UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

July 12, 2018

Mr. W. Anthony Nowinowski, Program Manager
PWR Owners Group, Program Management Office
Westinghouse Electric Company
1000 Westinghouse Drive, Suite 380
Cranberry Township, PA 16066

SUBJECT: REGULATORY AUDIT PLAN FOR JUNE 26-29, 2018, AUDIT OF CHANGES TO THERMAL HYDRAULIC METHODOLOGIES IN RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION FOR TOPICAL REPORT WCAP-17788-P "COMPREHENSIVE ANALYSIS AND TEST PROGRAM FOR GSI-191 CLOSURE" (EPID L-2015-TOP-0007)

Dear Mr. Nowinowski:

By letter dated July 17, 2015, PWR Owners Group (PWROG) submitted a licensing topical report (TR) intended for Generic Safety Issue (GSI)-191 closure, "Comprehensive Analysis and Test Program for GSI-191 Closure" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15210A668). The TR is an approach to define an in-vessel fibrous debris limit and provides a means for increasing the approved fibrous debris limit used by licensees to resolve GSI-191. On June 13, 2016, the U.S. Nuclear Regulatory Commission (NRC) staff issued requests for additional information (RAIs) for Volume 4 of the TR (ADAMS Accession No. ML16161A416). The PWROG responded to the Volume 4 RAIs on December 21, 2017 (ADAMS Accession No. ML18029A202).

The NRC staff has determined that a regulatory audit is needed to allow the NRC staff to gain a better understanding of detailed calculations and analyses in the December 21, 2017, RAI responses. The NRC staff will be performing a regulatory audit at Westinghouse offices in Rockville, Maryland on June 26-29, 2018. Enclosed for your information is a copy of the plan the NRC staff will follow on the audit.

Please contact Leslie Perkins at 301-415-2375 or via e-mail at Leslie.Perkins@nrc.gov with any questions you may have regarding this letter.

Sincerely,

/RA by Johnathan Rowley for/

Dennis C. Morey, Chief
Licensing Processes Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket: 99902037

Enclosure:
Audit Plan (Non-Proprietary)

SUBJECT: REGULATORY AUDIT PLAN FOR JUNE 26-29, 2018, AUDIT OF CHANGES TO THERMAL HYDRAULIC METHODOLOGIES IN RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION FOR TOPICA REPORT WCAP-17788-P “COMPREHENSIVE ANALYSIS AND TEST PROGRAM FOR GSI-191 CLOSURE” (EPID L-2015-TOP-0007) DATED JULY 12, 2018

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AUDIT PLAN

CHANGES TO THERMAL HYDRAULIC METHODOLOGIES

IN REQUST FOR ADDITIONAL INFORMATION RESPONSE FOR WCAP-17788-P

PRESSURIZED WATER REACTOR OWNERS GROUP

1. BACKGROUND

By letter dated July 17, 2015, Pressurized Water Reactor Owners Group (PWROG) submitted a topical report (TR) intended for Generic Safety Issue (GSI)-191 closure, "Comprehensive Analysis and Test Program for GSI-191 Closure" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15210A668). The TR is an approach to define an in-vessel fibrous debris limit and provides a means for increasing the approved fibrous debris limit used by licensees to resolve GSI-191. On June 13, 2016 the U.S. Nuclear Regulatory Commission (NRC) staff issued requests for additional information (RAIs) for Volume 4 of the TR (ADAMS Accession No. ML16161A416). The PWROG responded to the Volume 4 RAIs on December 21, 2017 (ADAMS Accession No. ML18029A202).

The NRC staff has determined that an audit of the TR will increase efficiency in the review. This audit will allow the NRC staff to gain a better understanding of detailed calculations and analyses in the December 21, 2017, RAI response.

2. REGULATORY AUDIT SCOPE

This scope of this audit includes changes to the thermal hydraulic models and methodologies included in the responses to RAIs for Volume 4 of the TR.

3. INFORMATION NEEDS

The PWROG is requested to have the documents used to create the December 21, 2017, RAI response related to the areas of focus listed below available for the audit team. The documentation could be provided electronically or by paper copies. For documentation provided electronically, understand that the audit team may choose to print if necessary. The following are the planned major areas of focus for detailed discussion and document review. Additional information needs identified during the audit will be communicated to the designated point of contact. Specific questions related to the December 21, 2017, RAI response are included in Appendix A.

1) Combustion Engineering (CE) plant category

    a. Initial and boundary conditions
        i. Justification for using chosen decay heat multiplier/uncertainty
        ii. Justification for axial power profile assumptions
        iii. Justification for emergency core cooling system (ECCS) performance simulation, determining limiting scenarios, and ECCS rate scalability
        iv. Applicability of alternate flow path (AFP) resistances under low/stagnant flow conditions
        v. Application of core inlet resistances to determine K_{max}, K_{split}, m_{split}

b. Code performance
    i. Code and plant model have been modified since original submittal
        1. Validation and verification of modified “conditionally certified code”
        2. Validation of modified plant model
    ii. Code validation at low/stagnant flows with long transient times
        1. Code capabilities to simulate flows in primary loops
    iii. Void fraction in the core and upper plenum (UP) needs justification
    iv. Interfacial drag multiplier used needs justification
    v. Concerns regarding modeling of upper plenum, its connection to core/ broken hot leg (HL), UP water drainage
    vi. Solution convergence, consistency between assessment (rod bundle heat transfer) and plant analysis
    vii. Identification of bundle boil-off tests that can be applied to validate the codes from 20,000 to 30,000 seconds

