a conservative bias toward larger PCT values. Once this break area has been determined, the uncertainties for this specific break are estimated following the CSAU guidance by sampling a limited set of model parameters defined in the FSLOCA methodology. Other model parameters and loop seal limiting conditions as noted in Table 22 of the draft final SER are not sampled, but are specified to provide a conservative bias. This approach overcomes the limited integral experimental database for code validation and the shortcomings associated with the two-phase level swell models. With these limitations and conditions, the staff is confident that SBLOCA results using the FSLOCA methodology will meet the PCT, MLO and CWO criteria with an acceptable confidence level. We concur with this approach.
We recommend that agreements reached between the staff and the applicant related to the FSLOCA Evaluation Model analyses procedures and inputs be clearly documented and referenced in the final SER. The current draft final SER lacks the required clarity and

completeness to enable the staff to efficiently review plant-specific applications, using this method for future licensing submittals. The draft final SER states that such plant-specific applications of the FSLOCA will "generally be considered acceptable" if they follow analysis guidance that has yet to be developed by the applicant to meet requirements described in WCAP-16996-P, as well as comply with the limitations and conditions identified in draft final SER Table 22. The table does not identify all of the agreed upon analysis procedures and inputs cited within the draft final SER text (or WCAP-16996-P), and some limitations are not discussed in the draft final SER text. Because the Westinghouse analysis guidance documents are normally not submitted or reviewed by the staff prior to issuance of the final SER, it is important that the staff ensures that the final SER clearly and consistently identifies all of the agreed upon analysis procedures and inputs with appropriate references to the applicant's documentation for additional information.

Uncertainty Analysis Procedure

The analysis procedure that involves treatment of uncertainties in the Westinghouse FSLOCA methodology is different between Region I and Region II. In Region I, the limiting break size is first determined by a variation of the break area and initial conditions, using a set of conservative model parameters and assumptions. Once the break area with the largest PCT has been determined, then the uncertainty is determined by sampling a limited set of model parameters.

In contrast, for Region II, the sampling of the break area and initial conditions (e.g., the axial power shape and pipe discharge coefficient) is combined with the sampling of a broad set of model parameters. The methodology in Region II does not explicitly follow the CSAU methodology as described in NUREG/CR-5249, since it does not first define the unique scenario, which in this case would be a limiting break size and initial conditions. The LBLOCA break size is sampled with equal probability between a double-ended guillotine break and a split break. While the double-ended guillotine break size is maintained constant, the split break sizes are sampled down to a minimum break size as small as 1 ft^2. By taking this analysis approach, the resulting uncertainty statistics are diluted by the non-limiting breaks. Thus, the confidence level on the limiting figure of merit is not well defined in the Region II methodology.

A different approach, which could be taken for Region II, would involve finding the limiting break size first. Using this limiting break size and initial conditions, the uncertainty of the figures of merit can be evaluated by sampling the model parameters. This would provide the uncertainty range on the figures of merit (PCT, MLO and CWO) and would be more consistent with the CSAU methodology, which clearly establishes a confidence level.

While this approach is desirable, the LBLOCA involves phenomena that make it intractable, because Westinghouse analysis shows that the calculated figures of merit have complex dependencies on parameters other than the break size. Therefore, a larger parameter set needs to be varied to define the most severe LBLOCA, as required by 10 CFR 50.46. Thus, there really is no one limiting break size, but rather a range of break sizes, where the figures of merit may be limiting and should be examined.

The Region II approach used by Westinghouse has been approved in the draft final SER based on the following considerations. First, the Region II approach is similar to the approved ASTRUM methodology for current LBLOCA analyses. Second, the governing regulatory guide does not specify a confidence level, but simply specifies a "high confidence" in the results. While the Region II analysis approach is different than the Region I approach, we find this to be appropriate

given the differences in the phenomena that govern the LOCA acceptance criteria, i.e., PCT, MLO, and CMO.

General Comment

Improvements in analysis methodology are not always the only approach, especially in cases where changes in plant configuration may increase margins sufficiently. For example, in SBLOCA cases, a controlling parameter is the accumulator setpoint, which determines the actuation time. Advanced calculational capabilities or improved instrumentation can be used to optimize these setpoints. A process by which licensees and vendors continuously revise not only their codes and methodologies, but also question the old design assumptions may result in plant configuration changes that can be beneficial for safety.

SUMMARY

Westinghouse has adopted the approved ASTRUM methodology using the WCOBRA/TRAC code to perform large-break LOCA ECCS performance evaluations for both Westinghouse 3-loop and 4-loop PWR designs with cold-leg injection systems. WCAP-16996-P extends this methodology to small- and intermediate-break LOCA transients. This methodology is acceptable for meeting the regulatory requirements of 10 CFR 50.46 provided the methodology adheres to the staff limitations in the draft final SER.

