Proprietary Markings for WCAP-16996-P, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)" Requests for Additional Information – Sixth, Seventh and Eighth Sets (Non-Proprietary)

June 2013

Westinghouse Electric Company LLC
1000 Westinghouse Drive
Cranberry Township, PA 16066

Question #77: Loop Seal Clearance in LSTF Test SB-CL-18

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.2, "Important Physical Processes and Scaling Laws," Subsection 18.2.1, "ROSA," considers experimental data from two integral effects, Test SB-CL-18 and Test SB-CL-14, performed at the Large Scale Test Facility (LSTF) as part of the Rig-of-Safety Assessment No. 4 (ROSA-IV) test program. LSTF was a full-pressure facility and preserved major component elevations of the reference Westinghouse-type four-loop 3,423 MWt (1,110 MWe) PWR at Tsuruga Unit 2 of Japan Atomic Power Company. LSTF had an overall volumetric scaling ratio of 1/48 and featured two equal-volume primary loops. The hot and cold legs had an Inner Diameter (ID) of 0.207 m (8.15 inch) determined to preserve the loop volumetric scaling ratio 2/48 and the length to square-root-of-diameter ratio ($L/\sqrt{D}$) for flow regime simulation. The prototypical PWR hot and cold leg IDs were 0.7366 m (29 inch) and 0.6985 m (27.5 inch), respectively. The cross-over legs of the loop seals in LSTF had an ID of 0.1682 m (6.62 in), compared to a prototypical cross-over leg diameter of 0.7874 m (31 inch), to scale volume and preserve height. In Test SB-CL-18 and Test SB-CL-14, the break unit was connected horizontally to the cold leg between the Reactor Coolant Pump (RCP) and the Reactor Pressure Vessel (RPV) in Loop B, which was not connected to the pressurizer.

Test SB-CL-18 simulated a 5 percent cold leg break, which corresponds to a break area of 0.205 ft^2 or a 6.1 inch equivalent break diameter based on the reference PWR cold leg diameter (27.5 inch). Test data is documented by H. Kumamaru et al., "ROSA-IV/LSTF Cold Leg Break LOCA Experiment Run SB-CL-18 Data Report," Japan Atomic Energy Research Institute Report JAERI-M 89-027, March 1989. Loop seal clearing occurred in both loops at approximately 140 s after the break. Core uncovery took place temporarily between approximately 120 s and 155 s during loop seal clearing and most of the core heater rods experienced superheating of up to about 342 °F (190 K). A Peak Clad Temperature (PCT) of approximately 872 °F (740 K) was observed during the core uncovery just prior to loop seal clearing.

Figure A.2, "Primary Loop A Instruments (II)," in JAERI-M 89-027 shows the instrumentation in the intact loop and Figure A.4, "Primary loop B Instruments (II)," in the same report shows the instrumentation in the broken loop. JAERI-M 89-027 Figure 5.32, "Differential Pressure LSA, PCA," plots measurements from differential pressure transducer DPE070 in the loop seal downhill side (channel DPE070-LSA, DP 17) and from transducer DPE080 in the loop seal uphill side (data channel DPE080-LSA, DP 19). Figure 5.33, "Differential Pressure LSB, PCB," exhibits measurements from transducer DPE210 in the loop seal downhill side (channel DPE210-LSB, DP 41) and from transducer DPE220 in the loop seal uphill side (data channel DPE220-LSB, DP 42). As reflected by the DPE210 data in Figure 5.33, the liquid level in the descending loop seal section, connected to the SG exit chamber, reduces significantly from an initial quasi steady-state absolute value of about 43 kPa (6.3 psid) down to an absolute value of about 8 kPa (1.2 psid) at approximately 140 s after the break. At this point, loop seal clearance begins as seen from DPE220 signal for the ascending loop seal section. The process occurs during a time window of about 60 s and it is completed by 200 s after the break. During loop seal clearance, the DPE220 signal in the ascending loop seal section reduces sharply from an initial quasi steady-state value of about 24 kPa (3.5 psid) to approximately 2 kPa (0.3 psid) whereas the DPE210 signal in the descending loop seal section decreases further only slightly from 8 kPa to about 6 kPa (0.9 psid).

The data measurements for the intact loop seal shown in Figure 5.32 exhibit a similar behavior.

Subsection 18.2.1 of the WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, topical report (TR) presents a single plot of Test SB-CL-18 data in Figure 18.2.1-1a, "Measured Pressure Drop in Broken Loop of ROSA 5 percent Break (Kumamaru, et al., 1989)." Figure 18.2.1-1a is a reproduction of Figure 5.33 in the JAERI-M 89-027 report. Referring to the Test SB-CL-18 data in Figure 18.2.1-1a, it is observed in Subsection 18.2.1 that "the liquid tends to be pushed towards the uphill bend and up the pump suction leg." Subsection 18.2.1 continues by stating that "this suggests that the remaining liquid after loop seal clearing will tend to be collected in the uphill side of the loop seal."

(1) The DPE220 signal in the uphill loop seal section reproduced in Figure 18.2.1-1a, "Measured Pressure Drop in Broken Loop of ROSA 5 percent Break (Kumamaru, et al., 1989)," for Test SB-CL-18 shows only a very small differential pressure of about 2 kPa towards the end of the loop seal clearance phase at 200 s. During the following part of the transient, the measurement reduces gradually down to zero at approximately 650 s and remains at this level thereafter. The DPE210 signal in the descending loop seal section shows a relatively small, in absolute value, differential pressure, which reduces slightly from approximately 6 kPa down to 3.5 kPa during the depicted post-clearance period from 200 s to 900 s. Please clarify how the DPE210 and DPE220 differential pressure measurements shown in Figure 18.2.1-1a support the interpretation in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 18.2.1 that liquid remaining in the loop seal piping following the loop seal clearance "will tend to be collected in the uphill side of the loop seal."

(2) Based on "assessment of WCOBRA/TRAC-TF2 relative to the experiments indicates," WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 18.4, "Conclusions," states, among other findings, that "the remaining liquid retained after loop seal clearing tends to collect in the uphill bend and RCP suction leg, as demonstrated in the ROSA tests (Section 21)." WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," Subsection 21.4.3, "Results and Conclusions from the SB-CL-18 Simulation," refers to Figures 21.4-1 through 21.4-20 when comparing code predictions against Test SB-CL-18 measurements. Figures 21.4-3 and 21.4-4 show a comparison of the calculated and measured loop seal differential pressures in both loops. It is stated in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 21.4.3 that [ ]a,c and clarifies that "the test data and calculations also show that after the loop seals clear, steam venting is established through both cross-over legs." Please explain which evidence from Test SB-CL-18, as presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, Subsection 21.4, "Simulation of SB-CL-18, 5-Percent Cold Leg Side," supports the conclusion in Subsection 18.4 that "assessment of WCOBRA/TRAC-TF2 relative to the experiments indicates" that "the remaining liquid retained after loop seal clearing tends to collect in the uphill bend and RCP suction leg, as demonstrated in the ROSA tests (Section 21)." Please present any additional experimental measurements and specific analyses, as appropriate, in support of this conclusion.

Question #78: Loop Seal Clearance in LSTF Test SB-CL-14 and Test SB-CL-18

In addition to LSTF Test SB-CL-18, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.2.1, "ROSA," presents data from LSTF Test SB-CL-14. Test SB-CL-14 simulated a 10% cold leg break, which corresponds to a break area of 0.413 ft^2 or an 8.7 inch equivalent break diameter based on the reference PWR cold leg diameter (27.5 in). Data from 6 ROSA-IV LSTF experiments, Test SB-CL-01, Test SB-CL-05, Test SB-CL-14, Test SB-CL-15, Test SB-CL-16, and Test SB-CL-18, were used for comparison with test predictions obtained with the NRC code TRACE as documented in "TRACE V5.0 Assessment Manual Appendix C: Integral Effects Tests," Agencywide Documents Access and Management System (ADAMS) Publication No. ML120060172. As indicated by the loop seal differential pressure measurements provided for Test SB-CL-14 in Subsection C.5.5.3, "Simulation of SB-CL-14," in this document, both loop seals experienced clearing between approximately 76 s and 100 s after the break opening. The core uncovered temporarily between approximately 60 s and 80 s just before loop seals clearing and the maximum observed heater rod temperature was by about 72 °F (40 K) higher than the initial rod temperature.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 18.2.1, "ROSA," includes a single plot of data from Test SB-CL-14, which is shown in Figure 18.2.1-1b, "Measured Pressure Drop in Broken Loop of ROSA 10 percent Break (Koizumi and Tasaka, 1988)." Figure 18.2.1-1b reproduces Figure 6.8, "Loop-B Cross-over Leg Differential Pressures," from Reference 3 listed in Subsection 18.5, "References," as: Koizumi, and Tasaka, K., 1988, "Quick Look Report for ROSA-IV/LSTF 10 percent Cold Leg Break LOCA Test, SB-CL-14," JAERI-memo 63-262. The curves in Figure 18.2.1-1b are marked with symbols labeled as "DP 41" and "DP 42" at the top of the plot. The vertical axis in the plot depicts differential pressure in units of kPa and has a label "DPE210-LSB." Referring to Figure 18.2.1-1b, Subsection 18.2.1 makes the observation that "the liquid tends to be pushed towards the uphill bend and up the pump suction leg" and continues stating that "this suggests that the remaining liquid after loop seal clearing will tend to be collected in the uphill side of the loop seal."

(1) Figure 18.2.1-1b, "Measured Pressure Drop in Broken Loop of ROSA 10% Break (Koizumi and Tasaka, 1988)," in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 18.2.1 shows a reproduction of Figure 6.8 in JAERI-memo 63-262. The graph shown in Figure 18.2.1-1b is not entirely legible. Please provide a legible plot for the data presented in Figure 18.2.1-1b. Explain the availability of Reference 3 in Subsection 18.5 and clarify if electronically recorded data measurements were also available and used as part of the assessment process.

(2) It appears that after the initial transitory period, one of the curves in Figure 18.2.1-1b shows practically zero differential pressure whereas the second one exhibits a rather high and persisting pressure difference, which slowly increases to reach about 30 kPa at the end of the displayed time interval. Some of the measurements from Test SB-CL-14 in Figure 18.2.1-1b are different, both in trend and in magnitude, when compared to the differential pressure measurements shown in Figure 18.2.1-1a, "Measured Pressure Drop in Broken Loop of ROSA 5 percent Break (Kumamaru, et al., 1989)," for Test SB-CL-18. Please explain the basis for asserting in Subsection 18.2.1, "ROSA," that data from both Test SB-CL-18 and Test SB-CL-14, as depicted

in Figures 18.2.1-1a and 18.2.1-1b, respectively, support the interpretation that liquid remaining in the loop seal piping following the loop seal clearance "will tend to be collected in the uphill side of the loop seal," when there are obvious and significant disparities between the experimental responses shown in these two figures.

Question #79: WCOBRA/TRAC-TF2 Assessment for LSTF Test SB-CL-14

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.2.1, "ROSA," refers to experimental observations from LSTF Test SB-CL-18 and Test SB-CL-14 when discussing loop seal clearance. Subsection 18.4, "Conclusions," states that "assessment of WCOBRA/TRAC-TF2 relative to the experiments indicates" that, among other findings, "the remaining liquid retained after loop seal clearing tends to collect in the uphill bend and RCP suction leg, as demonstrated in the ROSA tests (Section 21)."

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," Subsection 21.6.2, "Results and Conclusions for the SB-CL-14 Simulation," presents comparisons of WCOBRA/TRAC-TF2 predictions against Test SB-CL-14 data in Figures 21.6-1 through 21.6-16. Each of Figures 21.6-1 through 21.6-14 and Figure 21.6-16 contain two parts: Part (a), "Code Calculation," and Part (b), "Reported in JAERI-memo 63-262." The graphs included in Part (a) in these figures show code predictions whereas the graphs in Part (b) reproduce data plots from JAERI-memo 63-262. Reference 3 in Subsection 18.5, "References," lists JAERI-memo 63-262 as: Koizumi, and Tasaka, K., 1988, "Quick Look Report for ROSA-IV/LSTF 10% Cold Leg Break LOCA Test, SB-CL-14," JAERI-memo 63-262. Reference 6 in Subsection 21.20, "References," lists the same document as: Koizumi, Y. and Tasaka, K., 1988, "Quick Look Report for ROSA-IV/LSTF 10 percent Cold Leg Break LOCA Test, SB-CL-14," JAERI-memo 63-262. Table 21.1-1, "Selected ROSA-IV Test Series Description and Related Technical Reports," refers to "JAERI-memo 63-262 ('88, Koizumi)."

(1) The excerpts from JAERI-memo 63-262 showing individual graphs in Part (b) in each of Figures 21.6-1 through 21.6-14 and in Figure 21.6-16, are not entirely legible. In addition, the horizontal and vertical axes in these reproduced plots use ranges and scales that are different from the corresponding ones used in the plots showing the code predictions in Part (a) of the assessment figures in Subsection 21.6.2. Some of these figures show only a single calculated parameter in Part (a) and several measured quantities in Part (b), making it unclear which measured quantity, if any, can be used as a legitimate reference parameter for code comparison assessments. Such an approach to analyzing code performance and assessing it against test data does not allow for proper examination of code predictions and their comparison and validation against experimental measurements. Even when a plot compares a single predicted variable against a single measured quantity, comparison is not always straightforward. Often, it is necessary to consider if the model supports a direct comparison between computational results and data. For example, adequate capturing of experimental measuring points and other relevant conditions can require specific nodalization. Please explain and justify the adequacy of the used approach to assessing WCOBRA/TRAC-TF2 best-estimate capabilities as exemplified by the identified assessment analyses presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 21.6, "Simulation of the 10 percent Side Break Test SB-CL-14."

(2) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 21.6.2, "Results and Conclusions for the SB-CL-14 Simulation," Figure 21.6-7, "Comparison of Loop-B Cross-Over Leg Differential Pressures," Part (a), "Code Calculation," shows predictions for differential pressures in the downhill and uphill sections of the cold leg seal in the broken loop. The calculations presented in Figure 21.6-7 Part (a) appear remarkably different from the test data shown in Figure 21.6-7 Part (b), "Reported in JAERI-memo 63-2." This disparity between code results and test data was not acknowledged in WCAP-16996-P Revision 0 Subsection 21.6, "Simulation of the 10 percent Side Break Test SB-CL-14." Please explain why such a pronounced discrepancy in describing an important phenomenon such as the loop seal clearance remained unidentified and unexplained as part of the WCOBRA/TRAC-TF2 assessment analyses presented in Subsection 21.6.

(3) The WCOBRA/TRAC-TF2 code qualification and assessment of its capabilities of capturing adequately important physical processes and predicting in a best-estimate manner associated governing parameters is found complicated by aspects of the assessment approach as those discussed in Items (1) and (2) above. Based on the resolution of these items, please describe modifications to specific aspects of the WCOBRA/TRAC-TF2 assessment approach in WCAP-16996-P Revision 0 if such have been found appropriate for improving the clarity in demonstrating the technical basis for WCOBRA/TRAC-TF2 validation through proper presentation and documentation of results and findings from specific assessment studies. Include results and summarize outcomes from such modifications and revisions of the WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, TR as appropriate.

Question #80: LSTF Test SB-CL-14 Data Qualification

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.2.1, "ROSA," includes Figure 18.2.1-1b, "Measured Pressure Drop in Broken Loop of ROSA 10 percent Break (Koizumi and Tasaka, 1988)," which reproduces Figure 6.8, "Loop-B Crossover Leg Differential Pressures," from JAERI-memo 63-262. Section 21, "ROSA-IV Test Simulations," Subsection 21.6.2, "Results and Conclusions for the SB-CL-14 Simulation," includes Figure 21.6-7, "Comparison of Loop-B Cross-Over Leg Differential Pressures." Figure 21.6-7 Part (b), "Reported in JAERI-memo 63-262," reproduces the same Figure 6.8, "Loop-B Crossover Leg Differential Pressures," from JAERI-memo 63-262.

Subsection C.5.5.3, "Simulation of SB-CL-14," in "TRACE V5.0 Assessment Manual Appendix C: Integral Effects Tests," ADAMS Publication No. ML120060172, includes Figure C.5-124, "Differential Pressure along downhill Side of Loop-B Seal," and Figure C.5-125, "Differential Pressure along uphill Side of Loop-B Seal." The figures depict DPE210-LSB and DPE220-LSB data signals, respectively, for Test SB-CL-14.

(1) There are apparent and significant disparities between parameters shown in Figure 18.2.1-1b in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 18.2.1, "ROSA," and in Figures C.5-124 and C.5-125 in "TRACE V5.0 Assessment Manual Appendix C: Integral Effects Tests." In addition, the WCOBRA/TRAC-TF2 calculations in Figure 21.6-7 Part (a), "Code Calculation," differ significantly from the test data in Figure 21.6-7 Part (b), "Reported in JAERI-memo 63-2," which are identical with the test data shown in Figure 18.2.1-1b. Please

explain how Test SB-CL-14 measurements presented in Figure 18.2.1-1b, “Measured Pressure Drop in Broken Loop of ROSA 10% Break (Koizumi and Tasaka, 1988),” relate to the test data shown in Figures C.5-124, “Differential Pressure along downhill Side of Loop-B Seal,” and in Figure C.5-125, “Differential Pressure along uphill Side of Loop-B Seal,” in Appendix C, “Integral Effects Tests,” of “TRACE V5.0 Assessment Manual.”

(2) Please describe test facility selection and test data qualification processes with regard to test data used in WCOBRA/TRAC-TF2 assessment studies if such processes have been considered and applied as part of the WCOBRA/TRAC-TF2 assessment approach implemented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0,. As part of these processes, please explain if availability of published test reports, documenting measured data, and electronic data files containing recorded measurements were considered and examined. When both types of data sources were available, clarify if a cross-check was performed to examine and qualify important measurements that were used to assess WCOBRA/TRAC-TF2.

(3) Please explain reliance on and use of available information quantifying instrumentation accuracy for test data from experiments that have been selected and used in WCOBRA/TRAC-TF2 assessment studies. Please clarify if such considerations have been applied as part of the approach, implemented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, to asses WCOBRA/TRAC-TF2. Please explain how such aspects of the assessment approach relate to the analyses presented in Section 21, “ROSA-IV Test Simulations,” Subsection 21.6, “Simulation of the 10 percent Side Break Test SB-CL-14,” of WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, TR as an example.

(4) Based on the resolution of Items (1) through (3) above, please describe modifications to specific aspects of the WCOBRA/TRAC-TF2 assessment approach in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, if such have been found appropriate for improving the clarity in demonstrating the technical basis for WCOBRA/TRAC-TF2 validation through proper, accurate, and adequate presentation and documentation of results and findings from specific assessment studies. Include results and summarize outcomes and revisions of the WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, TR from such modifications as appropriate.