2) Westinghouse plant categories

a. Initial and boundary conditions
    i. Initial reactor power and power uncertainty
    ii. Justification for axial power profile assumptions
    iii. Assumptions for ECCS flow rate, temperature, injection location, determining limiting scenarios, and ECCS rate scalability
    iv. Applicability of AFP resistances under low/stagnant flow conditions
    v. Application of core inlet resistances to determine K_{split} and m_{split}
    vi. Applied downcomer flow rates to determine K_{split} and m_{split} ratios

b. Code performance
    i. Code has been modified since original submittal
        1. Confusion over which results are from which code version (original or modified) in Volume 4 analyses/code assessment
        2. Consistency of results
        3. Validation and verification of modified code
    ii. Concerns regarding modeling of upper plenum, its connection to core/ broken HL, and UP water drainage
    iii. Void fraction in the core and UP needs justification
    iv. Interfacial drag multiplier used needs justification
    v. Mass balance error check and solution convergence
    vi. Modeling of non-condensable gases
    vii. Code validation at low/stagnant flows with long transient times
    viii. Code capabilities to simulate flows in primary loops

4. TEAM ASSIGNMENTS

The audit team will consist of:

- Ashley Smith, Reactor Systems Branch Technical Reviewer, Office on Nuclear Reactor Regulation (NRR)
- Ben Parks, Nuclear Performance and Code Branch Technical Reviewer, NRR
- Steve Smith, Technical Specifications Branch (STSB) Technical Reviewer, NRR

- Victor Cusumano, Chief, STSB, NRR
- Vesselin Palazov, Contractor, Information Systems Laboratories
- Leslie Perkins, Project Manager, Licensing Processes Branch, NRR

The following support personnel are requested:

- WCOBRA/TRAC code developers for the Westinghouse upflow and Westinghouse downflow plant categories in WCAP-17788-P
- WCOBRA/TRAC plant model developers and loss-of-coolant accident (LOCA) analysts for the Westinghouse upflow and Westinghouse downflow plant categories in WCAP-17788-P
- S-RELAP5 code developers for the CE and Babcock & Wilcox (B&W) plant categories in WCAP-17788-P
- S-RELAP5 plant model developers and LOCA analysts for the CE and B&W plant categories in WCAP-17788-P

5. <u>LOGISTICS AND AGENDA</u>

The audit will be conducted at the Westinghouse office in Rockville, MD, from June 26 to June 29, 2018. Entrance and exit briefings will be held at the beginning and end of this audit, respectively.

The following logistics are also requested:

- Telephone available to call NRC Headquarters if necessary
- Wireless internet access for NRC staff
- Private space for internal NRC staff discussion separate from the PWROG staff
- A white board in the conference room to assist in discussion
- A projector and screen as needed to present information

Suggested Agenda:

Tuesday, June 26th

8:00 am	Introductions and opening remarks
8:30 am	Westinghouse discussions of audit questions
10:00 am	Break
10:15 am	Continue Westinghouse discussions
12:00 pm	Lunch
1:00 pm	Discussion of Westinghouse audit questions
2:00 pm	Break
2:15 pm	Continue Westinghouse discussions
4:00 pm	Wrap up meeting

Wednesday, June 27th

8:00 am	Continue Westinghouse discussions/Review Westinghouse documentation
10:00 am	Break
10:15 am	Continue Westinghouse discussions/Review Westinghouse documentation
12:00 pm	Lunch
1:00 pm	B&W discussion of audit questions
2:00 pm	Break

2:15 pm Continue B&W discussions
4:00 pm Wrap up meeting for CE and B&W items

Thursday, June 28th
8:00 am CE Discussion of audit questions
10:00 am Break
10:15 am Continue CE Discussions
12:00 pm Lunch
1:00 pm Discussions of CE audit questions
2:00 pm Break
2:15 pm Continue CE discussions
4:00 pm Wrap up meeting

Friday, June 29th
8:00 am Continue CE discussions/ Review CE documentation
10:00 am Break
10:15 am Wrap up meeting for CE items
11:00 am Exit meeting

6. SPECIAL REQUESTS

It is requested that the material presented by PWROG during the audit be provided electronically to the audit team to be included in the audit report.

7. DELIVERABLES

Within 45 days of the audit, the NRC staff will prepare a detailed audit report documenting the information reviewed during the audit, and any open items identified as a result of the audit. The NRC staff will also document its understanding of the proposed resolution of any identified open items. The audit report will be provided to PWROG in draft form for proprietary markup.

Appendix A – Questions for Discussion

Overall Comment:

There have been extensive revisions to the thermal-hydraulic methodology thus far. If an overall revision to the submittal is not provided, a roadmap of revisions since the initial submittal would be very helpful.

Combustion Engineering RAI Responses (ANP-3583P)

The following issues are identified as potentially having a significant effect on the analysis. That is, variation of these parameters could cause calculated peak cladding temperature (PCT) to exceed the acceptance criteria at the current t_{block} time or cause the t_{block} time to increase.

1. Axial Power Profile (RAI 4.5.a)

    a. Further justification is needed concerning the axial power profile. How does the axial power profile modeling account for uncertainties?

    b. The response states that the analysis is late in the core transient so axial profile is not as skewed as soon after the event. What is the basis for this statement considering that the analysis begins at sump switchover (SSO)?

    c. Use of a more bounding axial power profile could address issues with uncertainties and level of conservatism. Consider analyzing a small break loss of coolant accident (SBLOCA) profile.