Sincerely,

/RA/

Dennis C. Bley
Chairman

REFERENCES

1. Westinghouse Electric Company, "Submittal of Westinghouse WCAP-16996-P Volume I, Revision 1, and WCAP-16996-NP, Volume I, Revision 1, 'Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology) – WCOBRA/TRAC-TF2 Models and Correlations,' (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244," April 14, 2015 (ML15112A377).

2. Westinghouse Electric Company, "Submittal of Westinghouse WCAP-16996-P Volume II, Revision 1 and WCAP-16996-NP Volume II, Revision 1, 'Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology),' (Proprietary/Non-Proprietary)," June 29, 2015 (ML15202A099).

3. Westinghouse Electric Company, "Submittal of Westinghouse WCAP-16996-P Volume III, Revision 1 and WCAP-16996-NP Volume III, Revision 1, 'Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (Full Spectrum LOCA Methodology),' (Proprietary/Non-Proprietary)," October 1, 2015, (ML15292A350).

4. U.S. Nuclear Regulatory Commission, “Final Safety Evaluation for Topical Report WCAP-16996-P/ WCAP-16996-NP, Volumes I, II, And III, Revision 1, ‘Realistic Loss-Of-Coolant Accident Evaluation Methodology Applied to the Full Spectrum of Break Sizes’ (TAC No. ME5244) Westinghouse Electric Company Project No. 700,” (ML16143A002).

5. Westinghouse Electric Company, WCAP-16009-P-A, “Realistic Large-Break LOCA Evaluation Methodology Using the Automated Statistical Treatment of Uncertainty Method (ASTRUM),” Proprietary/Non-Proprietary, January 2005 (ML050910156).

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8. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.157, “Best-Estimate Calculations of Emergency Core Cooling System Performance,” May 1989 (ML003739584).

9. U.S. Nuclear Regulatory Commission, NUREG/CR-5249, “Quantifying Reactor Safety Margins: Application of Code Scaling, Applicability, and Uncertainty Evaluation Methodology to a Large-Break, Loss-of-Coolant Accident,” December 1989 (ML030380473).

10. Westinghouse Electric Company, “Summary of July 2013 NRC Code Workshop and August 2013 NRC Audit of the FULL SPECTRUM LOCA (FSLOCA) Evaluation Model (Proprietary/Non-Proprietary),” October 10, 2013 (ML13297A471).

11. Westinghouse Electric Company, “Submittal of Westinghouse Responses to ‘WCAP-16996-P, “Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)” Request for Additional Information - Third Set’ (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244.,” May 30, 2013 (ML131560255).

12. Westinghouse Electric Company, “Submittal of Westinghouse Responses to ‘WCAP-16996-P, “Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)” Request for Additional Information - Fourth Set’ (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244.,” May 30, 2013 (ML131690166).

13. Westinghouse Electric Company, “Submittal of Westinghouse Responses to ‘WCAP-16996-P, “Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)” Request for Additional Information - Second Set’ (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244.,” May 31, 2013 (ML131690416).

14. Westinghouse Electric Company, “Submittal of Westinghouse Responses to ‘WCAP-16996-P, “Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)” Request for Additional Information’ (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244.,” June 5, 2013 (ML131620442).

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18. Westinghouse Electric Company, “Submittal of Westinghouse Responses to ‘WCAP-16996-P, “Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)” Request for Additional Information – RAIs 36-39 (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244.,” March 24, 2014 (ML14090A018).

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21. Westinghouse Electric Company, “Submittal of Westinghouse Responses to ‘WCAP-16996-P, “Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)” Request for Additional Information – RAIs 77-82, 86-87, 93 and 112’ (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244.,” March 12, 2014 (ML14090A016).

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26. Westinghouse Electric Company, “Submittal of Westinghouse Responses to ‘WCAP-16996-P, “Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)” Request for Additional Information – Set 8 RAIs 122-126, 128-131 and 136’ (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244.,” February 12, 2014 (ML14051A641).

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methodology for current LBLOCA analyses. Second, the governing regulatory guide does not specify a confidence level, but simply specifies a “high confidence” in the results. While the Region II analysis approach is different than the Region I approach, we find this to be appropriate given the differences in the phenomena that govern the LOCA acceptance criteria, i.e., PCT, MLO, and CMO.

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Sincerely,
/RA/
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Chairman

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Letter to Mr. Victor McCree Executive Director for Operations, NRC, from Dennis Bley, Chairman, ACRS, dated July 19, 2016

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