Question #81: ROSA-IV LSTF WCOBRA/TRAC-TF2 Assessment Results Presentation

In RAI Questions 78, 79, and 80, additional information was requested to clarify aspects related to both the use of ROSA-IV LSTF test data as well as the presentation and comparison of WCOBRA/TRAC-TF2 predictions against test data in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," and in Section 21, "ROSA-IV Test Simulations," to demonstrating and assessing the code performance. With regard to the experimental database used in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, Subsection 21.1, "Introduction," refers to Table 21.1-1, "Selected ROSA-IV Test Series Description and Related Technical Reports," and states: "Table 21.1-1 shows the list of tests used for the validation work. It contains relevant reports and articles related to the ROSA-IV LSTF and the different test considered herein." WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," Subsection 21.5.2, "Results and Conclusions from the SB-CL-05 Simulation," in discussing WCOBRA/TRAC-TF2 assessment results, states: "Unfortunately, the SB-CL-05 electronic data file available in Westinghouse does not contain any recorded fuel rod cladding temperature measurements so that direct graphical comparison cannot be presented. However, rod cladding temperatures measured at the test can be found in Figure 5.468 through Figure 5.484 of the SB-CL-05 test report (Kawaji, et.al.)." Subsection 21.20, "References," identifies only one work by Kawaji listed in Reference 3 as: "Kawaji, M., et al., 1986, "ROSA-IV/LSTF 5 percent Cold Leg Break LOCA Experiment Data Report, Run SB-CL-05," JAERI-memo 61-056."

In addition to addressing RAI Questions 78, 79, and 80, the staff finds it necessary to request clarification of the following items.

(1) Please present a table that documents the source and type of experimental data from experiments performed at the ROSA-IV LSTF integral effect test facility and used to assess WCOBRA/TRAC-TF2 for the purpose of the Full Spectrum LOCA Methodology development as presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0. The table should contain the following pieces of information, each presented in a separate column: (1) test run (experiment) identifiers, (2) identification of data channel identifiers (experimental instrument tags) for measurements used to assess WCOBRA/TRAC-TF2, (3) accuracies of the sensors used in each data channel, (4) availability of electronic test data files and if the files contain the identified experimental measurements, (5) test reports documenting the identified experimental measurements, (6) any other sources of information describing the identified experimental measurements, (7) if examination of the identified experimental measurements (data channel signals) was performed to qualify the data as appropriate for code assessment. Please list each separate experiment (test run) separately in the table. If appropriate, please group data channels based on the type of measurements (for example, temperature, differential pressure, etc.) and list the groups in separate rows when providing their characteristics (accuracies, data sources, examination status). Please provide the meaning of the symbols used in the instrument tags (for example, "TE" for fluid temperature, "DP" for differential pressure, "TW" for wall temperature, etc.).

(2) When plotting WCOBRA/TRAC-TF2 code predictions against ROSA-IV LSTF test measurements that are considered of key importance for assessing the code capabilities, please explain why the depicted code predictions and test data represent a valid comparison for judging the code performance. In particular, it is important that the model nodalization reflects adequately experimental measuring points. For example, the computational node for a temperature prediction should closely match the location of the thermocouple used in the test. Also, when computing differential pressures for comparison against data, nodalization aspects and locations of differential pressure taps in the experiment should be considered. As appropriate, please include diagrams showing model nodalization and sensor locations in the same figure.

(3) Please redraw the figures that are used in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, to compare WCOBRA/TRAC-TF2 prediction results against ROSA-IV LSTF test measurements so that both the data measurements and the code predictions are depicted in a single common graph. Please plot the error bars associated with the presented test data when information is available.

(4) Please revise WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, to include the additional information requested in Items (1) through (3) above as found appropriate.

Question #82: Break Equivalent Diameter in LSTF Tests SB-CL-01, SB-CL-02, and SB-CL-03

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," Subsection 21.7.2.1, "2.5 percent Tests," presents WCOBRA/TRAC-TF2 assessment results against three ROSA-IV LSTF tests simulating a 2.5 percent cold leg break with different break orientations. Test SB-CL-01 simulated a side break, Test SB-CL-02 studied a bottom break, and Test SB-CL-03 examined a top break. All three tests used an orifice with a 16.0 mm (0.63 inch) opening diameter to model the break. Assessment results are shown in Subsection 21.7.2.1 Figures 21.7-3 through 21.7-10. Subsection 21.7.2, "Discussion of Results," states that Test SB-CL-01, Test SB-CL-02, and Test SB-CL-01-03 "simulated a 2.5 percent break in the cold leg, which approximates a 3 inch break in a PWR."

The 16.0 mm (0.63 inch) ID orifice, used to simulate a 2.5 percent cold leg break in the identified ROSA-IV LSTF tests, had an opening area of 201.1 mm^2 (0.00216 ft^2). The LSTF reference PWR cold leg inner diameter was 27.5 inch. Based on the LSTF volumetric scaling ratio, the 2.5 percent LSTF break size scales to a corresponding PWR cold leg break area, as follows:

PWR Break Area = 48 $\times$ LSTF Break Area = 48 $\times$ 0.00216 ft^2 = 0.1037 ft^2.

The above determined 2.5 percent PWR cold leg break area of 0.1037 ft^2 corresponds to an equivalent break diameter of 4.36 inch. This equivalent break diameter significantly differs from the 3 inch equivalent break diameter that is cited in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 21.7.2, "Discussion of Results."

Please explain how it was determined in Subsection 21.7.2, "Discussion of Results," that ROSA-IV LSTF Test SB-CL-01, Test SB-CL-02, and Test SB-CL-01-03 "simulated a 2.5 percent break in the cold leg, which approximates a 3 inch break in a PWR."

Question #83: Stratified Flow Multiplier HS_SLUG

WCOBRA/TRAC-TF2 superimposes horizontal stratified flow (including wavy-dispersed flow) onto the basic flow regime map. WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 4, "WCOBRA/TRAC-TF2 Flow Regime Maps and Interfacial Area," Subsection 4.4.5, "Horizontal Stratified Flow," analyzes test data by plotting modified Wallis numbers, as defined by Equation (4-108), versus void fraction in Figure 4-17, "Horizontal Stratified Flow Regime Transition and Relevant Data," and states that [

]^{a,c} The critical relative phase velocity for horizontal flow, $\Delta u_c = |u_g - u_l|_c$, is given in Equation (4-112) using a criterion based on the Wallis parameter. Equation (4-117) introduces a weighting factor, W_{st}, which is determined from the critical velocity using two adjustable constants, C_{hs_slug} and C_{stfru}. W_{st} is used in Equation (4-116) to modify the interfacial flow area, A_i. According to Subsection 4.4.5, the allowable input range C_{hs_slug} is from 0.1 to 9.9 with unity being the default value for C_{hs_slug} in WCOBRA/TRAC-TF2.

Referring to the data presented in Figure 4-17, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements," Subsection 29.1.7, "Horizontal Stratified Flow Regime Transition Boundary (HS_SLUG)," states that [

]^{a,c} Subsection 29.1.7 further explains that "the horizontal stratified flow regime transition boundary multiplier, HS_SLUG, is then introduced to adjust the critical relative velocity for horizontal stratified flow." It is also stated that "For the purpose of the uncertainty analysis a random value of HS_SLUG is sampled with [

]^{a,c}

(1) Please clarify if the above cited sentence, appearing in the second paragraph of WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 29.1.7, "Horizontal Stratified Flow Regime Transition Boundary (HS_SLUG) on page 29-34 is in error and if it should be corrected as follows: "For the purpose of the uncertainty analysis a random value of HS_SLUG is sampled with [
]^{a,c} Please explain and correct as appropriate.

(2) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 10, "WCOBRA/TRAC-TF2 One-Dimensional Component Models," Subsection 10.2, "Pipe Component," explains: "The HS_SLUG multiplier affects the transition between non-stratified and stratified flow regimes and is described in detail in Section 4.4.5." Subsection 4.4.5, "Horizontal Stratified Flow," does not mention the HS_SLUG quantity nor does it provide a reference to HS_SLUG. It is in Subsection 29.1.7, "Horizontal Stratified Flow Regime Transition Boundary (HS_SLUG)," where it is explained: "The horizontal stratified flow regime transition boundary multiplier, HS_SLUG, is then introduced to adjust the critical relative velocity for horizontal stratified flow. The multiplier is represented by the symbol C_{hs_slug} in

Equation 4-117." This way of identifying and describing the HS_SLUG quantity in WCAP-16996-P Revision 0 is found to be confusing and inappropriate as it lacks in accuracy, clarity, and adequacy of description. This represents one example when details, essential for the description of important quantities and features of the FSLOCA methodology, are found scattered among various sections in Volumes 1, 2, and 3 of WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0,. Please describe the process of ensuring that important aspects of the FSLOCA methodology are described in a clear, systematic, and coherent manner in the voluminous content of WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0,. In particular, please provide corrections, if such were deemed necessary, to improve the description provided with regard to HS_SLUG and C_{hs_slug}.

(3) Subsection 4.4.5, "Horizontal Stratified Flow," explains that "the allowable input range of C_{hs_slug} is from 0.1 to 9.9. Subsection 10.2, "Pipe Component," states that "the default value of HS_SLUG is 1.0 and can be modified through the $NAMELIST set of the model input within allowable range of 0.1≤ HS_SLUG ≤ 9.99." As both subsections refer to the same quantity, please explain why the provided allowable input ranges differ somewhat. Provide the limiting values for HS_SLUG and C_{hs_slug} as coded in WCOBRA/TRAC-TF2.

(4) Whereas HS_SLUG is sampled with[ ]^{a,c} the $NAMELIST set of the model input can be used to modify HS_SLUG within the allowable range of 0.1≤ HS_SLUG ≤ 9.99. Please explain the large disparity between the sampling range and the range of allowable values for HS_SLUG in WCOBRA/TRAC-TF2 taking into consideration that this extremely broad range of allowable values for HS_SLUG lacks a technical basis. Please explain the rationale for defining the range of allowable values and its intended application. In particular, describe how the use of inappropriate HS_SLUG values within the allowable range is controlled and prevented in plant safety analyses.

(5) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 10.2, "Pipe Component," explains that "additional user defined multipliers have been added in WCOBRA/TRAC-TF2 that affect specific models and correlations" and describes HS_SLUG as one of them. With regard to HS_SLUG, Subsection 10.2 states that "besides the PIPE component, it also affects the horizontal flow calculation for all 1D hydraulic components, except the PUMP." Please clarify if HS_SLUG is imposed on a global basis for an entire input deck model, if it can be applied selectively to individual qualifying components in an input model, or if it can be activated for individual cells/interfaces within a specific qualifying component.

(6) Please explain if WCOBRA/TRAC-TF2 allows excluding selected qualifying 1D hydraulic components in an input deck model from the effect of variation of HS_SLUG on horizontal flow modeling. In such a case, please explain the basis for exclusion and clarify how horizontal flow is modeled in such selected 1D hydraulic components.

(7) Please relate the responses to Items (4) through (6) above to specific features of PWR plant models used for LOCA analyses. Identify specific components in such models that are affected by HS_SLUG. Present diagrams from a reference plant model to explain and illustrate the application of the HS_SLUG parameter in PWR LOCA analyses.

Question #84: Stratified Flow Multiplier HS_SLUG Application

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 4.4.5, "Horizontal Stratified Flow," states that "the stratified flow regime is superimposed on the basic flow regime map." It also explains that if the flow is not fully stratified, i.e. the weighing factor W_{st} determined from Equation (4-116) is less than unity, "the code interpolates between the interfacial area determined for stratified flow, calculated as above, and the value otherwise determined with respect to the basic flow regime map." In the case of "fully horizontal stratified flow, the interfacial area can be calculated from the cell geometry." The expression for this interfacial area term, $A_{i,strat}$, is given by Equation (4-113).

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 16, "Horizontal Stratified Flow and Wavy-Dispersed Flow," Subsection 16.5, "Assessment Results," explains that "the weighting factors W_{st} =1 indicates stratified flow, while W_{st} =0 indicates a non-stratified flow in the basic flow regime map. In the interpolation region, 0 < W_{st} <1."

(1) W_{st} is used in Equation (4-116) to modify the interfacial flow area, A_i, when $0 \leq W_{st} \leq 1$. The equation appears as follows:

$$A_i = A_{i,st} = (1-W_{st})\, A_{i,map} + W_{st}\, A_{i,st}\,.$$

As provided, Equation (4-116) defines the quantity $A_{i,st}$, which appears simultaneously on both the left hand side and the right hand side of the equation. Please define the quantity $A_{i,st}$, appearing in Equation (4-116), and explain the meaning of this equation. In addition, please explain if the interfacial area for "fully horizontal stratified flow," $A_{i,strat}$, as defined by Equation (4-113), is used for interpolation purposes when $0 \leq W_{st} \leq 1$ and provide the corresponding expressions in such a case.

(2) Besides the interpolation of the interfacial flow area, performed when $0 \leq W_{st} \leq 1$, please explain if the weighing factor W_{st} and the HS_SLUG multiplier are used for modification of other physical quantities used in WCOBRA/TRAC-TF2 for two-phase flow modeling in 1D hydraulic components. In particular, please clarify if the calculation of interfacial friction and entrainment are affected due to variation of W_{st} and HS_SLUG. As applicable, please provide the corresponding relationships used for such modification purposes and describe the supporting technical basis.

Question #85: Stratified Flow and Inclination Limitation

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 4, "WCOBRA/TRAC-TF2 Flow Regime Maps and Interfacial Area," Subsection 4.4.5, "Horizontal Stratified Flow," explains that the[ ]a,c limitation for the inclination angle of a channel, β, in the described approach to stratified flow modeling is based on the assumption that the cosine value of the limiting angle[.]a,c is very close to unity. Thus, "the value can be approximated as 1.0 for simplicity, and cosβ can be removed from the stratification transition criterion."

(1) Please explain the WCOBRA/TRAC-TF2 approach to two-phase flow modeling in 1D hydraulic components, including prediction of flow stratification, for channels of any inclination angle and present the applicable technical basis.

(2) Figure 21.7-2, "WCOBRA/TRAC-TF2 Nodalization of LSTF Break Unit," shows that different values of the GRAV parameter apply to branches of different orientation that are used to model the break pipe. Please explain how the inclination angle is defined for each individual cell/interface in a 1D hydraulic component. Provide the range of allowable input values and the parameter used to define the inclination angle.

(3) If the horizontal flow calculation for a certain 1D hydraulic component is affected by the HS_SLUG multiplier, please explain how input parameters, related to inclination, determine the application of the stratified flow model for the component. In addition, please clarify how the actual inclination of the modeled flow piping is accounted for.

(4) Please relate the responses to Items (1) through (3) above to specific features of PWR plant models used for LOCA analyses. Identify specific components in such models that represent inclined sections of the primary coolant piping, such as the hot leg risers to the SG inlet chambers, and bend regions. In particular, please consider the representation of the bends in the PWR loop seals as well as the bends in the SG U-tube bundle. Show diagrams from a reference plant model to explain and illustrate the modeling of such inclined and bend regions in PWR plant models developed for WCOBRA/TRAC-TF2. Please present the technical basis in support of the modeling approach and any special modeling features implemented in WCOBRA/TRAC-TF2 to simulate these regions.

Question #86: MSTRTX, STRTX, STRTX1, and STRTX2 Multipliers

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 10, "WCOBRA/TRAC-TF2 One-Dimensional Component Models," Subsection 10.2, "Pipe Component," explains that in addition to the HS_SLUG multiplier, "user specified allowances for horizontal stratification within a PIPE component can be provided through the MSTRTX and STRTX input." Subsection 10.3, "TEE Component," states that "similar to the PIPE component, the user has the option to specify allowance for horizontal stratification in the main and side pipes through the STRTX1 and STRTX2 multipliers."

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, TR provide no description of the MSTRTX, STRTX, STRTX1, and STRTX2 multipliers. At the same time, Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over

Leg Noding," in Section 21, "ROSA-IV Test Simulations," of the WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, TR shows that specific values of STRTX linked to the common interface between the two adjacent cells used to model each of the 90° bends connecting the horizontal section of the LSTF loop seal to the downhill and uphill pipes of the cross-over leg.

(1) The MSTRTX, STRTX, STRTX1, and STRTX2 multipliers appear to be related to the modeling of important process in horizontal two-phase flow such as flow stratification. Please explain why the MSTRTX, STRTX, STRTX1, and STRTX2 multipliers were not described in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, TR.

(2) Please explain the meaning of the MSTRTX, STRTX, STRTX1, and STRTX2 multipliers, their modeling impact, and intended use. Provide the definitions of these quantities and describe how they relate to specific WCOBRA/TRAC-TF2 models and expressions.

(3) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 10.2, "Pipe Component," states that "user specified allowances for horizontal stratification within a PIPE component can be provided through the MSTRTX and STRTX input." Please clarify if MSTRTX, STRTX, STRTX1, and STRTX2 are user defined input parameters. Describe their initialization, default values, and allowable input ranges.

(4) Please explain how the default values and allowable input ranges for MSTRTX, STRTX, STRTX1, and STRTX2 have been determined and present the technical basis for their validation for the purposes of PWR LOCA analyses using WCOBRA/TRAC-TF2. Describe how the values of these multipliers are assigned and controlled in PWR plant LOCA analyses. Please relate the responses to Items (2) and (3) above to specific features of PWR plant models used for LOCA analyses. Identify specific components in such models that are affected by these parameters. Please present diagrams from a reference plant model to explain and illustrate their application in PWR LOCA analyses.

(5) Please revise WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, to include the additional information as requested in Items (2) through (4) above.

Question #87: WCOBRA/TRAC-TF2 Non-Sampled Modeling Multipliers

As addressed in RAI Question #86, the MSTRTX, STRTX, STRTX1, and STRTX2 multipliers, although related to the modeling of the highly ranked phenomenon of horizontal two-phase flow stratification, were not described in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, TR. At the same time, it appears that one such parameter, STRTX, was applied in WCOBRA/TRAC-TF2 assessment studies as indicated in Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over Leg Noding," in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations."

(1) Please provide a table that lists all parameters and multipliers related to the modeling of physical processes in WCOBRA/TRAC-TF2 and that are available for user input. The table should include separate columns that describe the following types of information: (1) the parameter identifier (for example, STRTX), (2) the PIRT ranking

for the process to which the parameter applies, (3) the analytic expression for the relation where the parameter appears as coded in the code source, (4) a summary description of the physical phenomenon to which the parameter applies, (5) default value and allowable input range for the parameter, as applicable. The parameters listed in the table should include all user defined quantities that are available in addition to the input parameters treated as random variables in the Full Spectrum LOCA methodology and described in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements."

(2) Please explain how the default values and allowable input ranges for the parameters identified in the response to Item (1) above have been determined and present the technical basis for their validation. Describe how the values of these multipliers are assigned and controlled in PWR plant LOCA analyses using WCOBRA/TRAC-TF2.

Question #88: LSTF Loop Seal Nodalization

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," Subsection 21.3, "Description of WCOBRA/TRAC-TF2 Model for ROSA/LSTF-IV," shows the 1D loop noding diagram of the LSTF model in Figure 21.3-8, "WCOBRA/TRAC-TF2 Loop Noding Diagram of LSTF." Components No. 13 and 23 are used to represent the loop seal piping in both primary loops. Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over Leg Noding," shows the 1D nodalization of the loop seal region in the pressurizer loop modeled by Component No. 13 with [ ]^{a,c} cells.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 5.2.4, "Primary Coolant Loop," in "ROSA-IV Large Scale Test Facility (LSTF) System Description," Japan Atomic Energy Research Institute Report JAERI-M 89-237, January 1985 explains that LSTF had two identical loops each representing two loops of the reference four-loop PWR. Pipes with 207 mm ID and 295 mm OD were used for the hot and cold legs and the cross-over leg pipes had 168.2 mm ID and 240.2 mm OD. The pipes were made of stainless steel SDS316L-TP. Important geometric dimensions of the loop seal piping are provided in Figure 5.2.34, "Primary Loop Dimensions (Elevation View)," in Figure 5.2.38, "Geometry of Primary Loop A," and in Figure 6.11(c), "Locations of Selected Primary Loop A and B Instruments," in the JAERI-M 89-237 report.