2. RAI response 4.1.b states "A 1.1 multiplier (10% positive uncertainty) adds additional conservatism to the evaluation, representing the maximum value of uncertainty for the period where relevant phenomena of interest occur, while still being a reasonably high conservative value for the first 1000 seconds, when it amounts to 50% of the maximum positive uncertainty." The first 1000 seconds, therefore, do not completely account for uncertainty in the analytic method. Show that when all uncertainty is accounted for, the results at 1000 seconds are essentially the same as those used in the current analyses. Alternatively, use a bounding multiplier.

3. Upper Plenum (UP) Modeling (RAI 4.7, 4.8.a, 4.23)

    a. Provide modeling (noding) of the UP and connected flow paths.

    b. How were the resistances developed? Are the values the same for all plants?

    c. Are any special model options activated for any of the node junctions?

    d. Modeling of drainage from UP to core when the core is blocked. Should the evaluation eliminate all drainage to core?

    e. Provide forward/backward flow resistance coefficients for the junctions connecting the UP to the core components in the "transition package" and in the new CE GSI-191 UP model. Provide the same information for the junctions connecting the UP to the HLs.

f. Describe the treatment of liquid fall back from UP in the core for each of the core components. Provide plots of liquid flows and steam flows through the junctions. Justify any fallback to the core from the UP during and following core blockage considering counter current flow limitation (CCFL) and the geometry of the region being analyzed.

4. Show that the k_{split} and m_{split} analyses considered the change in core flow resistance as driven by the change in boiling rate. Does the timing of the core inlet resistance shown in Figure RAI-20.1 affect the analysis? Can code driven oscillations significantly affect the timing of the analysis? (RAI 4.20)

5. How will it be assured that plants use the correct limiting single failure for the k_{split}/m_{split} and the t_{block}/k_{max} evaluations as these may be different? (RAI 4.20)

6. What method would be used to interpolate and extrapolate the k_{split} curve to different flow rates? The lower flow rate data appears to be less consistent than the higher flow rate data. Could this have an impact on the extrapolation? The updated results from RAI 4.20 are based on a line fitted from the original WCAP data which are not fully representative of the new data, especially at low flow rates. This may also apply to flow rates calculated using the method provided in RAI 4.5(a). (RAI 4.21 and RAI 4.25(d))

7. Is the code vulnerable to recirculating flow anomalies? How was this evaluated? (RAI 4.7)

8. Describe the decay heat curve in Figure RAI-4.10-1. The curve appears to be significantly different from typical decay heat curves. (RAI 4.10)

9. Describe why the use of 14.7 psi for containment pressure is bounding from a PCT perspective. (RAI 4.1(a) and RAI 4.5(a))

The following issues identify non-physical behavior of the code.

10. Void fraction and interfacial drag multiplier (RAI 4.8.a and RAI 4.9)

    a. Provide information to show the capability of the S-RELAP5 conditionally certified use/conditionally certified version/single-application code to predict mixture level swell and core void for the GSI-191 scenario.

    b. Address uncertainty in the results. The results in Figure RAI-4.8-1 overpredict the rod bundle heat transfer (RBHT) test data. **[**
    ] which indicates that the actual void fraction is lower than that predicted by the code. Table RAI-4.9-3 shows unphysical void fraction results.

    c. Identify the seven RBHT tests used to produce the results plotted in Figure RAI-4.8-1. Are all data from each test shown in this figure? Indicate the experimental error. Compare the nodalization of the RBHT test section model to the S-RELAP5 plant model. What are the differences (cell heights, spacer grids)? Justify that the differences between the model/code used for the test comparison and the plant analyses do not introduce bias in the results. Is the same S-RELAP5 code version used in the RBHT assessment as the new GSI-191 CE analysis of record (AOR)? If not, why?

d. Justify that the time step used in the analysis of the RBHT was adequate considering that the plant analysis was done using a **[ ]** second time step. How was numerical convergence controlled in RBHT assessment and the CE analyses?

e. Identify the bundle boil-off tests that can be applied to validate the codes from 20,000 to 30,000 seconds and justify any extension of the data by describing how it was accomplished.

f. Justify that the flow regimes and interfacial drag correlations in the code are appropriate for the modeled conditions. How were the conditions benchmarked?

   Explain the void fraction distributions that are provided in Tables RAI 4.9-2 and 3. Explain why the PCT occurs well after the void fraction in the node begins to decrease. Shouldn't the PCT be concurrent with the driest condition? Clarify "PCT node exit" and "PCT location" meanings.

g. Axial flow area and cross flow modeling. The axial flow area calculated from data in Table RAI-4.9-1 matches the initial submittal values, but is slightly different from one provided in the response to RAI 1.9 in Attachment 1 to Pressurized Water Reactor Owners Group (PWROG) letter LTR-SEE-17-2. How was the cross flow area calculated? The vapor axial and cross flow mass fluxes are significantly different, but the corresponding velocities are very close. Considering the flow areas, this does not appear to be a valid representation. Please explain. (RAI 4.9(b))

h. How was the cross flow transport between core regions modeled? How was the hot assembly cross-connected to the other core regions? For the cross-flow sensitivity studies, provide the locations and times at which the cross flow resistance was increased and the method used to implement the change in the core model. Describe why a 50% increase in resistance was used in the sensitivity and how the sensitivity was determined to provide meaningful results. Provide the base case and sensitivity case resistance values and explain how it was determined that cross flow resistance was increased by 50%. (RAI 4.27)

11. The PCT is calculated to occur when void fraction in the node is 1.0 and that liquid is not entrained with steam flowing into the node because the velocity is too low. In light of this, describe the heat transfer behavior depicted in Figure RAI-4.9-1. Also, how is it predicted that a mist flow regime (dry wall) occurs under these conditions as shown in Fig. RAI-4.9-2? Justify that the heat transfer mode and flow regime are appropriate or that the PCT response is insensitive. RAI 4.9 (c) and (d)

12. Explain why Case 25 did not result in core uncovery while all the other cases exhibited uncovery and have an increase in PCT. (RAI 4.16)

13. Is the saturated condition an adequate, conservative, simplifying assumption for the analysis? If the temperature increases, pressure has to go up. RAI 4.16(b) and (c)

14. Explain why Case 15 from RAI 4.16 has significantly different results than the base case when the only change is the emergency core cooling system (ECCS) temperature from 70°F to 110°F prior to SSO. It might be illustrative to plot the cases on the same graphs. Is 110°F a bounding temperature? (RAI 4.16(d))

15. Explain why the downcomer (DC) levels increase sharply after about 25,000 seconds in Fig. RAI-4.16-1. Explain the sharp increase in DC level shown in Figure RAI-4.20-5. Explain why this trend is only apparent for the higher flow cases. (RAI 4.20, RAI 4.16(d))

16. How were the abilities of the code to model the phenomena associated with the liquid discharge out the broken hot leg assessed? Consider these specific phenomena: two-phase mixture stratification, free surface formation, and level swell in the UP, and prediction of the two-phase flow regime in the hot leg (HL). The large oscillations in liquid flow may be numerically driven by the code. (RAI 4.17(c))

17. Provide an explanation for the magnitude of the vapor flow in the intact hot leg, following core blockage, indicated in Figures RAI 4.17-4 and 9. (RAI 4.17(d))

18. Show that the loss of coolant mass delivered to the DC as is evident from Figure RAI-4.17-8 does not adversely affect the analytical results.

The following issues require clarification during the audit to allow the NRC staff to determine if they are significant to the analysis and acceptance criteria as in Category 1, or the behavior of the code, as in Category 2.

19. Provide the number of fuel assemblies used in the analyses. (RAI 4.5(a))

20. What is the basis for the flow rates that range from 3.8 to 11.4 gallons per minute (gpm)? RAI 4.5(a)

21. Define “form losses provided by the analyst.” (RAI 4.7)

22. Was a reactor SCRAM or trip modeled into the simulation of the HL break scenario? (RAI 4.25(f))

23. The model assumes that flow from the high pressure safety injection (HPSI) pump is split evenly between all four cold legs (CLs). Is this alignment consistent with all plant designs? If not, justify that the assumption is acceptable. (RAI 4.24(h))

24. Provide the inputs used to develop the results in Fig. RAI-4.20-3 and 4 in separate plots. Provide plots for m_{BB}, m_{DC}, and the ECCS injection flow rates for the cases shown in the referenced figures. (RAI 4.20.)

25. How was the low flow regime ensured to be adequately represented by the calculations for the alternate flowpaths (AFPs)? Why is it acceptable to use nominal and historical dimensions to calculate loss coefficients? Are all AFPs credited larger than ¼ inch? (RAI 4.3)

26. Describe the flowpaths for liquid exiting the shroud region near the top of the core. Describe how these passages are modeled in the base CE model. Justify the modeling approach. Describe how the flow passages vary among the CE design plants and the applicability of results to the fleet. (RAI 4.3)

27. Describe the algorithms for calculating 10 and 20 second running averages. Compare the running average results with the individual results calculated and stored by the code. Identify the time frequency in the code for storing and plotting values. (RAI 4.9(c))

28. Provide the basis for the flow rates used in the k_{split} analysis. (RAI 4.20)

29. How was the timing of the core inlet differential pressure (dP) due to debris determined? Using testing as a basis for the amount of debris required to result in head loss may be justified, but does not justify timing. How was the assumed timing determined to be acceptable for the calculations? (RAI 4.26)

30. How was uncertainty related to heat transfer of single phase vapor at pressures close to atmospheric treated? (RAI 4.28)

31. For liquid that spills over the SG tubes in the broken loop SG, how is the fiber associated with the flow out of the break tracked? (RAI 4.30)

32. Provide nodalization diagrams (including details for AFP, core, UP, downcomer, and HL/CL) for the model used in the original submittal, as well as for the new CE AORs. Justify the use of taller axial nodes at the top of the core.

The following items identify apparent inconsistencies, book keeping issues, or errors in the submittal:

33. Bookkeeping issues with model, calculational notebooks, references. (RAI 4.1(b), RAI 4.5(a), RAI 4.6(b), RAI 4.6(c), RAI 4.7, and RAI 4.29)

    a. The pedigree, development, and documentation of the S-RELAP5 GSI-191 code version used in the new CE AORs leads to clarity on these items:

        i. What code model changes were done since the initial TR submittal?

           Describe each modification to the code and identify any code version related to each modification.

        ii. State whether each modification is relevant to the TR analysis.

        iii. How were the modifications documented?

        iv. What is a transition package? Describe transition packages used for each part of the analysis or subsequent studies.

        v. What revisions/versions of code were used for each part of the analysis?

        vi. Were different models or code versions used for any sensitivity studies?

        vii. Many titles are used for the S-RELAP5 code versions. (a) S-RELAP5 adjusted “developmental version” promoted to a “conditionally certified use-code,” (b) “conditionally certified version of S-RELAP5,” and (c) ‘unique “single-application” code version.’ Define each of these titles. How do the code versions move from one category to another?

    b. Did the review and approval of license amendment requests for St. Lucie (Reference RAI 29-1) result in any changes to the base model, based on the SONGS realistic large break LOCA (RLBLOCA) model that could be relevant to the TR analysis?