(1) Please provide a table that documents geometric input data for each cell in Component No. 13 shown in Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over Leg Noding," and used to model the loop seal piping. Provide length, elevation, flow area, volume, and inclination angle for each cell/interface and explain how the cross-over leg input model accounts for relevant LSTF elevation data of critical importance. Include loss coefficients, if such were input as part of the loop seal model. Describe any disparities, if present, between Component No. 13 and Component No. 23 that model the cross-over legs in both loops.

(2) Table 5.2.9, "Characteristics of Primary Loop Piping," in JAERI-M 89-237 provides the length of the cross-over leg as 9.5498 m (31.331 ft) and the cross-over leg volume, excluding the RCP volume, as 0.2122 m^3 (7.494 ft^3). The provided length and volume data correspond to the cross-over leg flow area of 0.0222 m^2 (0.2392 ft^2), which matches the 168.2 mm pipe ID. The total length of the cells of Component

No. 13 in Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over Leg Noding," amounts to 30.8608 ft. Table 26.1-4 in WCAP-16996-P Revision 0 Section 26, "WCOBRA/TRAC-TF2 Model of Pilot Plants," Subsection 26.1.2, "Modeling Consistency," lists the cross-over leg axial length, based on the LSTF noding model, as 30.86 ft. Please compare the cross-over leg integral cell length and volume based on the input data provided in response to Item (1) above against the geometric data for the LSTF cross-over leg provided in Table 5.2.9, "Characteristics of Primary Loop Piping," in JAERI-M 89-237. Please explain any differences, if present.

(3) Section 6.4.3, "Primary Loops Instruments," in JAERI-M 89-237 explains that Venturi flow meters were installed at each cross-over leg to measure the flow rate of primary coolant. Figure 6.11(c), "Locations of Selected Primary Loop A and B Instruments," in JAERI-M 89-237 shows the location of the flow meters in the uphill section of each loop seal. According to Table 5.7.4 in JAERI-M 89-237, the flow meters had a contraction ratio of 0.505 corresponding to a Venturi throat diameter of 85 mm (3.34 in). As explained in Section 5.7, "Valves and Orifices," in JAERI-M 89-237, the flow meters installed in the facility acted as flow resistance for fluid in piping. Please clarify how the flow meter presence was accounted for in the LSTF loop seal models.

(4) LSTF was equipped with flow control valves, installed upstream of the RCPs, to allow for considerable variation in the primary loop coolant flow during an experimental transient. As seen from Figure 6.11(c), "Locations of Selected Primary Loop A and B Instruments," in JAERI-M 89-237, the primary coolant flow control valves were installed in the horizontal sections of the loop seal cross-over legs in both loops. According to Figure 6.11(c), the length of the horizontal cross-over leg portion associated with the primary coolant flow control valves amounted to 2 mm + 762 mm + 2 mm = 766 mm (2.513 ft). Please clarify if the primary coolant flow control valves introduced additional flow resistance and if the presence of these valves was accounted for in the LSTF WCOBRA/TRAC-TF2 loop seal models.

Question #89: Modeling of LSTF Loop Seal Horizontal Section and Bend Regions

[ ]a,c in Component No. 13 in Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over Leg Noding,[

]a,c the length of the horizontal section of the cross-over leg, determined as 1.3817 m (2,383.7 mm – 2 × 501 mm = 1,381.7 mm = 1.3817 m), based on dimensions provided in Figure 5.2.34, "Primary Loop Dimensions (Elevation View)," and in Figure 5.2.38, "Geometry of Primary Loop A," in JAERI-M 89-237. The primary coolant flow control valves, as shown in Figure 6.11(c), "Locations of Selected Primary Loop A and B Instruments," in JAERI-M 89-237, occupy 2.513 ft of the 4.533-ft long horizontal sections of the LSTF loop seal cross-over legs.

(1) It is determined that the length-to-diameter ratio (L/D) for horizontal section of the LSTF loop seal cross-over leg amounts to:

L / D = 1,381.7 mm / 168.2 mm = 8.21.

Please explain the rationale for representing the entire horizontal portion of the loop seal piping[ ]^{a,c} in the WCOBRA/TRAC-TF2 model of LSTF.

(2) As shown in Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over Leg Noding," each of the 90° bends connecting the cross-over leg horizontal section to the downhill and uphill sides of the loop seal are modeled by [ ]^{a,c} Please explain how the noding of bend regions in the cross-over legs was determined and describe any special considerations taken with regard to the modeling of these regions. In particular, clarify the modeling approach with regard to capturing effects of inclination on the flow behavior. As inclination angles are associated with a specific noding scheme that is applied to a bend region, please explain how the noding relates to the two-phase flow being treated as horizontal, vertical or inclined as the flow transitions from horizontal to vertical (or vice versa) when it passes through the 90° bend.

Question #90: WCOBRA/TRAC-TF2 Features Applied in LSTF Loop Seal Modeling

Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over Leg Noding," in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," Subsection 21.3, "Description of WCOBRA/TRAC-TF2 Model for ROSA/LSTF-IV," shows the 1D nodalization of the loop seal region in the LSTF pressurizer loop. The overall 1D loop noding diagram of the LSTF model is presented in Figure 21.3-8, "WCOBRA/TRAC-TF2 Loop Noding Diagram of LSTF." Components Nos. 13 and 23 are used to represent the loop seal piping in both primary loops. WCOBRA/TRAC-TF2 assessment results using this model are presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations."

(1) Please explain which instrumentation devices, installed in the ROSA-IV LSTF loop seal cross-over leg, have been considered for the assessment of WCOBRA/TRAC-TF2 using ROSA-IV LSTF test data. If certain available and relevant measurements were not used in qualifying the code capabilities to predict loop seal clearing, please explain the reasons for this.

(2) In addition to implementing an adequate noding model, meaningful assessment of code prediction results against experimental data requires that node or junction points, at which computational variables are computed by the code, relate properly to the location of experimental measuring points of interest. Please explain how this was taken into account in establishing the WCOBRA/TRAC-TF2 loop seal cross-over leg model for LSTF. In particular, please explain how the elevations of the differential pressure tap locations, including the one in the horizontal section of the loop seal cross-over leg, were accounted for.

(3) For the LSTF loop seal model, please describe any specific modeling features that were applied on Component Nos. 13 and 23 a component-wide basis to or to specific cells/interfaces of these components in representing the LSTF loop seal regions. Identify individual cells/interfaces where sampling of input quantities, for example HS_SLUG, was applied and identify all sampled parameters. In addition, please identify any non-sampled user defined parameters or multipliers, e.g. C_{stfru} and STRTX, related to the modeling of participating physical processes such as flow

stratification, counter-current flow limitation (CCFL), or other relevant processes, that were applied in modeling the LSTF loop seals to assess WCOBRA/TRAC-TF2. Please provide a table that lists all such applied sampled and non-sampled user defined modeling parameters or multipliers applied in the LSTF loop seal modeling. Please include a brief description, the applied range, and the input values for each parameter listed in the table.

Question #91: V. C. Summer and Beaver Valley Unit 1 Loop Seal Models

Figure 6.2-8, "Virgil C. Summer Loop Model Noding Diagram," and Figure 26.3-14, "Beaver Valley Unit 1 Loop Model Noding Diagram," in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 26, "WCOBRA/TRAC-TF2 Model of Pilot Plants," show noding diagrams for the primary loops of the plant models across a horizontal plane. In both plant input models, Component Nos. 13, 23, and 33 represent the PWR cross-over legs in the primary coolant loops.

(1) Please provide detailed noding diagrams across a vertical plane for the cross-over leg regions in both plant models similar to the one shown for the LSTF loop seal in Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over Leg Noding." In these diagrams, please show important elevations including the elevation of the axis of the horizontal bottom section of the loop seal. Provide the elevations data using the Top of Active Fuel (TAF) elevation as the zero elevation point.

(2) Please provide a table that documents geometric input data for each cell in Component Nos. 13, 23, and 33 used to model the loop seal piping for both plants. Provide length, elevation, flow area, volume, and inclination angle for each cell/interface and explain how the cross-over leg input models account for relevant elevations of critical importance. Include loss coefficients, if such were input as part of the loop seal models. Describe any disparities, if present, between Component No. 13, Component No. 23, and Component No. 33 for each plant.

(3) For the loop seal models of the reference V. C. Summer and Beaver Valley Unit 1 PWR plants, please describe any specific modeling features that were applied to Component Nos. 13, 23, and 33 on a component-wide basis or to specific cells/interfaces of the loop seal components. Identify individual cells/interfaces where sampling of input quantities, e.g. HS_SLUG, was applied and identify all sampled parameters. In addition, please identify any non-sampled user defined parameters or multipliers, e.g. C_{stfru} and STRTX, related to the modeling of participating physical processes such as flow stratification, counter-current flow limitation (CCFL), or other relevant processes, that were applied to model the plant loop seals in the plant models. Please provide a table that lists all such applied sampled and non-sampled user defined modeling parameters or multipliers including brief descriptions, applied ranges, and input values for each listed parameter.

Question #92: PWR Loop Seal Horizontal Section and Bends Modeling

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 4, "WCOBRA/TRAC-TF2 Flow Regime Maps and Interfacial Area," Subsection 4.4.5, "Horizontal Stratified Flow," explains that the code allows horizontal flow when the pipe inclination angle is less than [ ]^{a,c} In addition, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements," Subsection 29.5.6, "Pump Suction Piping/Loop Seal," clarifies that [

]^{a,c}

Figure 21.3-9, "Hot Leg (Including Pressurizer), Steam Generator and Cross-Over Leg Noding," shows the 1D nodalization of the loop seal region in the pressurizer loop, which is modeled by Component No. 13 using[ ]^{a,c} cells. Figure 6.2-8, "Virgil C. Summer Loop Model Noding Diagram," and Figure 26.3-14, "Beaver Valley Unit 1 Loop Model Noding Diagram," show the noding diagrams for the primary loops across a horizontal plane. In both plant input models, Component Nos. 13, 23, and 33 represent the cross-over legs in the primary coolant loops.

(1) Please explain the noding of the horizontal section of the loop seal cross-over legs for both plant models. Provide the length-to-diameter ratio (L/D) for this horizontal section of the cross-over legs. Explain the rationale for the applied L/D ratio in the WCOBRA/TRAC-TF2 PWR models. Discuss any associated modeling guidelines along with analysis results that substantiate them, if available.

(2) Please explain the noding of the bends in the loop seals for both plant models. Show the geometry of these regions along with relevant pipe geometrical dimensions such as inner diameter and bend radii, and provide detailed noding diagrams.

(3) In a piping bend region, inclination for individual cells/interfaces depends on and varies with the degree of refinement in the implemented nodalization scheme. Please explain the approach to nodalization of the bends in a PWR loop seal cross-over leg and clarify how the response to Item (2) above relates to this approach. Discuss any associated modeling guidelines along with analysis results used to develop them, if available. Identify any WCOBRA/TRAC-TF2 modeling features that can be used to account for effects due to channel curvature and inclination in bend regions on the flow behavior and describe them, if available.

(4) Please explain if specific sensitivity analyses related to PWR loop seal cross-over leg modeling and realistic prediction of loop seal clearing have been performed to assess WCOBRA/TRAC-TF2 in this regard. If available, please summarize the results from such sensitivity analyses that are based on data from any integral effect test facilities, such the LSTF tests described in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," or performed using PWR plant models, e.g. the reference PWR plant models described in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 26, "WCOBRA/TRAC-TF2 Model of Pilot Plants," that demonstrate the WCOBRA/TRAC-TF2 capabilities to predict adequately PWR loop seal clearance and refill as related to modeling both small and large break LOCAs.

Question #93: Editorial Findings

Please address the findings identified below as they apply to various subsections of Section 21, "ROSA-IV Test Simulations," in Volume 2 of WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0.

(1) Subsection 21.4.3 states on page 21-8 that "Figures 21.4-1 through 22.4-20 compare predicted and measured results for the 5-percent cold leg break test SB-CL-18." Please explain if Figure 22.4-20 has been referred to in error instead of Figure 21.4-20 on page 21-8 of WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, and correct if appropriate.

(2) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 21.5.2, "Results and Conclusions from the SB-CL-05 Simulation," refers to Figures 21.6-7(a) and 21.6-7(b) on page 21-12 when discussing SG secondary side pressure in each loop. Please explain if Figures 21.6-7(a) and 21.6-7(b) have been referred to in error instead of Figures 21.5-7(a) and 21.5-7(b) on page 21-12 of WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, and correct if appropriate.

(3) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 21.16.2 is entitled "HS_SLUG Sensitivity with 5 percent Top Break test SB-CL-18." The first sentence in this subsection reads: "Two simulations of the 5 percent side break test SB-CL-18 test were performed with setting the HS_SLUG multiplier at its maximum[ ]a,c and minimum [ ]a,c values." Please confirm the LSTF test run that is considered in Subsection 21.16.2, verify the break orientation angle for this test, and provide relevant corrections if appropriate. Please check the proper wording of the sentence cited above.

(4) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," Subsection 21.11.2, "SB-CL-18 Simulation Without Hot Leg Nozzle Bypass Flow," states on page 21-33: "The results of this sensitivity, taken in conjunction with these presented in the previous Section 21.11.2, also shows that modeling lower overall bypass is conservative." Please confirm the subsection number referred to in this citation from Subsection 21.11.2 and correct the wording of the sentence as appropriate.

Question #94: Interpolation for Stratified Flow and C_{hs_slug} Parameter

Equation (4-117) defines the weighting factor, W_{st}, as a function of the relative phase velocity, $|u_g-u_l|$, the critical relative phase velocity, Δu_c, and two adjustable constants, C_{hs_slug} and C_{stfru}. Table 1 below shows the values for the ratio of the relative velocity to the critical relative velocity, $|u_g-u_l|/\Delta u_c$, at which the W_{st} weighting factor, as calculated from Equation (4-117), becomes equal to unity or zero for three different values of the C_{hs_slug} constant: [ ]a,c In computing the results provided in Table 1, the constant C_{stfru}, appearing in Equation (4-117), was set equal to its default value of [ ]a,c

Table 1: Velocity Ratio Values when W_{st} Equals 0 or 1 for C_{hs_ug} Values of [ ]a,c and at the Nominal Value of C_{stfru}=[ ]a,c

Constant C_{hs_slug}	Relative Velocity Ratio, $|u_g-u_l|/\Delta u_c$ (-)	
	Stratified Flow, W_{st}=1	Non-stratified Flow, W_{st}=0

[

]a,c

Figure 1 plots W_{st} as a function of the relative velocity ratio, $|u_g-u_l|/\Delta_c$, according to Equation (4-117) when the constant C_{hs_slug} is set equal to [ ]a,c as well as to its limiting values of 0.1 and 9.9. For the curves shown in Figure 1, the second adjustable constant C_{stfru} was set equal to its default value of [ ]a,c

[

]a,c

Figure 1: Effect of Constant C_{hs_slug} (HS_SLUG) in Equation 4-117 on the Weighing Factor W_{st} at C_{stfru}= [ ]a,c

As seen from the results provided in Table 1 and the curves presented in Figure 1 above, the interpolation range $0 \le W_{st} \le 1$ for the weighting factor, W_{st}, as defined by Equation (4-117), corresponds to a relative velocity ratio, $|u_g - u_l|/\Delta u_c$, ranging from [ ]^{a,c} when HS_SLUG varies between [ ]^{a,c} with C_{stfru} being set at its default value of [ ]^{a,c}

Please explain the significant disparity between the proposed HS_SLUG sampling range from [ ]^{a,c} and the relative velocity ratio range from [ ]^{a,c} that corresponds to W_{st} values being $0 \le W_{st} \le 1$ when C_{stfru} is set equal to its proposed default value of [ ]^{a,c} When $0 \le W_{st} \le 1$, an interpolation technique to account for the effect of stratification is applied WCOBRA/TRAC-TF2. Please relate the response to this request for additional information to the test data points that are plotted in Figure 4-17, "Horizontal Stratified Flow Regime Transition and Relevant Data." Also, please consider the statement provided in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 4, "WCOBRA/TRAC-TF2 Flow Regime Maps and Interfacial Area," Subsection 4.4.5, "Horizontal Stratified Flow," that [

]^{a,c}

Question #95: Interpolation for Stratified Flow and C_{stfru} Parameter

Equation (4-117) defines a weighting factor, W_{st}, using two adjustable constants, C_{hs_slug} and C_{stfru}. Discussing the weighting factor, W_{st}, and the corresponding interpolation range when $0 \le W_{st} \le 1$ in accordance with Equation (4-117), Subsection 4.4.5, "Horizontal Stratified Flow," explains that "the size of the interpolation region can be adjusted by the input variable C_{stfru}. The default value of C_{stfru} is [ ]^{a,c} The allowable input range of C_{stfru} is from [ ]^{a,c} The impact of the C_{stfru} constant on W_{st} is illustrated in Figure 1 below for three different values of C_{stfru}: its default value of [ ]^{a,c} and the lower and upper limiting values for the range of allowable input values for C_{stfru}, [ ]^{a,c} For the curves shown in Figure 1, the second adjustable constant, C_{hs_slug}, was set equal to its default value of 1.0.

[

]a,c

Figure 1: Effect of Parameter C_{stfru} in Equation 4-117 on the Weighing Factor W_{st} at C_{hs_slug}=1.0

Please explain the rationale for selecting [ ]a,c as the default value for the C_{stfru} parameter. In addition, explain the reasons for defining a range from [ ]a,c as allowable input values for C_{stfru} and describe the intended application of this proposed range. Clarify the way in which the input value for C_{stfru} is defined and describe how the use of inappropriate C_{stfru} values within the allowable range of input values is controlled and prevented in PWR plant LOCA analyses using WCOBRA/TRAC-TF2.

Question #96: PWR Upper Head Spray Nozzle Bypass Design Data

Upper head cooling spray nozzles are used in PWR to adjust the coolant temperature in the upper head plenum by providing a relatively small bypass flow of coolant at the cold leg temperature from the upper downcomer region into the upper head plenum. The exact configuration and bypass flow depend on the PWR design and the production line. WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.2.2.2, " Fluid Conditions Modeling Approach," explains that "typically, plants can be separated into two categories: those with sufficient bypass flow to maintain (T_{UH}) near (T_{cold}), and those with low bypass flow, in which (T_{UH}) remains close to T_{hot}." Taking into account that the upper head-to-downcomer bypass flow affects the upper head initial temperature at steady-state, Subsection 25.2.2.2, states that "the initial temperature of the fluid in the upper head (T_{UH}) has been found to strongly affect the blowdown PCT in other evaluation models (for Large Break LOCA)." During small break LOCA, this bypass releases steam from the upper plenum and the resulting "venting has a high importance during the loop seal clearing period when it relieves some of the core two-phase level depression," as explained in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements," Subsection 29.5.3, "Upper Head." Subsection 29.5.3 also explains that "the ability to vent steam through the upper head is strongly dependent on the flow area of the spray nozzles, which is the flow path connecting the upper head and the downcomer" and states that "the spray nozzle bypass itself is modeled in a best-estimate manner."

(1) Please explain if PWR upper head spray nozzle channels and relevant design features are modeled by implementing certain hydraulic components, component features, and/or activation of specific modeling options in WCOBRA/TRAC-TF2 vessel models of PWR plants and provide their corresponding description.