34. The staff would like to understand the history of Reference 6-3 from Volume. 4 regarding the calculation of barrel baffle (BB) resistance. Was Revision 0 superseded? Is Revision 1 valid? The RAI response points to the Revision 0 version. (RAI 4.3)

35. Were the two dimensional momentum equations used in the updated base case? If so, how were the equations implemented in each region? (RAI 4.27)

36. Why doesn't the lower curve in Figure RAI-4.20-4 bound all of the data? (RAI 4.20)

37. Is m_{DC} in equations RAI 4.20-2 and RAI 4.30-1 set equal to the total ECCS flow rate for calculation of m_{split}? If not, how were the m_{DC} rates determined? (RAI 4.30)

38. The response to RAI 4.30 states that "all debris that enters the Reactor Coolant System (RCS) is assumed to reach the reactor vessel downcomer and approach the core inlet where it will be deposited at the core inlet or transported to the heated core via the AFP." Table 1 below shows the estimated fractions of ECCS injected liquid mass that spills over through the intact SG based on the results presented in Figure RAI-4.30-1 through Figure RAI 4.30-24 for the 6 new cases analyzed to determine m_{split}. Reconcile the approach to determining m_{DC} for the purpose of calculating the m_{split} results shown in Figures RAI-4.20-3 and RAI-4.20-4.

Table 1: Integrated Broken SG Liquid Spillover as Fraction of ECCS Injected Liquid

Case	[ ]	ECCS Flow		Time Interval of Broken SG Liquid Spillover	Integrated Broken SG Liquid Spillover	Integrated ECCS Flow	Liquid Mass Ratio
No.	[ ]	gpm	lbm/s	s	lbm	lbm	%
newcase1	[ ]	827	110	20,000-28,000	6.0×10^4	8.8×10^5	7
newcase2	[ ]	1,654	220	22,000-30,000	1.4×10^5	1.76×10^6	8
newcase3	[ ]	2,481	330	14,000-30,000	1.8×10^6	5.28×10^6	34
newcase4	[ ]	827	110	22,000-30,000	4.5×10^4	8.8×10^5	5
newcase5(+)	[ ]	1,654	220	not predicted	n/a	n/a	n/a
newcase6	[ ]	2,481	330	15,000	1.2×10^6	4.95×10^6	24

(+) Only few isolates spikes appear in the result shown for this case in Figure RAI-4.30-18.

39. Explain why Figure RAI-4.8-1 in the B&W RAI responses is identical to the one in the CE responses.

<u>Babcock & Wilcox Responses (ANP-3584P)</u>

The following issues are identified as potentially having a significant effect on the analysis. That is, variation of these parameters could cause calculated PCT to exceed the acceptance criteria at the current t_{block} time or cause the t_{block} time to increase.

1. Justify the applicability of loss coefficients at full power flow conditions for calculating pressure losses associated with low flow rates. (RAI 4.2)

2. Justify that any AFPs with an opening less than 0.25 inch will remain unclogged if any were credited in the AFP resistance calculations. (RAI 4.2)

3. Justify how containment pressure is treated. (High pressure results in lower PCT?) Justify its treatment is bounding from a PCT perspective. (RAI 4.1.a, RAI 4.5.a, and RAI 4.29)

4. Between **[** **]** slots at the corner of the inside baffle plates. This elevation range falls between the elevations of the **[** **]** former plates provided in Table RAI-4.4-1. (RAI 4.4.f)

   a. Provide the configuration, dimensions (width and height), flow area, and elevations of each of the vertical slots.

   b. Explain how the slot area was **[** **]** in the RELAP5/MOD2-B&W model (note that Table RAI-4.4-1 lists data only for the first row of LOCA holes and slots at the elevation of 54.4 in).

   c. Artificially enlarging the flow area of a row of LOCA holes located at an elevation below the actual elevations of the vertical slots is non-conservative. The degree of non-conservatism can be significant based on the added area of the slots. Justify/correct the implemented modeling approach.

5. Explain the statement that “with respect to the potential for core uncovering when a complete core inlet blockage is applied, the highest decay heat rates, saturated minimum core inlet flows, lowest pressure, and top skewed power peaks minimize the core liquid inventory” with regard to the effect of the axial shape on the core liquid inventory. (RAI 4.23)

The following issues identify non-physical behavior of the code.

6. The figures associated with the RAI 4.17 response show some non-intuitive results. Explain the results shown. For example, it appears that there is no ECCS flow after the swap to recirculation in some figures. Figures 4.17.4 and 4.17.9 appear to show steam/liquid flow into the reactor vessel (RV) via the intact HL prior to SSO and continuing steam ingress after SSO. How is the flow to the RV supplied in the plant considering the statement in the response to RAI 4.24.h that Figure RAI-4.24-1 “includes the ECCS mass flow rate for direct injection to the reactor vessel?” (RAI 4.17, RAI 4.5.a, and RAI 4.24)

7. Void fraction and interfacial drag multiplier

   a. Justify that the differences between the RBHT test data and the code predictions shown in Figure RAI-4.8-1 are conservative. What interfacial drag multiplier would bring the predicted void fraction data below the diagonal line that represents no deviation between the test and code results? Identify the 7 RBHT tests that were analyzed used for the comparisons shown in Figure RAI-4.8-1. Provide details on the methods used to extend these benchmarks to lower decay heat levels. (RAI 4.8.a and c)

   b. Explain what is meant by “these correlations are appropriate in the calculation of the void fractions in the core and in the UP during the long-term core cooling following a LOCA” when discussing “correlations used in calculating the flow regimes and the interphase drag” based on “using primarily air-water test data.” Why does the void fraction in the UP go to 1 at the start of recirculation? Does the liquid fall into the core? Were any special models used (e.g. CCFL models, Wilson interphase drag model with the vertical smoothing relaxed in the UP)? (RAI 4.8 and RAI 4.23)

c. Provide information showing the void fractions are acceptable in the average channel, hot channel, BB, core exit, and UP. Include information describing how two-phase mixture levels were calculated and identify flow regimes.

The following issues require clarification during the audit to allow the NRC staff to determine if they are significant to the analysis and acceptance criteria as in Category 1, or the behavior of the code, as in Category 2.

8. Was any margin added to the BB channel resistance in the plant models?

9. Provide and justify the equations used to calculate a single K-factor representing **[ ]** different holes characterized with a maximum flow area ratio of **[ ]** and, possibly, different L/D ratios. How do the expected flow regimes through these holes relate to the K-factor? (RAI 4.4.f, RAI 4.7, and RAI 4.29)

10. Provide and justify the equations used to calculate a single K-factor representing **[ ]** different holes of **[ ]** different types. How are the K-factors calculated for "flow at full power conditions" applicable to low-flow regimes? (RAI 4.4.f, RAI 4.7, and RAI 4.29)

11. Provide information about collapsed flow passages including the elevation, K-factor, area, and K/A^2. (RAI 4.4.f)

12. Provide nodalization diagrams and key inputs (including details for AFPs, geometric data for each type of flow path opening, core, UP, downcomer, BB, and HL/CL), for the model used in the original submittal, as well as for the new B&W AORs. Justify that "the noding arrangement and modeling approach," described as "consistent with the Cold Leg Pump Discharge (CLDP) LOCA modeling options described in Sections 4 and 9 of BAW-10192P-A, Volumes I and II (Reference 4.29-1)" in the response to RAI 4.29, are appropriate for the GSI-191 long-term core cooling (LTCC) accident scenario analysis (hot-leg break). (RAI 4.4.f, RAI 4.16.a, RAI 4.22, and RAI 4.29)

13. As evident from Figures RAI-4.5-3 and RAI-4.5-4, the lengths of the top two noding cells of the active core region appear significantly larger than the sizes of the remaining 18 cells. Justify the nodalization in the top core region is adequate. (RAI 4.5.b)

14. How will variability in the applied loss factors affect the analysis results? (RAI 4.7)

The following items identify apparent inconsistencies, book keeping issues, or errors in the submittal:

15. Decay heat curve: RAI 4.10

a. Was the curve shown in Figure RAI-4.10-1, described as "used for the SBLOCA evaluation," used in the GSI-191 limiting LBLOCA Hot Leg Break (HLB) analyses for the B&W plant category? If so, why?

b. Explain the disparity between the result plotted in Figure RAI-4.10-1 and the results shown in Figure A.3**, "**Comparison of ANS5.1 1979 decay heat standard plus two sigma uncertainty with 1.0 x ANS5.1 1971 decay heat standard plus B&W heavy isotopes," in BAW-10192N-A.

16. Decay heat modeling: RAI 4.7

    a. Which actinide product decay model was used?

    b. How different are the contributions from the actinide capture decay power calculated using the default model based on the 1979 ANS decay heat standard equations and the B&W heavy isotope model, in terms of percentage additional decay heat yield?

    c. Was power from decay due to neutron capture in fission products included in the decay heat calculation?

17. Why are the values for loss coefficients so different in Table 4.4-1 (**[**
    ])? (RAI 4.4.f)

18. Discuss how the throttling of ECCS flow after SSO is controlled to ensure adequate cooling. What are the flow limits? Are there any limits on when the throttling can take place? (RAI 4.5.a)

19. Are the analyzed Low Pressure Injection (LPI) (Figure. RAI-4.5-1) and High Pressure Injection (HPI) (Fig. RAI-4.5-2) flow curves limiting for all 6 B&W plants listed in Table RAI-4.4-2? (RAI 4.5.a)

20. Provide dates for all references in ANP-3584P.

21. Clearly identify the code version used for analysis in the evaluation model (EM) and any subsequent changes. Which EM/code was used for the post-reflood LTCC transient phase? (RAI 4.6.b)

22. Provide References 4.6-0, 4.7-0, and 4.8-0.

23. Confirm that the use of nominal flow resistances for components in the RCS is consistent with the approach used in developing the EMs. (RAI 4.4.e and RAI 4.7)

<u>Westinghouse Responses (Attachment 1 to LTR-SEE-17-102, Revision 0)</u>

The following issues are identified as potentially having a significant effect on the analysis. That is, variation of these parameters could cause calculated peak cladding temperature (PCT) to exceed the acceptance criteria at the current t_{block} time or cause the t_{block} time to increase.

1. Axial Power Profile: (RAI 4.5.a)

    a. Further justification is needed concerning the axial power profile. How does the axial power profile modeling account for uncertainties?

    b. The response states that the analysis is late in the core transient so axial profile is not as skewed as soon after the event. What is the basis for this statement considering that the analysis begins at SSO?

    c. Use of a more bounding axial power profile could address issues with uncertainties and level of conservatism. Consider analyzing a SBLOCA profile.