(2) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 26, "WCOBRA/TRAC-TF2 Model of Pilot Plants," Subsection 26.4, "Steady State Calculation/Calibration," states that "core bypass flow (including the thimble bypass flow and the spray nozzle flow) should closely match those provided by the mechanical design data." Please explain what "mechanical design data" of the upper head spray nozzles is used to simulate these nozzles in WCOBRA/TRAC-TF2 vessel models of PWR plants.

(3) Please identify design data of upper head spray nozzles, including any relevant reactor features and conditions, such as number of spray nozzles, nozzle diameters, lengths, loss coefficients, flow areas, and other geometric dimensions and conditions, that are used for the upper head bypass simulation in WCOBRA/TRAC-TF2 vessel models. Explain the source, availability, and accuracy of data quantifying upper head bypass and explain how such bypass flow data is obtained for PWR plants of interest. Clarify how the design data is used in developing COBRA/TRAC-TF2 PWR plant models used for the purposes of LOCA analyses. Provide a table that provides the typical ranges for these parameters.

(4) Please provide the range of spray nozzle bypass capacities for PWR plants included in the scope of intended WCOBRA/TRAC-TF2 applications for LOCA analyses and estimate the uncertainties associated with provided PWR upper head spray nozzle bypass capacities.

(5) Please explain how Items (1) through (4) above relate to the statement that "the spray nozzle bypass itself is modeled in a best-estimate manner" in WCOBRA/TRAC-TF2 PWR plant LOCA analyses. Please explain how the information requested in Items (1) through (4) is taken into consideration in ensuring that "the spray nozzle bypass itself is modeled in a best-estimate manner." Describe any other relevant WCOBRA/TRAC-TF2 PWR plant model details and modeling features if implemented in the Full Spectrum LOCA methodology in this regard.

Question #97: PWR Upper Head Spray Nozzle Bypass Flow Tune-up

Considering steady-state acceptance criteria for plant initial conditions, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 26, "WCOBRA/TRAC-TF2 Model of Pilot Plants," Subsection 26.4, "Steady State Calculation/Calibration," provides Table 26.4-1, "Criteria for an Acceptable Steady-State," which contains a checklist with 17 significant parameters "to verify whether these variables have reached their acceptable steady-state values." Item (12) in this table lists the "Upper Head Nozzle Flow/Vessel Flow" variable and provides a corresponding acceptance criterion, according to which the "calculated value" should be within [ ]a,c of the "desired value."

Considering application aspects related to the spray nozzle bypass modeling, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," Subsection 21.11.3, "Spray Nozzle Bypass Ranging Sensitivity with the SB-CL-18 Test," states that "during the steady state tune-up procedure, the bypass flow through the spray nozzle is adjusted to be within [ ]a,c of the desired value, established for each plant."

(1) Please explain how "the bypass flow through the spray nozzle is adjusted to be within [ ]a,c of the desired value, established for each plant" and describe the "steady state tune-up procedure" used to achieve this. Identify plant model input variables and related features that are subject to this "steady state tune-up" and describe how such parameters are varied. Explain it these parameters are subject to variation within certain allowable limits and, if this is the case, please describe how the corresponding limits are established.

(2) Please explain how the "desired value" for the variable "Upper Head Nozzle Flow/Vessel Flow" identified in Table 26.4-1, "Criteria for an Acceptable Steady-State," is established for each plant and clarify how it is used in PWR LOCA analyses using WCOBRA/TRAC-TF2.

(3) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 26.4 states that "core bypass flow (including the thimble bypass flow and the spray nozzle flow) should closely match those provided by the mechanical design data, within the tolerances given in Table 26.4-1. The allowable variation is essentially equivalent to a 1 percent variation in the loop flowrate." Please explain the meaning of the statement that [ ]a,c Clarify how this statement relates to the criterion that the "calculated value" of the "Upper Head Nozzle Flow/Vessel Flow" parameter is within [ ]a,c of the "desired value."

(4) The "steady state tune-up" procedure establishes the upper head bypass flow under the reactor initial conditions at steady-rate operation. Please explain how PWR vessel model hydraulic features implemented in WCOBRA/TRAC-TF2 PWR plant models and adjustments to such model features aimed at verifying that a certain "desired value" bypass flow is achieved at the end of an initial steady-state plant simulation ensure that the bypass flow is realistically modeled during a LOCA transient calculation.

(5) Please explain how the information requested in Items (1) through (4) is taken into consideration in ensuring that "the spray nozzle bypass itself is modeled in a best-estimate manner." Describe any other relevant WCOBRA/TRAC-TF2 PWR plant model details and modeling features if implemented in the Full Spectrum LOCA methodology in this regard.

Question #98: PWR Upper Head Temperature Tune-up

The upper head liquid temperature is dependent on the venting flow between the upper head and the reactor downcomer through the upper head spray nozzles. WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements," Subsection 29.5.3, "Upper Head," states that "the initial upper head liquid temperature is calibrated during the steady-state calculation." WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 26, "WCOBRA/TRAC-TF2 Model of Pilot Plants," Subsection 26.4, "Steady State Calculation/Calibration," Table 26.4-1, "Criteria for an Acceptable Steady-State," includes Item (14), which lists the "Upper Head Temperature" variable and provides a corresponding acceptance criterion, according to which the "calculated value" should be within [ ]^{a,c} of the "desired value."

(1) Please explain how the "desired value" for the variable "Upper Head Temperature" identified in Table 26.4-1, "Criteria for an Acceptable Steady-State," is established for each plant and describe how it is used in PWR LOCA analyses using WCOBRA/TRAC-TF2.

(2) As explained in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 29.5.3, "the initial upper head liquid temperature is calibrated during the steady-state calculation" so that it is within [ ]^{a,c} of the "desired value." In addition, Subsection 29.5.3 states that "upper head liquid temperature uncertainty is considered by varying the temperature based on the ranging of vessel average temperature." As the upper head liquid temperature is influenced by the bypass flow between the upper head and the reactor downcomer through the upper head spray nozzles, please explain if the process of upper head initial temperature calibration and its uncertainty consideration have any effects on the spray bypass flow modeling.

(3) For PWR small break LOCA analyses, adequate prediction of the upper head bypass flow is of primary importance. WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements," Subsection 29.5.3, "Upper Head," states that "the spray nozzle bypass itself is modeled in a best-estimate manner" in plant LOCA analyses using WCOBRA/TRAC-TF2. Please explain how this is done for PWR small break LOCA analyses, taking into consideration the information requested in Items (1) and (2) above, to ensure that the upper head bypass flow is not inappropriately affected due to upper head temperature adjustments.

Question #99: PWR Upper Head Spray Nozzle Bypass in WCOBRA/TRAC-TF2 Pilot Plant Models

Figures 26.2-3 through 26.2-6 in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 26, "WCOBRA/TRAC-TF2 Model of Pilot Plants," Subsection 26.2.1, "V. C. Summer WCOBRA/TRAC-TF2 Nodalization," show the RPV nodalization for the three-loop V. C. Summer plant. As seen from Figure 26.2-3, "Virgil C. Summer Vessel Model Noding Diagram," the vessel is divided into nine vertical sections with Section 1 at the bottom and Section 9 at the top. In this model, Sections 7, which contains two vertical cells, represents the uppermost region and "extends vertically from the top of the hot leg to the top of the upper support plate." The downcomer region in Section 7 is modeled by nine channels occupying the peripheral ring, Channels 40, 41, 42, 82, 83, 84, 85, 86, and 87. As described, each of these channels "represent one-ninth of the downcomer annulus volume between the vessel inner wall and the core barrel outer wall." Section 8, which has one vertical cell, models the lower section of the upper head region and "extends vertically from the top of the upper support plate to the top of the upper guide tube." As seen from Figure 26.2-6, "Virgil C. Summer Vessel Sections 7 through 9," this section is divided into two radial rings with the interface boundary "formed by the cylinder which intersects the inside of the upper head sphere at the top of the upper guide tube." Channels 47, 88, and 89 occupy the outer ring and each of them include one-third of the volume in the upper head outer region. Subsection 26.2.1 states that "Channels 40 through 42 and 82 through 87, however, connect vertically to vessel Section 8 via the upper head spray nozzles."

The Beaver Valley Unit 1 three-loop PWR RPV nodalization is described in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 26.3.1, "Beaver Valley Unit 1 WCOBRA/TRAC-TF2 Nodalization." The spray nozzle bypass is modeled in a similar manner and the subsection repeats that "Channels 40 through 42 and 82 through 87, however, connect vertically to vessel Section 8 via the upper head spray nozzles."

(1) Please describe how the bypass flow path through the spray nozzles connecting the downcomer and upper head regions were represented in the WCOBRA/TRAC-TF2 pilot models for the V. C. Summer and Beaver Valley Unit 1 PWR plants descried in Section 26. Provide a table that lists the input parameters associated with hydraulic components and modeling features employed to simulate the spray nozzles passages. Provide noding details that show how Channels 40 through 42 and 82 through 87 "connect vertically to vessel Section 8 via the upper head spray nozzles" for each vessel model.

(2) Please provide spray nozzles geometric data and drawings of the spray nozzles for both pilot plants and explain how plant design data was used in modeling the spray nozzle bypass flow passages in the WCOBRA/TRAC-TF2 vessel models for the V. C. Summer and Beaver Valley Unit 1 PWR plants. Please explain how spray nozzle design data was used to model the spray nozzle bypass and calculate the input parameters requested in Item (1) above.

(3) Please explain how the "steady state tune-up procedure," used to "adjust" the bypass flow through the spray nozzle "within[ ]^{a,c} of the desired value, established for each plant," was performed for the V. C. Summer and Beaver Valley Unit 1 pilot PWR plants. Describe how the "desired value" for the variable "Upper Head Nozzle

Flow/Vessel Flow" listed in Table 26.4-1, "Criteria for an Acceptable Steady-State," was established for each plant and compare the "calculated value" versus the "desired value" at the end of the steady-state runs for both plants. Also, please provide a table that lists all parameters subject to modification "during the steady state tune-up procedure." For each such parameter, provide its values at the beginning and at the end of the "steady state tune-up procedure" as well as the allowable variation range listing each parameter in a separate column.

Question #100: Upper Head Spray Nozzle Bypass in LSTF Tests

To model the upper head spray nozzle bypass, the LSTF vessel featured 8 spray nozzle openings, each with a 3.4-mm (0.134-in) inlet inner diameter, a 10-mm (0.394-in) exit inner diameter, and a 175-mm (6.9-in) length, where inlet and exit values correspond to normal flow direction from the downcomer into the upper head at normal operation. Based on the spray nozzle inlet diameter, the total spray nozzle bypass flow area amounts to 0.726 cm^2 (7.826×10^{-4} ft^2), which corresponds to an equivalent opening diameter of 0.961 cm (0.379 inch). Detailed geometrical data related to the upper head spray nozzles can be found in Figure 5.2.4, "Coolant Flow Path in Pressure Vessel," in Figure 5.2.6, "Downcomer-Upper Head Spray Nozzle Details," and in Figure 5.2.7, "Upper Head Cross Section," in "ROSA-IV Large Scale Test Facility (LSTF) System Description," Japan Atomic Energy Research Institute Report JAERI-M 84-237, January 1985.

(1) Please provide a table that documents the spray nozzle bypass capacities as measured in the LSTF tests that are analyzed in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," and in Section 24, "Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2." Describe each individual LSTF test in a separate row including the following parameters, each in a separate column: test identifier (e.g. SB-CL-05), test date, data source documents, upper plenum-to-upper head bypass unit, and experimental upper plenum-to-upper head bypass value. Explain the source, availability, and accuracy of data quantifying the LSTF upper head bypasses in these tests and explain if the bypass data was examined and qualified as part of the WCOBRA/TRAC-TF2 assessment.

(2) Please compare LSTF upper head spray nozzle bypass data against downcomer-to-upper head bypass capacities simulated in WCOBRA/TRAC-TF2 LSTF test analyses presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," and in Section 24, "Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2." In the table requested in Item (1) above, include an additional column, which documents the downcomer-to-upper head bypass values for all WCOBRA/TRAC-TF2 LSTF tests used in the simulations in consistent units. Clearly state if the downcomer-to-upper head bypass capacities in the WCOBRA/TRAC-TF2 LSTF test simulations were adjusted to account for any effects other than the downcomer-to-upper head bypass through the upper head spray nozzle openings present in the LSTF pressure vessel.

Question #101: Upper Head Spray Nozzle Bypass in LSTF WCOBRA/TRAC-TF2 Model

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," describes the noding of the LSTF pressure vessel in Subsection 21.3, "Description of WCOBRA/TRAC-TF2 Model for ROSA/LSTF-IV." Figure 21.3-1, "WCOBRA/TRAC-TF2 Model of LSTF Pressure Vessel," Figure 21.3-5, "LSTF Pressure Vessel Sections 7 and 8," and Figure 21.3-6, "LSTF Pressure Vessel Sections 9 and 10," show nodalization details pertinent to modeling of the bypass flow path between the downcomer and the upper head.

(1) Figure 21.3-1, "WCOBRA/TRAC-TF2 Model of LSTF Pressure Vessel," illustrates that the upper head bypass nozzles were modeled as [ ]a,c with a certain length. Please describe how the bypass flow paths through the upper head spray nozzles in the LSTF test vessel were represented in the WCOBRA/TRAC-TF2 vessel model of LSTF. Provide noding details that show how[ ]a,c connect vertically to hydraulic components in vessel Section 9 to represent the upper head spray nozzles. Include a table that lists the input parameters associated with hydraulic components and modeling features employed to model these bypass flow paths in the LSTF pressure vessel and provide the input values for all LSTF tests analyzed in WCAP-16996-P Revision 0 Section 21, "ROSA-IV Test Simulations," and in Section 24, "Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2.

(2) Please explain how the spray nozzles geometric and other design data were used to model the spray nozzle bypass flow passages between the downcomer and upper head in the WCOBRA/TRAC-TF2 model of the LSTF pressure vessel and to calculate the input parameters requested in Item (1) above.

(3) Table 21.4-1, "Steady-State Parameter Checklist (Initial Conditions) for the SB-CL-18 Test," provides a downcomer-to-upper head flow rate of 0.30 percent of the core flow for both the "target (measured)" and "modeled" parameters. Table 21.5-1, "Steady-State Parameter Checklist (Initial Conditions) for the SB-CL-05 Test," lists a value of ~0.70 percent of "core flow" for the "modeled" downcomer-to-upper head flow rate and provides the "target (measured)" value as "N/A." Table 21.9-1, "Initialization of the SB-CL-02 Natural Circulation Test Simulation," gives a "target" value of 0.9% and a "calculated" value of 0.70 percent for the downcomer-to-upper head flow rate in percentage of "total core" at the end of Stage 1 of the LSTF experiment, which was run at nominal conditions. Please explain how the downcomer-to-upper head bypass flow rates, defined as "target (measured)" and "modeled" in Tables 21.4-1 and 21.5-1 and as "target" and "calculated" in Table 21.9-1, were established and explain the reported differences. Clarify why the "calculated" value, provided in Table 21.9-1, resulted in 0.70 percent.

(4) The downcomer-to-upper head flow is provided in Table 21.9-1 in units of "kg/sec" and "% total core." It appears that the provided percentage values correspond to the ratio of the downcomer-to-upper head flow rate to the total loop flow rate, which parameter is also listed in the table. At the same time, the downcomer-to-upper head flow is provided in Tables 21.4-1 and 21.5-1 in percentage units described as "% core flow." The listed values correspond to the ratio of the downcomer-to-upper head flow rate to the core inlet flow rate, which quantity is also listed in these tables.

Please explain why different definitions for the downcomer-to-upper head flow ratio were used for the percentage values in these tables.

(5) Please explain if a "steady state tune-up procedure" was used to "adjust" the bypass flow through the spray nozzles in the WCOBRA/TRAC-TF2 model of the LSTF pressure vessel. In such a case, please describe how the "desired value" for the downcomer-to-upper head bypass flow was established for the analyzed LSTF experiments. Please provide a table that lists all parameters subject to modification "during the steady state tune-up procedure." For each listed parameter, provide the corresponding values at the beginning and at the end of the "steady state tune-up procedure" as well as the allowable variation range for the parameter. Please list each parameter in a separate column in the table.

(6) Provide a table that documents the "calculated value" for the downcomer-to-upper head bypass at the end of the steady-state runs and the corresponding "desired values" for all LSTF tests analyzed in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," and in Section 24, "Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2."

Question #102: LSTF Upper Head Spray Nozzle Bypass Relevance to PWR

As reported by Y. Kukita et al., "Quasi-Static Core Liquid Level Depression and Long-Term Core Uncovery During a PWR LOCA, Nuclear Safety, Vol. 34, No. 1, 1993, pp. 33-48, the LSTF pressure vessel bypasses included upper head spray nozzles and a hot-leg nozzle leak line between each hot leg and the downcomer that simulated bypass flow rates of about 0.3 percent and 0.2 percent (for both loops) of the total core flow rate at single-phase (liquid) steady-state operation, respectively. These normal LSTF bypass flow capacities were representative of the upper vessel bypasses of Japanese-built Westinghouse-type PWR plants with a total bypass flow rate of 0.5 percent. According to the same authors, spray nozzle bypass capacities, ranging typically from 1 percent to 4 percent, were representative for most of the U.S. Westinghouse PWR configurations. A bypass of 1.8 percent of the total downcomer mass flow rate for the Westinghouse standardized four-loop single-unit plant described in the Reference Safety Analysis Report (RESAR) RESAR-3S, sometimes referenced to as a "typical" Westinghouse plant, was provided by the authors. A special 0.5-inch tubing bypass line connected the downcomer to the upper head in the LSTF pressure vessel to simulate the leakage between these two components in commercial PWRs. A somewhat broader range from 0.5 percent to 4 percent of the total core flow for the leakage between the downcomer and the upper head in a commercial PWR is provided by G. G. Loomis and J. E. Streit, "Results of Semiscale Mod-2C Small-Break (5 percent) Loss-of-Coolant Accident Experiments S-LH-1 and S-LH-2," NUREG/CR-4438, EGG-2424, November 1985.

Based on LSTF design data provided in "ROSA-IV Large Scale Test Facility (LSTF) System Description," Japan Atomic Energy Research Institute Report JAERI-M 84-237, January 1985, the total flow area of the LSTF upper head bypass nozzles amounted to 0.726 cm^2 (7.826×10^{-4} ft^2), which scales to a 35.03 cm^2 (0.0377 ft^2 or 5.43 in^2) PWR bypass flow area with an equivalent opening diameter of 6.68 cm (2.63 inch) based on the volume scaling ratio for the LSTF pressure vessel upper head region.

(1) Please provide the upper head spray nozzle bypass capacities as scaled to prototypical PWR conditions based on the LSTF upper head spray nozzle bypasses measured in each of the LSTF tests analyzed in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," and in Section 24, "Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2." Explain how the LSTF bypass values were scaled to prototypical PWR conditions. List each LSTF test in a separate row and provide both the measured LSTF upper head spray nozzle bypass value and the scaled PWR bypass value.

(2) Please explain how the PWR upper head spray nozzle bypass values as scaled from the LSTF test data and provided in the table requested in Item (1) above, represent the range of upper head spray nozzle bypass capacities of PWR plants that will be modeled for the purpose of LOCA analyses using WCOBRA/TRAC-TF2.

(3) According to Y. Kukita et al., "Quasi-Static Core Liquid Level Depression and Long-Term Core Uncovery During a PWR LOCA, Nuclear Safety, Vol. 34, No. 1, 1993, pp. 33-48, ROSA-IV LSTF Test ST-LS-04 was conducted with a vent line connecting the upper plenum top region directly to the upper downcomer annulus to simulate a bypass flow rate of 4 percent compared to a 0.5 percent value in the standard LSTF test vessel bypass geometry. The experiment simulated conditions relevant to PWR plants with large bypass areas. The upper plenum vent line was equipped with a 44-mm (1.73-inch) inner diameter orifice and a valve. If the bypass capacity in ROSA-IV LSTF Test ST-LS-04 is within the range of spray nozzle bypass capacities of PWR plants to be analyzed with WCOBRA/TRAC-TF2, please provide WCOBRA/TRAC-TF2 prediction results for this test. Please compare the obtained results against the experimental measurements for ROSA-IV LSTF Test ST-LS-04 and assess the code performance.

Question #103: Pressure Vessel Internal Leaks in LSTF Tests

According to Y. Kukita et al., "Data Report for ROSA-IV LSTF 5 percent Cold Leg Break LOCA Experiment Run SB-CL-08," Japan Atomic Energy Research Institute Report JAERI-M 89-220, January 1990, modifications to the LSTF design were made during the time period between 27 March 1986 and 9 November 1989 when Test SB-CL-08 was performed. As described in Subsection 2.3.1, "Sealing of Upper Pressure Vessel Internal Leaks," in the report, one modification was performed in May 1986 to seal off an unintentional small bypass leak between the upper plenum and the upper head, which was discovered at the control guide tube penetrations through the upper core support plate during facility checks.

Table 21.1-1, "Selected ROSA-IV Test Series Description and Related Technical Reports," in WCAP-16996-P Revision 0 Section 21, "ROSA-IV Test Simulations," states that Test SB-CL-05 was performed on 26 June 1985 when the LSTF pressure vessel internal leak still existed. Therefore, as explained in Subsection 2.3.1, "Sealing of Upper Pressure Vessel Internal Leaks," in JAERI-M 89-220, "Run SB-CL-05 had an estimated flow rate through the upper head spray nozzles during the initial steady state of about 2.1 percent of the total core flow rate (vs. 0.3 percent for Run SB-CL-08)." K. Tasaka et al., "The Results of 5 percent Small-Break LOCA Tests and Natural Circulation Tests at the ROSA-IV LSTF," Nuclear Engineering and Design, Vol. 108, 1988, pp. 37-44, also report, in Table 2, "Test Conditions of 5 percent Break Tests," a 2.1 percent core flow downcomer-to-upper head bypass value for Test SB-CL-05.

Table 21.5-1, "Steady-State Parameter Checklist (Initial Conditions) for the SB-CL-05 Test," in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," gives a value of ~0.70 percent in "% core flow" for the "modeled" downcomer-to-upper head flow rate and lists the "target (measured)" downcomer-to-upper head flow rate value as "N/A." With regard to the hot leg-to-downcomer "target (measured)" leakage flow rate, the table provides a value of ~0.10 kg/s (0.20 percent core flow), which agrees with the data provided in JAERI-M 89-220 (0.05 kg/s per loop) and the value identified by K. Tasaka et al., "The Results of 5 percent Small-Break LOCA Tests and Natural Circulation Tests at the ROSA-IV LSTF," Nuclear Engineering and Design, Vol. 108, 1988, pp. 37-44 (0.2 percent of core flow).

(1) Please explain why the upper head-to-downcomer bypass, existent in ROSA-IV LSTF Test SB-CL-05 and documented in the above identified sources as amounting to a relatively high value of 2.1 percent of the core flow, was not identified in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," for the purposes of WCOBRA/TRAC-TF2 assessment analyses based on this test. Please explain the technical basis for determining the appropriateness of an upper head-to-downcomer bypass of ~0.70 percent as documented in the steady-state parameter checklist for the initial conditions obtained for Test SB-CL-05 with WCOBRA/TRAC-TF2 and listed in Table 21.5-1 in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21.

(2) Please provide a table that documents if unintentional bypasses between the LSTF upper head and the upper downcomer due to pressure vessel internal leaks existed in any of the LSTF tests analyzed in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," and in Section 24, "Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2." Describe each individual ROSA-IV LSTF test in a separate row providing the following test parameters, each in a separate column: test identifier (e.g. SB-CL-05), test date, data source documents, bypass flow unit, unintentional bypass flow between the upper head and upper downcomer due to pressure vessel internal leaks if such were found to exist in the test. In an additional column, please provide the measured downcomer-to-upper head bypass value and state clearly if this downcomer-to-upper head bypass value includes the upper head spray nozzle bypass and any other bypass flows existing in the test. Include in a separate column the bypass value through the vent line connecting the upper plenum top region directly to the upper downcomer annulus to simulate larger spray nozzle bypass capacities or vent line between the upper plenum and the downcomer annulus or the operation of Babcock and Wilcox (B&W)-type core barrel vent valves as it was the case in ROSA-IV LSTF Test SB-CL-07. Explain the source, availability, and accuracy of the data quantifying the unintentional LSTF pressure vessel bypass in these tests. Please explain if the provided bypass data was examined and qualified as part of the WCOBRA/TRAC-TF2 assessment.

(3) Compare LSTF experimental downcomer-to-upper head bypass data against downcomer-to-upper head bypass capacities simulated in the WCOBRA/TRAC-TF2 LSTF test analyses presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," and in Section 24,

"Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2." In the table requested in Item (2) above, include an additional column documenting, in consistent units, the downcomer-to-upper head bypass values calculated in the WCOBRA/TRAC-TF2 ROSA-IV LSTF test simulations. Clearly state if the downcomer-to-upper head bypass capacities in the WCOBRA/TRAC-TF2 ROSA-IV LSTF test simulations were adjusted to account for downcomer-to-upper head bypass through the upper head spray nozzle openings and any pressure vessel internal leaks, if such were known to exist.

Question #104: Hot Leg-to-Downcomer Bypass Modeling in LSTF and PWR LOCA Analyses

A bypass leakage between the upper downcomer region and the upper plenum occurs in the PWR design via the gap opening along the periphery of the hot leg (HL) nozzles that penetrate through the downcomer (DC). In the LSTF pressure vessel used in the ROSA-IV tests, the hot leg-to-downcomer (HL-to-DC) leakage was simulated by two dedicated hot leg leak lines. The bypass flow through these hot leg leak lines was one of the test variables in the LSTF SBLOCA tests according to Y. Kukita et al., "Data Report for ROSA-IV LSTF 5 percent Cold Leg Break LOCA Experiment Run SB-CL-08," Japan Atomic Energy Research Institute Report JAERI-M 89-220, January 1990.

Design details for the LSTF hot leg leak lines are provided in Tables 5.2.2, 5.2.4, 5.2.10, 5.7.1, 5.7.4, and A.1.1 in "ROSA-IV Large Scale Test Facility (LSTF) System Description," Japan Atomic Energy Research Institute Report JAERI-M 84-237, January 1985. According to the information provided in this report, each hot leg leak line was connected to the pressure vessel downcomer via a 21.2-mm (0.835-inch) inner diameter nozzle (Tags N-11a and N-11b) and to the hot leg via a Nominal Size 1 Schedule 160 nozzle (Tags N-1a and N-1b). The lines were equipped with a 0.687 contraction ratio orifice flow meter (Tags FE-010-HLA and FE-150-HLB) and a 0.24 kg/s normal flow capacity hand control valve (Tags HCV-010 and HCV-150) installed in each line.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," Subsection 21.11.2, "SB-CL-18 Simulation Without Hot Leg Nozzle Bypass Flow," explains that the hot leg leakage was modeled in the WCOBRA/TRAC-TF2 pressure vessel model of LSTF with Gaps 21 and 22 as shown in Figure 21.3-4, "LSTF Pressure Vessel Sections 5 and 6."

(1) According to H. Kumamaru et al., "ROSA-IV/LSTF Cold Leg Break LOCA Experiment Run SB-CL-18 Data Report," Japan Atomic Energy Research Institute Report JAERI-M 89-027, March 1989, Table 3.2, "Specified Operational Setpoints and Conditions for Run SB-CL-18," a HL-to-DC leakage of 0.049 kg/s per loop is provided as a "specified" operational setpoint for LSTF Test SB-CL-18. At the measured core inlet flow rate of 48.7 kg/s provided in Table 3.1, "Initial Conditions for Run SB-CL-18," in the same report, the resulting total HL-to-DC leakage via the gaps of both LSTF hot leg nozzles as a fraction of the core flow rate is:

HL-to-DC leakage = [(0.049 kg/s/loop) $\times$ (2 loops)] / (48.7 kg/s) = 0.0020 $\doteq$ 0.20%.

K. Tasaka et al., "The Results of 5 percent Small-Break LOCA Tests and Natural Circulation Tests at the ROSA-IV LSTF," Nuclear Engineering and Design, Vol. 108, 1988, pp. 37-44, report a downcomer-to-hot leg bypass of 0.2 percent of core flow for LSTF Test SB-CL-05 in Table 2, "Test Conditions of 5 percent Break Tests."

Table 21.4-1, "Steady-State Parameter Checklist (Initial Conditions) for the SB-CL-18 Test," provides a HL-to-DC leakage flow rate of 0.124 kg/s or 0.25 percent of the core flow rate for both the "target (measured)" leakage and the "modeled" leakage. Table 21.5-1, "Steady-State Parameter Checklist (Initial Conditions) for the SB-CL-05 Test," lists ~0.10 kg/s or 0.20 percent "core flow" for the "target (measured)" HL-to-DC leakage and 0.127 kg/s or 0.26 percent "core flow" rate for the "modeled" HL-to-DC leakage. Please clarify how the "target (measured)" leakage and the "modeled" HL-to-DC leakage values provided in Tables 21.4-1 and 21.5-1 were established and explain the reported discrepancies between the measured and modeled values.

(2) Please provide a table that documents the HL-to-DC leakage observed in the ROSA-IV LSTF tests analyzed in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," and in Section 24, "Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2." Describe each individual ROSA-IV LSTF test in a separate row including the following test parameters, each in a separate column: test identifier (e.g. SB-CL-05), test date, data source documents, HL-to-DC leakage unit, and experimental HL-to-DC leakage value. Explain the source, availability, and accuracy of data quantifying the LSTF HL-to-DC leakage bypass in these tests and explain if the bypass data was examined for qualification purposes.

(3) Please explain if a "steady state tune-up procedure" was used to "adjust" the HL-to-DC leakage in the WCOBRA/TRAC-TF2 model of the LSTF pressure vessel. In such a case, please describe how the "desired value" for the HL-to-DC leakage was established for the LSTF analyses. Please provide a table that lists all parameters subject to modification "during the steady state tune-up procedure." Describe each parameter in a separate row providing the corresponding values at the beginning and at the end of the "steady state tune-up procedure" as well as the allowable variation range.

(4) Provide a table that documents the "calculated value" for the HL-to-DC leakage at the end of the steady-state runs and the corresponding "desired values" for the ROSA-IV LSTF tests considered in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," and in Section 24, "Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2."

(5) Compare LSTF HL-to-DC leakage test data against HL-to-DC leakage capacities simulated in WCOBRA/TRAC-TF2 ROSA-IV LSTF test analyses presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," and in Section 24, "Assessment of Compensating Error in Evaluation Model Using WCOBRA/TRAC-TF2." In the table requested in Item (2) above, include an additional column documenting, in consistent units, the leg-to-downcomer leakage values obtained in the WCOBRA/TRAC-TF2 ROSA-IV LSTF

test simulations. Clearly state if the HL-to-DC leakage capacities in the WCOBRA/TRAC-TF2 ROSA-IV LSTF test simulations were adjusted to account for any effects other than the HL-to-DC leakage through the hot leg leak lines installed in the LSTF pressure vessel.

Question #105: Representation of LSTF Bypasses in WCOBRA/TRAC-TF2 LSTF Test Simulations

Analyzing WCOBRA/TRAC-TF2 prediction results for ROSA-IV LSTF Tests SB-CL-01, SB-CL-02, and SB-CL-03, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, Subsection 21.7, "Break Orientation Study: Simulation of Top/Side/Bottom 0.5 percent (SB-CL-16/12/15) and 2.5 percent (SB-CL-03/01/02) Cold Leg Breaks," presents code predictions in Figures 21.7-3 through 21.7-10. Figure 21.7-5, "Comparison of Predicted and Measured Mixture Levels in Broken Cold Leg (ROSA-IV 2.5-Percent Cold Leg Break Runs), (a) Code Calculations" shows the predicted cold leg liquid levels and Figure 21.7-5 Part (b), "Reported in Reference 5," reproduces Figure 8, "Mixture levels in cold-leg B measured for side, bottom and top break experiments," appearing in a publication by Y. Koizumi et al., "Investigation of Break Orientation Effect during Cold Leg Small-Break LOCA at ROSA-IV LSTF," Journal of Nuclear Science and Technology, Vol. 25, No. 9, September 1988.

With regard to the comparison in Figure 21.7-5, Subsection 21.7 states:[

] a,c

Discussing WCOBRA/TRAC-TF2 calculation results for ROSA-IV LSTF Test ST-NC-02, WCAP-16996-P Revision 0 Section 21, Subsection 21.9, "Simulation of ST-NC-02, 2 percent Power Natural Circulation Test," shows code calculations in Figures 21.9-2 through 21.9-8. Figure 21.9-8, "Downcomer-to-Upper Plenum Differential Pressure," shows a comparison of the downcomer-to-upper plenum differential pressures for the test. With regard to the comparison in Figure 21.9-8, Subsection 21.9 states: [

] a,c

The above results illustrate the sensitivity of WCOBRA/TRAC-TF2 predictions to the modeling of flows through bypass flow paths between the downcomer and the upper head or plenum that existed in the LSTF pressure vessel when the ROSA-IV tests were performed. Such bypasses are particularly important for the progression of small break LOCA transients and their inaccurate modeling test simulations can affect the validity of comparing code predictions against test data in evaluating the WCOBRA/TRAC-TF2 performance.

Please assess the adequacy of modeling LSTF pressure vessel bypasses in WCOBRA/TRAC-TF2 analyses of ROSA-IV LSTF tests presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 21, "ROSA-IV Test Simulations," in Section 24, "Assessment of Compensating Error in Evaluation Model

Using WCOBRA/TRAC-TF2," or discussed elsewhere in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0. As part of this assessment, please identify test simulations in which the LSTF pressure vessel bypasses were not accurately modeled. Please reanalyze these cases with accurate representation of the LSTF pressure vessel bypasses and update WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, sections in which ROSA-IV LSTF WCOBRA/TRAC-TF2 assessments are presented and/or discussed. Please provide a summary table, which lists the ROSA-IV LSTF tests that have been analyzed as part of the WCOBRA/TRAC-TF2 assessment and identify those that have been reanalyzed. Describe major results and summarize modifications in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, as applicable.

RAI Question #107: Pressurized Water Reactor Hot Leg Bypass in WCOBRA/TRAC-TF2 Plant Simulations

Addressing the modeling of bypass via gaps that exist at the interface of the core barrel and the hot leg nozzles, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements," Subsection 29.5.3, "Upper Head," states that "because the spray nozzle bypass itself is modeled in a best-estimate manner, neglecting the hot leg to downcomer gap, less bypass is modeled than is physically expected, so there is no need to range this parameter." As further explained in Subsection 29.5.4, "Upper Plenum," the gaps at the interface of the core barrel and the hot leg nozzles provide for leakage paths between the upper plenum and the upper downcomer region during all operating modes. It is explained that "for small breaks, these leakage paths are expected to have high importance during the loop seal clearing period when they provide alternative paths from the upper plenum to the cold leg break location to vent steam and relieve some two-phase level depression." Subsection 29.5.4, "Upper Plenum," concludes that "the ROSA sensitivity study in Section 21.11 shows that neglecting this gap is conservative." Accordingly, Section 21, "ROSA-IV Test Simulations," Subsection 21.11.2, "SB-CL-18 Simulation Without Hot Leg Nozzle Bypass Flow," states that "the results provided in this section clearly show that not modeling HL-to-DC bypass is a conservative modeling approach for the ROSA 5 percent small break transient."

The hot leg gaps in the LSTF pressure vessel were simulated by two dedicated hot leg leak lines. Based on the leak line 21.2-mm (0.835-inch) pressure vessel nozzle ID and the 0.687 contraction ratio of the orifice installed in each line, the LSTF hot leg gap bypass area for both loops amounted to 3.33 cm2 (36.05×10-4 ft2) with an equivalent diameter of a 2.060 cm (0.811 inch). Based on the LSTF upper head volume scaling ratio, the LSTF hot leg gap bypass area corresponds to a PWR hot leg gap bypass area of 160.7 cm2 (0.173 ft2 or 24.9 in2) with an equivalent diameter of 14.3 cm (5.63 inch). For the reference Tsuruga Westinghouse-type four-loop Unit 2 PWR, the LSTF bypass area corresponds to a 0.068-inch gap width of the opening between the barrel and the vessel exit nozzle based on the hot leg inner diameter of 29.0 inch specified in Table 5.2.9, "Characteristics of Primary Loop Piping," in "ROSA-IV Large Scale Test Facility (LSTF) System Description," JAERI-M 84-237, January 1985.

(1) Please state clearly if no hot leg gap bypass is credited for the purposes of LOCA analyses of any PWR plant designs using the FSLOCA methodology. Also, clarify if no other features of WCOBRA/TRAC-TF2 PWR vessel models are somehow modified or adjusted because of not modeling hot leg bypass in PWR LOCA analyses.

(2) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements," Subsection 29.5.3, "Upper Head," states that "the spray nozzle bypass itself is modeled in a best-estimate manner" and explains that "there is no need to range this parameter" as "less bypass is modeled than is physically expected" due to "neglecting the hot leg to downcomer gap." The staff finds this justification insufficient. Please provide the range of upper head spray nozzle bypass capacities of PWR plants considered for intended WCOBRA/TRAC-TF2 LOCA analysis applications. Provide the uncertainties associated with this parameter and described the plant conditions considered in assessing them. Then, provide the range of hot leg bypass capacities along with their uncertainties for the considered PWR plants taking into account the variation of the hot leg gap during a LOCA transient. Explain which

upper head spray nozzle bypass values are used in WCOBRA/TRAC-TF2 PWR models so that "the spray nozzle bypass itself is modeled in a best-estimate manner" and demonstrate that these values are conservative considering the provided hot leg bypass capacities and the uncertainties for the upper head spray nozzle bypass and the hot leg gap bypass.

RAI Question #108: WCOBRA/TRAC-TF2 Assessment Using Counter-Current Flow Data by Costigan et al.

A simple experimental study of counter-current flow limitation was carried out at Harwell by Costigan et al., "Counter-current two-phase flow in horizontal channels of circular cross-section," 2nd international Conference on Multiphase Flow, Paper F3, London, 1985. The apparatus operated at close to atmospheric pressure and consisted of a H-shaped test section. Water was injected into the left-hand limb, simulating the steam generator, and air into the right-hand limb representing the reactor upper plenum.

(1) Please compare WCOBRA/TRAC-TF2 predictions of the observed flooding phenomena against the experimental data of Costigan et al. Present sensitivity studies showing the impact of the H_SLUG parameter variation. Plot the comparison results using the phase Wallis parameters or any other appropriately defined dimensionless number.