2. Justify the radial peaking factor of 0.20 for the low power assemblies. Provide the number of assemblies in each group and explain how the hot assembly was related to any group. RAI 4.5

3. Modeling of ECCS flow rates and flow rate changes. (RAI 4.1, RAI 4.17, RAI 4.18, and RAI 4.20)

   a. Some of the flow changes at the start of recirculation appear to be step changes while others appear to be ramp functions. Is this intended? Would flow rates be interrupted during SSO? Are the step changes and ramp functions realistic? If not, how would the analysis be affected? Justify the extended time intervals over which the core inlet resistances were applied.

   b. Can artificially inflated injection flow rates (prior to recirculation) result in non-conservative estimates of PCT or affect the t_{block}, K_{max}, and/or K_{split} / m_{split} outputs?

   c. Identify and justify the single failure assumptions for each portion of the analysis, including the resulting flow rates.

   d. How were the fuel assembly (FA) flow rates associated with the analysis determined to be acceptable? What is the basis for the FA flow rates (8-40 gallon per minute (gpm)) used in the analysis? What are the ECCS flow rates corresponding to these FA flow rates?

   e. Is it acceptable to assume that all loops receive the same ECCS flow? Provide the flow rates assumed per loop, summed for all loops, and per fuel assembly for the injection and recirculation phases for both plant categories. How would assuming realistic flow rates to each loop affect the analysis?

   f. How was a SSO time of 20 minutes determined to be limiting and what time is the clock started for the 20 minutes?

4. ECCS Temperature Modeling: (RAI 4.5 and RAI 4.16)

   a. Justify the fluid temperature assumed during the injection phase of the analysis. The values used appear to be low compared to limiting values. Provide the temperatures assumed for each plant category for injection and recirculation and the times to which these temperatures apply.

   b. How do the assumed ECCS temperatures ensure that the analysis is bounding for the plants covered by the topical report?

5. Considering that the height of the downcomer is the controlling parameter, why is it acceptable to scale ECCS flow rates based on downcomer volume? The scaling approach does not take core side losses into account. Does the size of the core (number of FAs) need to be accounted for in the scaling? (RAI 4.5 and RAI 4.14)

6. How was it ensured that M_{boil} calculated for the analysis was conservatively minimized? How was the M_{boil} calculated for the plant conservatively maximized considering the same factors? Note that H_{fg} depends on the containment backpressure. (RAI 4.5)

7. Upper Plenum Drainage (RAI 4.7, RAI 4.23, RAI 4.2, and RAI 4.28)

    a. Provide information and basis to support how the liquid is drained from the UP to the core.

    b. Verify that the flow regimes and interfacial drag coefficients used in the analysis were appropriate.

    c. How was liquid fallback evaluated for each core power region? Provide plots of the liquid flow from the core components to the UP and the steam and liquid velocities through the connection points.

    d. If liquid fallback was credited, substantiate that it is a physical representation of what would occur in the plant. Could debris at the top of the core affect liquid fallback? Consider CCFL.

    e. Justify that choosing the limiting hot assembly location accounts for the uncertainties associated with drain distribution from the upper plenum considering the hardware in the upper plenum.

    f. Provide the core side 2-phase mixture levels as requested in RAI 4.23. It is not included in the RAI response.

8. How was it determined that assuming a low containment pressure results in calculation of a conservative PCT. (RAI 4.5)

The following issues identify non-physical behavior of the code.

9. Was the code and it application for the TR examined for anomalous flow circulation? Explain the behavior seen in Figure RAI-4.8-7 RAI 4.7

10. Void fraction and interfacial drag multiplier. (RAI 4.8 and RAI 4.9)

    a. Why does the void fraction sometimes decrease, then increase while moving higher in core elevation?

    b. Why does void fraction decrease at the time of PCT at the highest elevations of the fuel?

    c. How is it assured that the void fraction oscillations are not caused by code deficiencies? These could also cause errors in PCT calculations.

    d. Provide details of the G1/G2 void fraction testing including test sensor details and how their outputs were used to develop the measured swell results. Provide instrumentation error information and how such error was considered when producing the results. Describe how any averaging or filtering of the raw outputs were used to develop the results. Was all test data included in the RAI response?

    e. Provide details on the model used to simulate the G1/G2 testing. What version of the code was used? What models, correlations, and inputs were used, including any special features? Show that the features used were within ranges applicable for the analysis. How were the code predictions processed to plot Figure RAI 4.8-1?

f. Compare the nodalization for the HLB model and the G1/G2 model and show that they will provide consistent results.

g. Figure 4.8-1 showing G1/G2 data vs. predictions shows that the code consistently over predicts swell. Justify the use of the multiplier used in the analysis. Provide a plot of the calculated void fractions, mixture levels in the hot assembly nodes, average guide tube, non-guide tube and low power level nodes as a function of time for the top five nodes (10-14).

11. Why is there liquid phase present at the PCT location in Figures RAI 4.9-2 and 4? How does this affect the heat transfer in the model? (RAI 4.9)

12. Why is there significant flow into the RV via the intact hot legs and liquid discharge through the broken HL shortly following core blockage as seen in Figures RAI-4.17-10 and 4? Why do the flows through the intact HLs decrease and the flow through the broken HL, steam generator side resume around the same time (10,000 s)? (RAI 4.17)

13. How is it possible for the hot legs to deliver a cumulative excess of 100,000 lb to the upper plenum as shown in Figures RAI-4.17-10 and 11? (RAI 4.17)

14. How does flow diversion toward the crossover legs occur for case 5 when the collapsed liquid level is far below the HL nozzles? (RAI 4.18)

15. Provide a description of the physical processes that cause the downcomer levels to fluctuate significantly below the levels of the BB and low power fuel channels. Justify that the model results in a realistic prediction of behavior. (Reference Figure RAI-4.18-4) (RAI 4.18)

16. Why is the heat generation rate much higher than the decay heat curve? Why is there a fluctuation in the downflow category heat generation curve? (RAI 4.10)

The following issues require clarification during the audit to allow the NRC staff to determine if they are significant to the analysis and acceptance criteria as in Category 1, or the behavior of the code, as in Category 2.