(2) Please present sensitivity results illustrating the effect of nodalization refinement in representing the horizontal limb of the H-shaped test facility. For this purpose, please present code predictions using fine noding with cell length-to-hydraulic diameter ratio less than or equal to one and coarse noding with cell length-to-hydraulic diameter ratio greater two.

RAI Question #109: Semi-scale Test S-LH-1 Assessment of WCOBRA/TRAC-TF2

Semiscale test facility was based on the full-height full-pressure scaling concept. Semiscale Mod-2C was a scaled model representation of a Westinghouse four-loop PWR plant with a fluid volume scaling ratio of about 1/1,705. The pressure vessel featured an external downcomer, the intact primary loop simulated three combined unaffected loops and the broken primary loop simulated one loop with a break. Accordingly, the intact loop steam generator (SG) consisted of six inverted U-tubes and the broken loop SG had two inverted U-tubes. As documented in Table 1, "Comparison of Semiscale Systems," by G. G. Loomis, "Summary of the Semiscale Program (1965-1986)," NUREG/CR-4945, EGG-2509, July 1987, the Semiscale Mod-2C primary system piping was all stainless steel with the broken loop being 1.5-inch Schedule 160 pipe and most of the intact loop being 2.5-inch Schedule 160 pipe.

A special 0.5-inch tubing bypass line connected the downcomer to the upper head to simulate the leakage between these two components in commercial PWRs. According to G. G. Loomis and J. E. Streit, "Results of Semiscale Mod-2C Small-Break (5 percent) Loss-of-Coolant Accident Experiments S-LH-1 and S-LH-2," NUREG/CR-4438, EGG-2424, November 1985, this PWR leakage flow varies between 0.5 percent and 4 percent of the total core flow.

Test S-LH-1, which simulated a 5 percent cold leg, centerline, communicative break in the loop piping between the pump and the vessel downcomer, exhibited important small break LOCA phenomena including liquid holdup in SG U-tubes, consequent core uncovery, and sequential loop seal clearance in the intact and broken loops. The upper head to downcomer bypass flow was calibrated at 0.9 percent of the recirculation flow by installing 0.125-inch thick flat plate orifice with 0.116-inch diameter hole in the bypass line to reduce steam venting through the spray nozzles during the transient. The experiment is described by G. G. Loomis and J. E. Streit, "Results of Semiscale Mod-2C Small-Break (5 percent) Loss-of-Coolant Accident Experiments S-LH-1 and S-LH-2," NUREG/CR-4438, EGG-2424, November 1985.

An early core uncovery prior to loop seals clearance caused a first heater-rod heatup. The observed loop seal clearing in the intact loop at 171.4 s and in the broken loop at 262.3 s allowed the core to refill and cool after the first core uncovery. During the period of the first core uncovery, the uphill side of the SGs had liquid holdup, which was dependant on the heat transfer and CCFL phenomenon in the U-tubes. A second core uncovery was caused by reduced system inventory later in the transient.

(1) Please describe the WCOBRA/TRAC-TF2 model used to simulate Semiscale Mod-2C Test S-LH-1. Explain which special modeling features were activated in the analysis and describe any modeling parameter adjustments if such were employed in the analysis.

(2) Please present WCOBRA/TRAC-TF2 assessment results using Semiscale Mod-2C Test S-LH-1 experimental data. Show comparison plots for important parameters such as core collapsed and two-phase mixture levels, differential pressures reflecting manometric fluid head balance in both tests loops, and heater rod temperatures. In particular, please compare differential pressures and collapsed liquid levels in the uphill and downhill sides of the SGs, loop seal uphill and downhill differential pressures for both loops, rod surface temperature at the 208-cm elevation, break mass flow rate and integrated break mass flow.

RAI Question #110: Semiscale Test S-LH-2 Assessment of WCOBRA/TRAC-TF2

Semiscale Tests S-LH-1 and S-LH-2 were performed using the Semiscale Mod-2C facility configuration. Both tests simulated a 5 percent centerline communicative break in the cold leg piping between the pump exit and the vessel downcomer. For this purpose, the break was simulated by an orifice of a 0.20-ft2 scaled area and an equivalent break diameter of 6.1 inch corresponding to a 4.92 percent break size based on a 27.5-inch PWR cold leg diameter.

In Test S-LH-1, a flat plate orifice with a 0.25 contraction ratio hole was installed in the special 0.5-inch tubing bypass line between the downcomer and the upper head. In Test S-LH-2, this orifice was removed. This resulted in initial condition core bypass flows of 0.9 percent and 3 percent in Test S-LH-1 and Test S-LH-2, respectively. Although these bypass flows differed by a ratio of 3.3, both values were thought to be within the range of possible PWR bypass flow. The bypass line hydraulic resistances for both tests are provided by G. G. Loomis and J. E. Streit, "Results of Semiscale Mod-2C Small-Break (5 percent) LOCA Experiments S-LH-1 and S-LH-2," NUREG/CR-4438, EGG-2424, November 1985.

As performed, Tests S-LH-1 and S-LH-2 examine the effect of the core bypass flow on the small break LOCA transient response. With regard to loop seal clearance in particular, Test S-LH-1, which had 0.9 percent bypass flow, exhibited loop seal clearance in both loops, first in the intact loop at 171.4 s followed by the broken loop at 262.3 s. In contrast, Test S-LH-2, which simulated 3 percent bypass flow, exhibited loop seal clearance only in the intact loop at 205.4 s with no clearance in the broken loop.

(1) Please describe the representation of the special 0.5-inch tubing bypass line between the downcomer and the upper head in the WCOBRA/TRAC-TF2 model used to simulate Semiscale Mod-2C Test S-LH-1 and Test S-LH-2.

(2) Please present WCOBRA/TRAC-TF2 assessment results using Semiscale Mod-2C Test S-LH-2 experimental data. Show comparison plots for important parameters such as core collapsed and two-phase mixture levels, differential pressures reflecting manometric fluid head balance in both tests loops, and heater rod temperatures. In particular, please compare differential pressures and collapsed liquid levels in the uphill and downhill sides of the SGs, loop seal uphill and downhill differential pressures for both loops, rod surface temperature at the 208-cm elevation, break mass flow rate and integrated break mass flow.

(3) Please present comparison results between WCOBRA/TRAC-TF2 predictions for Semiscale Mod-2C Test S-LH-1 and Test S-LH-2. Show comparison plots for important parameters such as core collapsed and two-phase mixture levels, differential pressures reflecting manometric fluid head balance in both tests loops, and heater rod temperatures. In particular, please compare differential pressures and collapsed liquid levels in the uphill and downhill sides of the SGs, loop seal uphill and downhill differential pressures for both loops, rod surface temperature at the 208-cm elevation, break mass flow rate and integrated break mass flow. As part of the comparative analysis, use experimental data from both tests when assessing the WCOBRA/TRAC-TF2 capabilities in modeling effects associated with core bypass flow, particularly with regard to impact on loop seal behavior.

RAI Question #111: Sensitivity of WCOBRA/TRAC-TF2 Semiscale Predictions to SG Nodalization

The 5 percent SBLOCA Semiscale Test S-UT-8, performed with the Semiscale Mod-2A test facility system configuration, revealed the possibility for primary liquid holdup in the PWR SGs during a small break LOCA. In this test, condensation-induced filling of the SG tubes in the intact loop caused an extreme core liquid level suppression prior to the clearance of the liquid seal formed in the pump suction crossover piping. Test S-UT-8 data is reported by W. W. Tinle, "Test data Report on Westinghouse Reactor Vessel Level Indicating System Performance during Semiscale Test S-UT-8," EGG-SEMI-5827, March 1982. The same effect was observed in Semiscale Mod-2C Tests S-LH-1 and S-LH-2 as reported by G. G. Loomis and J. E. Streit, "Results of Semiscale Mod-2C Small-Break (5 percent) Loss-of-Coolant Accident Experiments S-LH-1 and S-LH-2," NUREG/CR-4438, EGG-2424, November 1985.

The Semiscale Mod-2C intact loop was equipped with a Type II SG, which was a lumped representation of the three SGs in the intact loops of the reference Westinghouse four-loop plant. The affected Semiscale Mod-2C loop was equipped with a Type III SG featuring an external downcomer for γ-densitometer measurements. Accordingly, the intact loop Type II SG model had 6 inverted U-tubes: 2 short, 2 medium and 2 long tubes representative of the range of bend elevations in a typical PWR SG, as described by Y. S. Bang et al., "Assessment of RELAP5/MOD3.2 With the Semiscale Natural Circulation Experiment, S-NC-8B," NUREG/IA-0144, August 1998. The affected loop Type III SG model had two inverted U-tubes with a 22.2-mm (0.87-inch) OD.

A simple sensitivity study on the nodalization of the SGs using an earlier version of RELAP5 was performed by C. Lee, T. Ito, and P. B. Abramson, "Sensitivity of SBLOCA Analysis to Model Nodalization," Paper CONF-830901-2, Anticipated and Abnormal Plant Transients in Light Water Reactors Conference, 26 September 1983, Jackson, Wyoming. The analysis examined a 4-inch cold leg break in a Westinghouse four-lop plant using a coarse SG nodalization with 4 vertically stacked secondary side nodes in the U-tube region and the corresponding 8 nodes in the U-tubes, 4 in the uphill side and 4 in downhill side. The U-tube bend sections were modeled with 2 nodes, one on each side. In the fine noding scheme, the number of nodes in the SGs was doubled while keeping the rest of the plant model identical. In this case, the U-tube bends were represented by 4 nodes, 2 on each side.

The study revealed that the predicted transient behavior was quite sensitive to the implemented SG nodalization schemes. While global system parameters, such as integrated break mass discharge, primary liquid inventory, and primary system pressure were relatively insensitive to the nodalization, the predicted distribution of coolant inventory in the primary loops was significantly affected by change in nodalization. In particular, more detailed nodalization led to prediction of higher liquid holdup in the SG U-tubes thus resulting in less coolant inventory in the reactor vessel and therefore causing earlier and more severe core uncovery.

(1) Please present sensitivity results for Semiscale Mod-2C Tests S-LH-1 and S-LH-2, which examine the effect of SG nodalization on small break LOCA predication results. For this purpose, please present test prediction results obtained with a SG nodalization scheme corresponding to the standard noding approach adopted in WCOBRA/TRAC-TF2 for modeling of SGs with inverted U-tube bundles. In addition, please present test prediction results obtained with a refined noding using a doubled number of nodes (cells) to represent the SG U-tube bundle. Also, please present sensitivity results examining the impact of refined nodalization of the 180°-bend region of the U-tube bundle by increasing further the number of cells representing this region. Compare the code test predictions against key measured quantities in each test.

(2) Please present sensitivity results, as requested in Item (1) above, using SG models with split representation of the U-tube bundles. For this purpose, please model when the intact loop Type II SG U-tubes using three PIPE hydraulic components each representing two U-tubes. Please split the U-tubes in the SG bundle based on the U-tube apex elevations so that tubes with a different length are represented by individual hydraulic components. Please use two PIPE hydraulic components to model the broken loop Type III SG U-tubes individually.

(3) When providing the information requested in Items (1) and (2) above, please include, among other important parameters, WCOBRA/TRAC-TF2 predictions for the SG U-tube bundle upside and downside collapsed liquid levels in the broken and in the intact loops, the uphill and downhill loop seal collapsed liquid levels in both loops, and

the vessel core-side and downcomer-side collapsed liquid levels. Please compare obtained code predictions against test measurements as appropriate.

RAI Question #112: Sensitivity of WCOBRA/TRAC-TF2 Small Break LOCA Predictions to Steam Generator Nodalization

Please present sensitivity results for a reference four-loop Westinghouse plant using WCOBRA/TRAC-TF2, which examine the effect of SG nodalization on small break LOCA predication results. Show the sensitivity impact for the limiting small break size, which yields the most severe core level suppression for the selected PWR plant model and applying nominal input parameters.

(1) Please present code results using a standard SG nodalization scheme, adopted for WCOBRA/TRAC-TF2 modeling of SGs with inverted U-tubes, and a refined noding in which the number of nodes representing the SG U-tube bundle is doubled. In particular, explain and present sensitivities to refined nodalization of the 180°-bend region of the U-tube bundle.

(2) Please present sensitivity results as requested in Item (1) above when the SG U-tube bundle in each PWR primary loop is modeled using two and tree pipe hydraulic components. In modeling the U-tubes in each SG bundle by multiple pipe components, please split the U-tubes into individual groups based on the U-tube apex elevations so that the tallest, middle, and shortest tubes are represented by individual hydraulic components.

(3) In responding to Items (1) and (2) above, please include, among others, comparison plots for the SG U-tube upside and downside collapsed liquid levels in the broken and intact loops, uphill and downhill loop seal collapsed liquid levels in the broken and intact loops, vessel core-side and downcomer-side collapsed liquid levels, core void fractions, and peak clad temperatures.

RAI Question #113: WCOBRA/TRAC-TF2 UPTF Loop Seal Nodalization

Full-scale separate effect experiments describing the loop seal clearing process in a PWR primary loop during a LOCA were produced as part of the Transient and Accident Management (TRAM) experimental program, carried out at the full-scale UPTF in Mannheim, Germany. The UPTF loop seal piping had an inner diameter of 0.750 m (33.46 inch or 2.8 ft) and the length of the bottom horizontal section of the loop seal piping was equal to 1.734 m (68.3 inch or 5.7 ft), which resulted in a length-to-diameter ratio (L/D) of 2.3 for this section. Also, the facility employed pump simulators to model the RCPs in a PWR.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.3.1, "WCOBRA/TRAC-TF2 Simulation of the UPTF 3-Bar and 15-Bar Tests," presents assessment results based on UPTF TRAM loop seal clearance tests. Figure 18.3-1, "WCOBRA/TRAC-TF2 Model of the UPTF Separate Effects Loop Seal Clearing Tests," shows the implemented UPTF loop seal nodalization. As described, PIPE component No. 2 with [ ]^{a,c} cells was used to simulate the loop seal piping including the RCP simulator. In this model, [ ]^{a,c} was used to represent the loop seal bottom horizontal section and [ ]^{a,c} cells were used to model each of the

90° bends connecting the horizontal section of the loop seal to the downhill and uphill pipes of the cross-over leg.

(1) Please provide a table that documents the WCOBRA/TRAC-TF2 input parameters for the WCOBRA/TRAC-TF2 UPTF loop seal model shown in Figure 18.3-1, "WCOBRA/TRAC-TF2 Model of the UPTF Separate Effects Loop Seal Clearing Tests." Describe each component separately and include full description for PIPE Component No. 2 used to represent the UPTF loop seal piping. Provide length, elevation, flow area, volume, and inclination angle for each cell/interface and explain how the loop seal input model accounts for relevant UPTF geometry and instrumentation locations.

(2) Please explain why the bend regions in the loop seal nodalization model appear as asymmetric in Figure 18.3-1. It is seen that the curvature of the uphill bend is much larger than the radius of the downhill bend. The UPTF loop seal piping had equal bend radii of 0.798 m (31.4 inch or 2.6 ft) for both bend regions.

(3) If input parameters, such as pressure loss coefficients, were used to compute pressure losses as part of the specified WCOBRA/TRAC-TF2 UPTF loop seal model, please define these input quantities and provide the formulas used for their computation. Explain any assumptions used to determine the input values for these parameters.

(4) Please explain how the UPTF RCP simulator, present in the simulated region of the UPTF primary circuit, was accounted for in the WCOBRA/TRAC-TF2 UPTF loop seal model. Provide any input parameters that were used to model the RCP simulator and explain how these parameters were computed. Provide and explain used formulas, applied assumptions, and calculated input values.

RAI Question #114: Upper Plenum Test Facility TRAM Loop Seal Instrumentation and WCOBRA/TRAC-TF2 Upper Plenum Test Facility Model

A valid and meaningful assessment of WCOBRA/TRAC-TF2 prediction results against UPTF TRAM separate effect loop seal clearance test data imposes, as part of a code assessment study, special requirements that the model accounts adequately for the type and location of test instrumentation and measuring locations. In turn, the data channels to be used for the purposes of the code assessment study should be determined considering available test instrumentation, relevance to the phenomena being assessed and code models used for their prediction, signal behavior and data accuracy, among other factors of relevance.

(1) Please describe how the loop seal differential pressures were measured in the UPTF TRAM separate effect loop seal clearance tests. Explain how the locations of the differential pressure tap points were reflected in the WCOBRA/TRAC-TF2 UPTF loop seal models used to assess the code. Describe how the predicted loop seal differential pressure quantity was determined from the WCOBRA/TRAC-TF2 calculation results. As appropriate and relevant, please identify nodes and/or cell interfaces in the WCOBRA/TRAC-TF2 UPTF loop seal model at which thermal hydraulic quantities were calculated by the code and used to determined the loop seal differential pressure predication for comparison against test data.

(2) Please describe how the loop seal residual water levels were measured in the UPTF TRAM separate effect loop seal clearance tests. Explain how the locations of the

differential pressure tap points were reflected in the WCOBRA/TRAC-TF2 UPTF loop seal models used to assess the code. Describe how the computed loop seal residual water levels, used for comparison against test data, were determined from the WCOBRA/TRAC-TF2 calculation results. Identify the thermal hydraulic quantities that were used to determine these predicted residual loop seal water levels. As appropriate and relevant, please identify nodes and/or cell interfaces in the WCOBRA/TRAC-TF2 UPTF loop seal model at which these thermal hydraulic quantities were calculated by the code.

RAI Question #115: WCOBRA/TRAC-TF2 Sampled Parameters and Special Options in Loop Seal Modeling

WCOBRA/TRAC-TF2 models and correlations that are relevant to predicting loop seal clearance in PWR plant LOCA analyses include such as those used for describing transition to non-stratified flow, CCFL, and liquid entrainment mechanisms. WCOBRA/TRAC-TF2 features user defined parameters and multipliers that can be applied to modify these models and criteria. Some of these user defined parameters and multipliers are sampled as part of the plant uncertainty analysis and others are not included in the sampling process.

Regarding relevant sampled parameters, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "29 Assessment of Uncertainty Elements," Subsection 29.1.7, "Horizontal Stratified Flow Regime Transition Boundary (HS_SLUG)," describes that a horizontal stratified flow regime transition boundary multiplier, HS_SLUG, is employed in WCOBRA/TRAC-TF2 to adjust the critical relative velocity for horizontal stratified flow. HS_SLUG is sampled [ ]^{a,c} for the purpose of the uncertainty analysis.

Examples of WCOBRA/TRAC-TF2 parameters and multipliers that are not part of the sampling process include the parameters Cstfru and STRTX. For example, WCAP-16996-P Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.3.1, "WCOBRA/TRAC-TF2 Simulation of the UPTF 3-Bar and 15-Bar Tests," states that [ ]^{a,c}

(1) Please provide a table that identifies and describes any user defined parameters, multipliers, and/or options, implemented as part of WCOBRA/TRAC-TF2 models and correlations that are used to predict loop seal clearance in PWR plant LOCA analyses, including such related to describing non-stratified flow transition, CCFL, and liquid entrainment mechanisms. Please explain if a parameter is implemented on a component-wide basis or it can be applied to specific cells/interfaces of hydraulic components used to represent the PWR loop seal region. In addition, identify if a parameter is being sampled or not as part of the plant uncertainty analysis. Include mathematical expressions that show modeling equations and quantities that can be modified through such user defined input parameters and/or special options. Present the technical rationale for the implementation of these special modeling options and provide the allowable input values. In addition, please explain how the input values for these options are determined for the purpose of performing PWR LOCA analysis using the Full Spectrum LOCA methodology.