17. Provide nodalization diagrams and key inputs (including details for AFPs, geometric data for each type of flow path opening, core, UP, downcomer, BB, and HL/CL), for the model used.

18. Explain what channels 13 and 15 simulated in the analysis. Was the PCT recorded in the hot channel for both up and downflow categories? What is the basis for the axial flow area of 57.6 sq in.? (RAI 4.9)

19. Provide the ranges of applicability for the flow regimes and heat transfer models/correlations used in the analysis, based on their supporting databases. (RAI 4.9)

20. How was uncertainty in the use of the single phase vapor heat transfer model at pressures close to atmospheric treated? Could this have a significant effect on PCT? (RAI 4.9)

21. Alternate flowpath resistance calculations (RAI 4.2 and RAI 4.3)

a. How was the full power THRIVE information determined to be applicable to low flow rate conditions?

b. What does the margin added to the BB channel resistance represent? Why is the margin appropriate?

c. Provide the geometric characteristics for the former plate flow paths. Show that debris won't block or add resistance to credited flowpaths with clearances less than those tested or with more complex flow geometry.

d. Explain how the equations used to calculate the flow split and pressure drop for the resistance calculations were developed. How it is ensured that the dP is calculated correctly for various flow rates considering the averaging scheme used for flowpath resistances?

22. Describe the flowpaths for liquid exiting the shroud region near the top of the core. Describe how these passages are modeled in the base CE model. Justify the modeling approach. Describe how the flow passages vary among the CE design plants and the applicability of results to the fleet. (RAI 4.3)

23. Does measurement uncertainty need to be accounted for in the calculation of scaling flow path resistances or determination of equivalent ECCS flow? (RAI 4.5)

24. Large Vessel Mass Error (RAI 4.6 and RAI 4.17)

    a. What change was made to reduce the potential for large vessel mass error?

    b. How was it validated that the change resulted in the desired outcome and the code behavior is acceptable?

    c. How was this error identified?

    d. Were any modeling requirements imposed as a part of the resolution? If needed how were they implemented in the Volume 4 RAI response code runs?

    e. What were the maximum time step limits used?

    f. How was it ensured that that a vessel mass error did not occur in the RAI analyses?

    g. Did the vessel mass error affect any of the previous WCAP analyses or any of the current RAI response analyses? How was this determined?

    h. It was noted in the RAI 17 response that about 750,000 lbm of coolant accumulated in the primary coolant loops from about 1200 to 9500 seconds in upflow case 1B. Does this indicate that a vessel mass error occurred?

25. Demonstrate that the non-condensable gas treatment and the treatment of stratified flow in the code do not adversely affect the results. (RAI 4.7)

26. The timing of debris buildup at the core will be variable depending on the plant. How do the timing assumptions assure that all plants are bounded? (RAI 4.7)

27. Was a reactor SCRAM or trip modeled into the simulation of the HL break scenario? (RAI 4.10)

28. Explain why the hot assembly has the lowest inlet mass flow integral. (RAI 4.15)

29. Why does the mass flow rate entering the cold leg nozzles decrease soon after core blockage is applied? (RAI 4.17)

30. Explain how adding a colorimetric uncertainty of 2% meets the Appendix K requirement of assuming the reactor has been operating at 1.02 times the licensed power level. (RAI 4.28)

31. Verify that the m_{split} methodology does not underestimate the fiber amount predicted to arrive at the core inlet. Consider a case in which (a) debris bypass due to the flow split at the ECCS injection points in the cold legs is realistically accounted for and (b) m_{split} is calculated based on the total ECCS rate that will is expected to be used in plant-specific applications to calculate the core inlet load using m_{split}. (RAI 4.30)

32. Provide the reference zero time for the calculation of core blockage events like t_{block}. (RAI 4.5)

33. How will plants that do not have upper head spray nozzles (UHSN) resistances be bounded by the analyses? (RAI 4.5)

34. What quality assurance (QA) was performed for the updated cases presented in the response to RAI 4.20? The results shown in Figuress RAI 4.20-4. 6 and 7 have considerable variability. (RAI 4.20)

The following items identify apparent inconsistencies, book keeping issues, or errors in the submittal:

35. Bookkeeping Issues (RAI 4.6, RAI 4.13, RAI 4.9, and RAI 4.29)

    a. Provide bookkeeping for the code versions used.

    b. What change process was used?

    c. What verification and validation (V&V), QA, and testing was performed on each version or change to the code? How was it determined that the code contains no significant deficiencies?

    d. Was more than one code version used to obtain results for the analysis? If so, how are the results assured to be consistent?

    e. Provide references to the technical reports that were developed for the changes described in Table RAI-4.29-1. Include the QA status for each of the references. Did the NRC approve the upflow and downflow models and if so, were any changes to the models required by that NRC review?

36. How was the information that replaces Ref 6-2 developed? How were the results validated? What QA process was used?

37. Provide the plotting time frequency and the frequency at which the code stores calculated results for the figures provided in the Westinghouse Volume 4 RAI responses. (RAI 4.9)

38. Issues with Reference 6-3 identified in the CE questions are also applicable to the Westinghouse submittal. The staff would like to understand the history of Reference 6-3 from Vol. 4 regarding the calculation of BB resistance. Was Revision 0 superseded? Is Revision 1 valid? The RAI response points to the Revision 0 version. (RAI 4.3)