(2) Please identify which of the parameters, multipliers, and/or options, identified in Item (1) above, were used in the WCOBRA/TRAC-TF2 loop seal assessment study

presented in Subsection 18.3.1, "WCOBRA/TRAC-TF2 Simulation of the UPTF 3-Bar and 15-Bar Tests." Present the technical rationale for applying or not applying a specific parameter, multiplier, or option. Explain if a specific parameter, multiplier, or option was applied on component-wide basis and/or to specific cells/interfaces only of component PIPE 2 used to represent the UPTF loop seal in the WCOBRA/TRAC-TF2 model. Provide a table that lists each individual modeling parameter, multiplier, and option such as the one used to prescribe that [

]^{a,c}

RAI Question #116: UPTF TRAM Loop Seal Clearance Data and WCOBRA/TRAC-TF2 Assessment

The UPTF TRAM loop seal clearance experiments comprise both integral effect and separate effect tests. The separate effect tests were performed using combined steam and water or steam injection only with various flow rates and at two different pressure levels of 0.3 MPa and 1.5 MPa (43.5 psia and 217.6 psia). As described in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.3.1, "WCOBRA/TRAC-TF2 Simulation of the UPTF 3-Bar and 15-Bar Tests," UPTF TRAM separate effect tests were used to assess the code. Regarding the test data, Subsection 18.3.1 refers to publications by J. Liebert and R. Emmerling, "UPTF Experiment: Flow Phenomena During Full-Scale Loop Seal Clearing of a PWR," Nuclear Engineering and Design, Vol. 179, No. 1, pp. 51-64, 1998, and by J. Ohvo et al., "Simulation of Full-Scale UPTF Loop Seal Experiments with APROS, CATHARE and RELAP," ICONE6-6090, 6th International Conference on Nuclear Engineering, May 10-15, 1998, San Diego, CA. The work by Ohvo et al. includes a summary of the main parameters for the UPTF TRAM tests.

(1) Please provide a table identifying the UPTF TRAM separate effect test data that were used to assess WCOBRA/TRAC-TF2 as described in Subsection 18.3.1. For each data point, provide the system pressure, steam and water injection flow rates, and corresponding measured test quantities. Please explain how the test boundary conditions were simulated in UPTF WCOBRA/TRAC-TF2 model and present separate assessments for the cases with and without water injection. Explain if any UPTF TRAM test data points were excluded from the assessment results presented in Figures 18.3-2, 18.3-4, and 18.3-5 in Subsection 18.3.1. Please clarify if Figure 18.3-5 includes all data points presented in Figure 18.3-2 and in Figure 18.3-4.

(2) For each UPTF TRAM data point shown in Figures 18.3-2, 18.3-4, and 18.3-5 in Subsection 18.3.1, provide transient code prediction results for important thermal hydraulic quantities. In particular, please include plots for inlet and exit steam and liquid mass flow rates, liquid entrainment rates, phase velocities, void fractions in the horizontal section, bend regions, and downhill and uphill sections of the loop seal, as well as liquid coolant inventory residing in these simulated loop seal regions. In addition, please depict the two-phase flow regimes as identified in the loop seal nodes. Provide plots for the predicted volumetric concentrations of the interfacial friction force.

(3) Please present plots showing WCOBRA/TRAC-TF2 calculation results against measured residual loop seal water levels and loop seal pressure losses observed at various injection flow rates. Provide consideration of measurement accuracies, observed hydraulic flow oscillations and any other factors of relevance to the presented code assessment results.

(4) For each UPTF TRAM data point shown in Figures 18.3-2, 18.3-4, and 18.3-5 in Subsection 18.3.1, provide plots comparing local transient thermal hydraulic conditions against corresponding critical conditions or criteria used in WCOBRA/TRAC-TF2 to describe phenomena of governing importance for predicting loop seal clearance including transition to non-stratified flow, CCFL, and participating liquid entrainment mechanisms. Plot the computed thermal hydraulic quantities and corresponding critical parameters as a function of transient time and at locations in the loop seal where such phenomena play a governing role.

(5) In responding to Items (1) through (4) above, please assess UPTF TRAM 0.5 MPa tests and the 1.5 MPa tests separately. Provide detailed pressure scaling considerations based on contributing WCOBRA/TRAC-TF2 models. Derive and provide corresponding pressure scaling relationships and explain how the UPTF TRAM full-scale loop seal clearance data support them.

RAI Question #117: WCOBRA/TRAC-TF2 Upper Plenum Test Facility Loop Seal Nodalization Sensitivity Study

Various nodalization approaches have been applied in analyzing loop seal clearance test data in assessing reactor safety codes. For example, in the work by J. Ohvo et al., "Simulation of Full-Scale UPTF Loop Seal Experiments with APROS, CATHARE and RELAP," Paper ICONE6-6090, 6th International Conference on Nuclear Engineering, May 10-15, 1998, San Diego, CA, the bottom horizontal section of the UPTF the loop seal piping was represented by 2 nodes in the APROS model, by 7 nodes in the CATHARE model, and by 2 nodes in the RELAP5 model. Correspondingly, each of the 90° bend regions was represented by 3, 5, and a single node.

When describing the UPTF loop seal model, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.3.1, "WCOBRA/TRAC-TF2 Simulation of the UPTF 3-Bar and 15-Bar Tests," states that "the noding in this model is judged sufficient for simulation of the UPTF tests, and similar modeling is expected to be used in the plant simulations." At the same time, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," provides no justification for this statement.

NRC Regulatory Guide 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance," May 1989, Subsection 2.1.1, "Numerical Methods," requires that "Sensitivity studies and evaluations of the uncertainty introduced by noding should be performed." WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," does not examine the impact of noding on WCOBRA/TRAC-TF2 prediction results in assessing the code capabilities to predict loop seal clearance.

(1) Please perform and present results from WCOBRA/TRAC-TF2 nodalization sensitivity studies that employ 2, 3, and 4 cells of an equal length to model the UPTF loop seal bottom horizontal section, which would correspond to cell length-to-diameter ratios (L/D) of 1.16, 0.77, and 0.58. Examine any additional nodalization schemes, as deemed appropriate. Show plots comparing both the residual loop seal levels and loop seal pressure losses against measured data.

(2) Please perform and present results from WCOBRA/TRAC-TF2 nodalization sensitivity studies that employ 3, 4, and 5 cells to model each of the 90° bends

connecting the bottom horizontal section of the loop seal to the downhill and uphill pipes of the UPTF cross-over leg. Show plots comparing both the residual loop seal liquid levels and loop seal pressure losses against measured data.

(3) Present and discuss the technical basis used to establish the PWR loop seal nodalization approach considered adequate for predicting loop seal clearance in WCOBRA/TRAC-TF2 plant LOCA analyses as part of the Full Spectrum™ LOCA methodology. Describe the approach to PWR loop seal modeling implemented for LOCA analyses using the Full Spectrum™ LOCA methodology. Please explain how the results from the UPTF TRAM loop seal nodalization sensitivity study support this approach.

RAI Question #118: WCOBRA/TRAC-TF2 Upper Plenum Testing Facility Loop Seal Modeling Options Sensitivity Study

RAI Question No. 115 Item (1) requests information regarding user defined parameters, multipliers, and/or options, implemented in WCOBRA/TRAC-TF2 models and correlations relevant to predicting loop seal clearance in PWR plant LOCA analyses, including such related to describing non-stratified flow transition, CCFL, and liquid entrainment mechanisms.

Please provide results from WCOBRA/TRAC-TF2 sensitivity studies based on the UPTF TRAM full-scale separate effect loop seal clearance tests, which show the effect of varying or sampling of parameters, multipliers, and/or options relevant to the prediction of the loop clearance process. Examine each such user defined quantity and describe the bases for allowing variation or proposing sampling of input values. Provide a table, which lists all examined parameters. For the parameters, multipliers, and/or options being subject to variation or sampling, please provide the sampling range and distribution or proposed input values and allowed ranges. For the sampled parameters, such as HS_SLUG, apply the sampling approach used in PWR plant LOCA analyses. For all remaining user defined parameters, multipliers, and/or options, explain the basis for the proposed input values and ranges regardless if a specific user defined quantity is being described a subject to variation or not for the purpose of plant LOCA analyses using the Full Spectrum LOCA methodology. Analyze each parameter individually and independently from the remaining ones. In particular, demonstrate the effect of variation in Cstfru and STRTX input, is variation is allowed in plant LOCA analyses. Please present the WCOBRA/TRAC-TF2 sensitivity results and provide comparisons against UPTF TRAM full-scale separate effect loop seal clearance test data. In addition, provide comparisons among analyzed sensitivity cases, as appropriate.

RAI Question #119: WCOBRA/TRAC-TF2 UPTF Loop Seal Time Step Limit Sensitivity Study

A special case of a user defined parameter of a global importance to code predictions, including loop seal clearance, is the maximum allowable time step size. WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 28, "Scoping and Sensitivity Studies," Subsection 28.2.4, "Time Step and Convergence Criteria Studies – SBLOCA," analyzes the impact of different DTMAX values on PWR plant LOCA predictions and notes that observed "differences among the cases arise from the prediction of loop seal clearance timing and extent of clearance." In the analyzed plant

LOCA sensitivity studies, time step upper limits of 1 millisecond, 2 milliseconds, and 5 milliseconds were used.

Considering uncertainty in PWR plant LOCA analyses, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Subsection 29.3.3, "Uncertainty Associated with Maximum Time Step Size," explains that the maximum allowable time step size in WCOBRA/TRAC-TF2 is set by the user through the DTMAX input parameter. The subsection states that "WCOBRA/TRAC-TF2 uses DTMAX as the time step throughout significant portions of the transient." It also explains that "in the analysis, a choice of DTMAX is made and is applied in all transients." Thus, DTMAX is not sampled in PWR plant LOCA analysis using the using the Full Spectrum™ LOCA methodology.

NRC Regulatory Guide 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance," May 1989, Subsection 2.1.1, "Numerical Methods," requires that "the effect of time-step size should also be investigated." WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," does not examine the impact of the maximum allowable time step size on WCOBRA/TRAC-TF2 prediction results in assessing the code capabilities to predict loop seal clearance.

Considering the importance WCOBRA/TRAC-TF2 capabilities to predict the loop seal clearance phenomenon, please present sensitivity results based on the UPTF TRAM full-scale separate effect loop seal clearance tests that show the effect of the maximum allowed time step size. Demonstrate if reduction of the maximum allowed time step size can lead to obtaining code predictions that remain insensitive, when considering major predicted quantities, to further restrictions of the maximum allowed time step size. Please plot the WCOBRA/TRAC-TF2 sensitivity results and provide comparisons against UPTF TRAM full-scale separate effect loop seal clearance test data. In addition, provide comparisons among examined sensitivity cases, as appropriate.

RAI Question #120: IVO Loop Seal Clearance Data and WCOBRA/TRAC-TF2 Assessment

A full-scale separate effect test facility, constricted by Imatran Voima Oy (IVO) in Finland, was used to study two-phase flow phenomena in a PWR loop seal region following a cold leg break LOCA. The full-scale loop seal test facility used a piping with an inner diameter (ID) of 0.850 m (33.46 inch or 2.8 ft) and a length of the horizontal section of the seal of 4.3 m (169.3 inch or 14.1 ft), which resulted in a length-to-diameter ratio (L/D) of 5.1 for this section. The tests were conducted at atmospheric pressure and room temperature using air and water. As part of this experimental effort, two reduced-scale loop seal models were constructed using transparent pipes with an ID of 0.080 m (3.15 inch) to examine effects of scaling and geometry on the loop seal processes and flow regime transitions. Test data from these facilities were used for comparison against the full-scale loop seal geometry tests. The IVO tests are described by H. Tuomisto, "Large-Scale Air/Water Flow Tests for Separate Effects During LOCAs in PWRs," Nuclear Engineering and Design, Vol. 102, No. 2, pp. 171-176, 1987 and by H. Tuomisto and P. Kajanto, "Two-Phase Flow in a Full-Scale Loop Seal Facility," Nuclear Engineering and Design, Vol. 107, No. 3, pp. 295-305, 1988.

IVO separate effect loop seal clearance test data has have been used for assessing various reactor safety thermal hydraulic codes. Results from a RELAP5 assessment study are documented by O. Kymäläinen, "The Assessment of RELAP5/MOD2 against

IVO Loop Seal Tests," NUREG/IA-0082, April 1992. In this work, RELAP5/MOD2 analyses for both the full-scale and the 1/10-scale atmospheric air-water loop seal facilities were performed. The calculated residual water levels differed from the measured data and the code yielded lower values. Also, the predicted gas superficial velocities, needed for loop seal clearing, was lower than the experimentally values. Even with interfacial drag modifications, agreement with the experimental data was not found. Results from a more recent TRACE assessment study are presented by S. Hillberg, "Full Scale Loop Seal Experiments with TRACE V5 Patch 1," NUREG/IA-0403, December 2011. The assessment was focused on the code capability to predict the residual water level in the horizontal pipe section of the loop seal and examined the pressure behavior during the clearance of the loop seal. Effects related to loop seal nodalization, maximum time step size, and initial liquid levels were studied. The simulations revealed sensitivities to loop seal nodalization particularly with regard to representing the 90° bends of the seal piping.

IVO full-scale loop seal experiments are discussed in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.2.2.4, "Effect of Scale," and void fraction data points are compared against three different limiting lines in Figure 18.2.2-12, "IVO Full-Scale Final Void Fraction and Limit Lines." However, no assessment of WCOBRA/TRAC-TF2 prediction results against IVO separate effect loop seal experiments was reported.

(1) Please perform an additional assessment study for WCOBRA/TRAC-TF2 using IVO separate effect atmospheric air-water test data obtained from both the full-scale and the 1/10-scale loop seal test facilities. Please describe the applied WCOBRA/TRAC-TF2 models for the IVO test facilities as requested in RAI Question No. 112 Items (1) through (4) with regard to the WCOBRA/TRAC-TF2 UPTF loop seal model. Also, describe the IVO loop seal tests instrumentation, test data, and assessed code predication results as requested in RAI Question No. 113, Items (1) and (2), with regard to the WCOBRA/TRAC-TF2 UPTF TRAM loop seal clearance test data. Document user defined parameters, multipliers, and/or options used in the WCOBRA/TRAC-TF2 IVO loop seal models as requested in RAI Question No. 114, Items (1) and (2), with regard to the WCOBRA/TRAC-TF2 UPTF TRAM loop seal model.

(2) Please present detailed results from the WCOBRA/TRAC-TF2 assessment using IVO separate effect atmospheric air-water test data from the full-scale and the 1/10-scale loop seal test facilities as requested in RAI Question No. 115 Items (1) through (4) with regard to the WCOBRA/TRAC-TF2 UPTF TRAM loop seal tests assessment study.

(3) Please perform and present results from sensitivity calculations assessing effects related to IVO the full-scale and 1/10-scale loop seal test facilities nodalization in the applied WCOBRA/TRAC-TF2 IVO loop seal models as requested in RAI Question No. 116 Items (1) through (3) with regard to the WCOBRA/TRAC-TF2 assessment using the UPTF TRAM loop seal tests. The length of the bottom horizontal section of the full-scale IVO loop seal piping had an L/D ratio of 5.1, which was significantly larger than the corresponding ratio in the full-scale UPTF loop seal facility characterized by an L/D ratio of 2.3. Therefore, please adjust the number of cells in the WCOBRA/TRAC-TF2 IVO full-scale loop seal model so that the cell length-to-diameter ratios in the IVO full-scale loop seal model are close to the ratios examined in the UPTF full-scale loop seal model (L/D of 1.16, 0.77, and 0.58). Examine any additional nodalization schemes, as deemed appropriate.

(4) Please provide results from WCOBRA/TRAC-TF2 sensitivity studies based on the IVO separate effect full-scale and 1/10-scale loop seal clearance tests, which show the effect of varying or sampling of parameters, multipliers, and/or options relevant to the prediction of the loop clearance process. Perform and document the code assessment results as requested in RAI Question #118 with regard to the WCOBRA/TRAC-TF2 UPTF loop seal model.

(5) Please provide results from WCOBRA/TRAC-TF2 sensitivity calculations based on the IVO separate effect full-scale and 1/10-scale loop seal clearance tests that show the effects related to the applied maximum allowed time step size (DTMAX). Perform and document the code assessment results as requested in RAI Question #119 with regard to the WCOBRA/TRAC-TF2 UPTF TRAM loop seal assessment study.

RAI Question #121: ECTHOR Loop Seal Clearance Data and WCOBRA/TRAC-TF2 Assessment

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.2.2, "PWS 2.3 Loop Seal Tests," discusses scaled air-water experiments examining the hydraulic behavior of a U-tube under conditions similar to those encountered in a PWR loop seal during a small break LOCA. The tests were performed as part of the ECTHOR (an acronym from French "Ecoulements dans des Tuyauteries Horizontales en Eau-Air," which stands for Water-Air Flow in Horizontal Pipes) Program carried out under an agreement between Framatome, Électricité de France, Commissariat à l'Energie Atomique, and Westinghouse. Description of the ECTHOR tests is provided by J. P. Bourteele, "Investigation of Stratified and Countercurrent Flows in Horizontal Piping during a Loss-of-Coolant Accident," European Two-Phase Flow Group Meeting, Glasgow, June 3-6, 1980, and by R. J. Skwarek, "Experimental Evaluation of PWR Loop Seal Behavior during Small LOCAs," Proceedings of the ANS Specialists Meeting on Small Break Loss-of-Coolant Accident Analyses in LWRs: Conference Papers, August 25-27, 1981, Monterey, California, pp. 5.1-5.12.

The ECTHOR separate effect air-water scaled loop seal tests were performed at atmospheric pressure in a U-tube pipe with an inner diameter of 0.25 m (9.84 inch or 0.82 ft) representing the geometry of a PWR loop seal at a scaling ratio of 0.32 (approximately 1/3). ECTHOR loop seal tests have been used in the past for interfacial drag model development and assessment of various reactor safety thermal hydraulic codes such as CATHARE (acronym from Code for Analysis of Thermalhydraulics during an Accident of Reactor and safety Evaluation) and RELAP5.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 18, "Loop Seal Clearance," Subsection 18.2.2, "PWS 2.3 Loop Seal Tests," Figures 18.2.2-3 shows residual liquid level data, Figures 18.2.2-4 and 18.2.2-5 depict average void fraction data, and Figure 18.2.2-9 plots U-tube differential pressure data from the ECTHOR tests. The test data are compared against limiting lines for governing participating processes in Figures 18.2.2-7 and 18.2.2-8. However, no assessment of WCOBRA/TRAC-TF2 prediction results against ECTHOR separate effect air-water scaled loop seal data was reported.

Please perform an additional assessment study for WCOBRA/TRAC-TF2 using ECTHOR separate effect air-water scaled loop seal test data. Perform this study and document the code assessment results as requested in RAI Question #120 Items (1) through (5) with regard to the WCOBRA/TRAC-TF2 IVO separate effect atmospheric air-water tests.

RAI Question #122: Upper Bound Approach to Reactor Coolant Pump Trip Time during Loss-of-Coolant Accident with Offsite Power Available

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.3, "Reactor Accident Boundary Conditions," explains that "offsite power determines whether RCS pumps initially remain on, and whether pumped safety injection (and containment safeguards) come on with only valve opening and alignment delays. The effect of the RCS pumps on the LOCA transient may be significantly different, depending on whether they are assumed to coast down or continue running (until operator action is taken, if applicable)." Section 30, "Technical Basis of Statistical Procedures Applied in Full Spectrum™ LOCA (FSLOCA) Uncertainty Methodology," Subsection 30.4, [ ]a,c describes a statistical approach for treatment of Offsite Power Availability (OPA) at the time of a postulated small or large break LOCA event (OPA=ON or OPA=OFF) in the FSLOCA methodology.

In analyzing LOCAs with offsite power available, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.5.2, "Variability of Plant Conditions Due to Operation Actions," summarizes that [ ]a,c The upper bound to operator action time to trip the RCPs is taken as [ ]a,c from the time reactor trip occurs, and this time is used in the reference break spectrum with offsite power available in Section 27, Volume 3 of this document." WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 27, "Reference Break Spectrum Analysis," describes representative LOCA analyses of small, intermediate, and large breaks for the reference V. C. Summer and Beaver Valley Unit 1 plants.

Please provide the following additional information regarding the approach to RCP trip time modeling with offsite power available as implemented in the FSLOCA methodology.

(1) The analysis provided in Subsection 25.5.2 considers the short-term phase of a small break LOCA (SBLOCA) and refers to Emergency Operating Procedures (EOPs) specific to Indian Point Unit 2, a four-loop Westinghouse PWR. At the same time, Subsection 25.5.2 states that the upper bound to operator action time to trip the RCPs, assessed at [ ]a,c from the time reactor trip occurs, is used in the LOCA analyses for large, intermediate, and small break sizes described in Section 27, "Reference Break Spectrum Analysis." Please clarify if the described approach based on an upper bound to operator action time to trip the RCPs set at [ ]a,c from the time when reactor trip occurs is considered applicable on a generic basis for performing LOCA analyses with the FULL SPECTRUM™ LOCA methodology. Please provide a justification for the described approach.

(2) Please describe the rationale for introducing "an upper bound to operator action time to trip the RCPs" as part of the approach for simulating RCPs operation during LOCAs with offsite power available in the FULL SPECTRUM™ LOCA methodology. Explain how such "an upper bound to operator action time to trip the RCPs" can be

credited for modeling RCPs operation with offsite power available in performing best-estimate analyses of both small and large break LOCA. Describe the technical basis that demonstrates the validity of the approach implemented in the FSLOCA methodology.

RAI Question #123: Factors Affecting Reactor Coolant Pump Trip Time for Loss-of-Coolant Accident Analyses with Offsite Power Available

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 2, "Evaluation Model Functional Requirements," Subsection 2.3.1, "LOCA Scenario Specification," recognizes the possibility of operator action in the accident scenario. Subsection 2.3.1 also explains that the availability of the RCPs following a reactor trip event is considered so that "variability in the pump trip time does exist."

Section 3.15, "Special Considerations for a Small-Break Loss-of-Coolant Accident in Pressurized Water Reactors," in U.S. NRC Regulatory Guide (RG) 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance," May 1989, requires that "the pump operation assumptions used in the calculations should be the most likely, based on operating procedures, with appropriate consideration of the uncertainty of the pump operation during an actual event."

Please provide additional information regarding the approach to model RCP trip time with offsite power available as part of the FULL SPECTRUM™ LOCA methodology as follows.

(1) Explain specifically how the approach to model RCP trip time with offsite power available for LOCA analyses takes into consideration the following factors: (a) plant-specific design features, (b) relevant EOP requirements and applicable criteria, (c) break size, (d) plant monitored conditions, (e) availability, performance, and correct use of equipment, (f) operator recognition of the event and action, as well as any other factors considered of relevance.

(2) Please provide an assessment for the uncertainties associated with each individual factor identified in Item (1) above with regard to the RCP trip time. Please consider each factor individually and assess its contribution to the overall uncertainty in the RCP trip time. Include appropriate ranges and associated uncertainties. Present examples of assessment results for PWR plant types with similar design features, EOP requirements, and other relevant factors, for which the FULL SPECTRUM™ LOCA methodology is considered applicable. Include a table that documents the assessed time contribution to RCP trip time due to each individual factor, the RCP trip time uncertainty range, and the RCP trip time credited in LOCA analyses. If appropriate, please provide a separate table for each plant type. Describe the introduced assumptions, explain and discuss the analysis results, and compare the assessments.

RAI Question #124: Reactor Coolant Pump Trip Time for Small Break Loss-of-Coolant Accident Analyses with Offsite Power Available

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.5.1, "EOP Sequences for a Small Break LOCA," summarizes Emergency Operating Procedures (EOPs) relevant to the short-term phase of a small break LOCA for Indian Point Unit 2. The procedures are summarized in Table 25-1, "Condensed EOPs for Indian Point Unit 2, Short-Term Portion." In particular, it is explained that [

]a,c The RCP trip time variability is caused by the time the operators take to identify that the trip conditions exist during their periodic scan of system parameters, and the small increment required to actually perform the trip." Subsection 25.5.1 also states that "plants typically follow a generic template for the generation of EOPs, and plant-to-plant differences in the EOP structure are not expected to be important for the purpose of performing a LOCA safety analysis."

Please provide the following additional information regarding the approach to RCP trip time modeling with offsite power available as implemented in the FULL SPECTRUM™ LOCA methodology for performing small break LOCA analyses.

(1) Explain how the approach to modeling RCPs trip due to operator action in determining the boundary conditions for small break LOCA analyses is applied on a plant-by-plant basis in the FULL SPECTRUM™ LOCA methodology. In particular, identify relevant contributing factors and types of plant-specific information (for example, available data, EOPs and criteria, etc.) that are considered for modeling RCP trip time on a plant-by-plant basis in individual plant analyses. Provide and explain the uncertainty and significance, in terms of having an impact on the credited RCPs trip time, associated with such factors and plant-specific information.

(2) Provide examples of assessed RCPs trip times considered applicable for small break LOCA analyses and determined for different PWR plant types based on design features, EOP requirements, and other pertinent factors. Present examples of assessment results for PWR plant types for which the FULL SPECTRUM™ LOCA methodology is considered applicable. Include a table that documents the assessment results for the examined cases. Describe the introduced assumptions, explain and discuss the analysis results, and compare the assessments.

(3) The upper bound to operator action time to trip the RCPs of [ ]a,c from the time when reactor trip occurs, is provided in Subsection 25.5.2, "Variability of Plant Conditions Due to Operation Actions," on the basis of small break LOCA considerations. Please provide the plant-specific values for the RCPs trip times used in the demonstration plant small break LOCA analyses for the FULL SPECTRUM LOCA methodology presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 28, "Scoping And Sensitivity Studies," and in Section 31, "Full Spectrum LOCA Demonstration Analysis." Describe the introduced assumptions, explain and discuss the applicability of the analysis results, and compare the assessments. Explain the basis for the used RCPs trip times considering the response to Item (1) above.

RAI Question #125: Reactor Coolant Pump Trip Time for Large Break Loss-of-Coolant Accident Analyses with Offsite Power Available

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 28, "Scoping and Sensitivity Studies," Subsection 28.1.2, "Offsite Power Availability – LBLOCA," analyzes effect of offsite power availability on RCPs behavior for large break LOCA analyses performed with WCOBRA/TRAC-TF2 for the reference V. C. Summer (CGE) and Beaver Valley Unit 1 (DLW) plants. Subsection 28.1.2 explains that "with LOOP, the RCP trip is modeled coincident with the reactor trip at the beginning of the transient, so the pumps in the intact loops coast down while the pump in the broken loop is accelerated by the flow toward the break." In the case "with offsite power available (OPA), the pumps continue to rotate at a fixed speed until operator trip."

The RCP rotational speeds in the intact loops and in the broken one the V. C. Summer (CGE) nominal double-ended guillotine (DEG) break demonstration plant analysis are shown in Figure 28.1.2-2, "Intact Loop Pump Speed, CGE Offsite Power Availability Sensitivity," and in Figure 28.1.2-3, "Broken Loop Pump Speed, CGE Offsite Power Availability Sensitivity," respectively. For the Beaver Valley Unit 1 (DLW) nominal DEG break demonstration plant analysis, the RCP rotational speeds in the intact loops and in the broken one are shown in Figure 28.1.2-8, "Intact Loop Pump Speed, DLW Offsite Power Availability Study," and in Figure 28.1.2-9, "Broken Loop Pump Speed, DLW Offsite Power Availability Study," accordingly. As it can be scaled from these graphs, the RCPs pump speeds in all loop start decreasing at about [ ]a,c following the break initiation in the analyses with offsite power available for both plants.

Please provide the following additional information regarding the approach to RCP trip time modeling with offsite power available as implemented in the FULL SPECTRUM™ LOCA methodology for performing large break LOCA analyses.

(1) Explain how the approach to modeling RCPs trip due to operator action in determining the boundary conditions for large break LOCA analyses is applied on a plant-by-plant basis in the FULL SPECTRUM™ LOCA methodology. In particular, identify relevant contributing factors and types of plant-specific information (for example, available data, EOPs and criteria, etc.) that are considered for modeling RCP trip time on a plant-by-plant basis in individual plant analyses. Provide and explain the uncertainty and significance, in terms of having an impact on the credited RCPs trip time, associated with such factors and plant-specific information.

(2) Provide examples of assessed RCPs trip times considered applicable for large break LOCA analyses and determined for different PWR plant designs based on design features, EOP requirements, and other pertinent factors. Present examples of assessment results for PWR plant types for which the FULL SPECTRUM™ LOCA methodology is considered applicable. Include a table that documents the assessment results for the examined cases. Describe the introduced assumptions, explain and discuss the applicability of the analysis results, and compare the assessments.

(3) Please provide the plant-specific values for the RCPs trip times used in the demonstration plant large break LOCA analyses for the FULL SPECTRUM™ LOCA methodology presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 28, "Scoping And Sensitivity Studies," and in Section 31, "Full

Spectrum LOCA Demonstration Analysis." Describe the introduced assumptions, explain and discuss the analysis results, and compare the assessments.

(4) The upper bound to operator action time to trip the RCPs of [ ]a,c from the time when reactor trip occurs, provided in Subsection 25.5.2, "Variability of Plant Conditions Due to Operation Actions," on the basis of small break LOCA considerations, agrees closely with the timing of about [ ]a,c following the break initiation when the RCP pump speeds were predicted to start decreasing with offsite power available in the large break demonstration plant analyses presented in Subsection 28.1.2. Please explain the basis for the implemented RCPs trip time considering the response to Item (1) above.

RAI Question #126: Delay in Operator Action to Trip Reactor Coolant Pumps during Small Break Loss-of-Coolant Accidents

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.5.2, "Variability of Plant Conditions Due to Operation Actions," explains that [

]a,c

(1) Please clarify if the above identified range of [ ]a,c expected in operator action to trip the RCP for small break LOCAs is considered applicable on a generic basis in performing LOCA analyses using the FULL SPECTRUM™ LOCA methodology.

(2) Regarding the operator action to trip the RCPs during SBLOCAs, Subsection 25.5.2 clarifies that [

]a,c Please identify the "studies" described as [ ]a,c in the above provided citation form Subsection 25.5.2 and provide references for the source documents containing these studies. In particular, provide details and explain how the identified [

]a,c demonstrates the acceptability and appropriateness of the provided delay time of [ ]a,c needed for operator action to trip the RCPs during a LOCA event.

(3) Please explain if uncertainty in human reliability was considered in the approach to model the operator action to trip the RCPs implemented in the FULL SPECTRUM™ LOCA methodology.

(4) If the approach for determining the delay time needed for operator action to trip the RCPs during a LOCA event will be applied in FULL SPECTRUM™ LOCA methodology on a plant-by-plant basis, please identify and describe the type of plant-specific information that will be considered in individual plant applications.

RAI Question #127: Single Failure Assumptions in Loss-of-Coolant Accident Analyses

Criterion 35, "Emergency Core Cooling," in Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, requires that a single failure be assumed when analyzing safety system performance. U.S. NRC RG 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance," May 1989, states that "Appendix A to 10 CFR Part 50 requires that a single failure be considered when analyzing safety system performance and that the analysis consider the effect of using only onsite power and only offsite power."

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.3, "Reactor Accident Boundary Conditions," in its part "Single Failure Assumption," states that "the loss of a train may be assumed for the determination of pumped ECCS flow during the LOCA, while the train will be assumed to operate in the calculation of containment backpressure." It is also explained that "alternatively, a more complete analysis using consistent assumptions may be performed on a plant-by-plant basis."

(1) Please provide a table that lists single failure assumptions considered possible and applicable for the purposes of LOCA analyses using the FULL SPECTRUM™ LOCA methodology. Please use a separate raw for each combination and formulate the single failure assumptions in two separate columns. Include the single failure assumption applicable for modeling the reactor coolant system (RCS) response with WCOBRA/TRAC-TF2 in the first column and the one applicable for the containment backpressure modeling in the second column. Please consider small and large break LOCA analysis applications. Explain the identified single failure assumptions along with pertinent conditions and supporting considerations.

(2) Subsection 25.3, "Reactor Accident Boundary Conditions," in its part "Single Failure Assumption," states that "a more complete analysis using consistent assumptions may be performed on a plant-by-plant basis." Please explain what such "a more complete analysis," when "performed on a plant-by-plant basis," includes. Identify and describe the "consistent assumptions" that are considered applicable for performing the analysis. Describe the types of plant-specific information that are considered in individual plant analyses. If failure-related assumptions that can be identified and used in analyses on a on a plant-by-plant basis are not included in the response to Item (1) above, please provide a table that describes them. Explain the identified single failure assumptions along with pertinent conditions and supporting considerations.

RAI Question #128: Prolonged RCP Operation during Small Break Loss-of-Coolant Accidents

J. Gonzalez-Cadelo et al., "Applying Integrated Safety Assessment Methodology. Analysis of Cold Leg SBLOCA With Failed HPSI," 21st International Conference Nuclear Energy for New Europe Ljubljana 2012, September 5-7, Ljubljana, Slovenia, provided results from a small break LOCA study of predicted PWR peak clad temperatures (PCTs) as a function of the break size and the RCPs trip delay. The work was performed for the Almaraz Unit I Nuclear Power Plant (NPP), a Westinghouse three-loop PWR, using the U.S. NRC code TRACE. Small breaks in the cold leg ranging between 1 inch and 5 inches of equivalent break diameter were analyzed with an increment as low as 0.25 inch. RCP trip delays ranging between zero and up to 10,000 seconds (~167 minutes) were examined with a time interval as low as 500 seconds. The study referenced Westinghouse Emergency Operating Procedures (EOPs) EOP E-0, EOP E-1, and EOP ES-1.2 along with pertinent foldout pages related to small break LOCA sequences with early secondary-side depressurization and uncertain RCP trip time due to assumed failure of High Pressure Safety Injection (HPSI). The reported results exhibited a damage domain trend with PCTs in excess of 2,200 °F (1,204.4 °C or 1,477.6 K) at relatively short RCP trip times (about 500 seconds or less), for cold leg breaks between 2.5 inches and 3 inches in diameter.

(1) Please identify and describe small break LOCA sequences and accident conditions under which RCPs can remain in operation for prolonged time periods. Such sequences can be characterized with large uncertainties in RCP trip time. In identifying and describing these LOCA sequences and related accident conditions, please provide consideration of initial plant conditions, plant design and safety features, availability and performance of equipment, single failure assumptions, EOP requirements, and other relevant factors.

(2) Please explain how LOCA sequences, as identified in the response to Item (1) above, are accounted for in analyzing small break LOCAs using the FULL SPECTRUM™ LOCA methodology.

(3) Please describe the analyses that established the technical basis for prolonged RCP operation for the LOCA transients identified in the response to Item (1) above. Explain how corresponding EOP requirements and criteria related to RCP operation and trip were developed. Summarize and present the results from such analyses and identify those performed with WCOBRA/TRAC-TF2, as applicable.

(4) Please provide WCOBRA/TRAC-TF2 prediction results for a spectrum of break sizes that analyze small break LOCAs with prolonged RCP operation. In addition, please compare these predictions against results from WCOBRA/TRAC-TF2 analyses in which RCPs were tripped to illustrate the impact of RCP operation.

RAI Question #129: Early RCP Trip during Small Break Loss-of-Coolant Accidents

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.5.1, "EOP Sequences for a Small Break LOCA," describes continuously monitored conditions that are used in Emergency Operating Procedure (EOP) E-0 "Reactor Trip or Safety Injection" for comparison against established RCP trip criteria when determining boundary conditions assumed for small break LOCA analysis calculations. It is mentioned in Subsection 25.5.1 that although the description is specific to Indian Point Unit 2, "plants typically follow a generic template for the generation of EOPs."

(1) Please identify and describe small break LOCA sequences and accident conditions under which RCPs are tripped early in the transient. In identifying and describing these LOCA sequences and related accident conditions, please provide consideration of initial plant conditions, plant design and safety features, availability and performance of equipment, single failure assumptions, EOP requirements, and other relevant factors.

(2) Please describe the analyses that established the technical basis for tripping RCPs in the class of LOCA transients identified in the response to Item (1) above. Explain how corresponding EOP requirements and criteria related to RCP operation were established in the generic template used for generation of EOPs. Summarize and present the results from such analyses and identify those performed with WCOBRA/TRAC-TF2.

(3) Please provide WCOBRA/TRAC-TF2 prediction results for a spectrum of break sizes that analyze small break LOCAs with RCPs tripped early in the transients. In addition, please compare these predictions against results from WCOBRA/TRAC-TF2 analyses in which RCPs were not tripped to illustrate the impact of RCP operation.

RAI Question #130: Break Location Impact in Previous Small Break Loss-of-Coolant Accident Analyses

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 2, "Evaluation Model Functional Requirements," Subsection 2.3.1, "LOCA Scenario Specification," states: "Sensitivity studies based on Appendix K methods have identified a cold leg break to be the most limiting in terms of location. Since this was also true of earlier best-estimate cases analyzed, this is taken to be the limiting break location for the following PIRT discussion."

(1) Please identify and describe the conservative analyses of the effect of break location described as "sensitivity studies based on Appendix K methods" in the above given citation from Subsection 2.3.1. Summarize the findings from the performed analyses and present major prediction results using tables and graphs as appropriate. Include description of relevant modeling assumptions and computer codes used. Also, please provide a list of references identifying the source documents containing these studies.

(2) Please identify and describe the best-estimate studies analyzing the effect of break location and described as "earlier best-estimate cases analyzed" in the above given

citation from Subsection 2.3.1. As for Item (1) above, please summarize the findings from the performed analyses and present major prediction results using tables and graphs as appropriate. Include description of relevant modeling assumptions and computer codes used. Provide a list of references identifying the source documents containing these analyses.

RAI Question #131: Break Location Impact in Small Break Loss-of-Coolant Accident Analyses Using WCOBRA/TRAC-TF2

As pointed out in Section 4.4.2, "Break Location," in NUREG-0623 (see B. Sheron, "Generic Assessment of Delayed Reactor Coolant Pump Trip during Small Break Loss-of-Coolant Accidents in Pressurized Water Reactors," NUREG-0623, November 1979), vendor analyses identifying limiting breaks with regard to break location led to different findings. Thus, Westinghouse "concluded that a break in the cold leg discharge piping with the pumps running resulted in the limiting consequences" whereas Combustion Engineering concluded that "the breaks postulated in the hot leg with delayed pump trip or pumps running were the most limiting with regard to peak cladding temperatures." Also, no best-estimate analyses of small break LOCAs by Westinghouse were identified in Section 4.4.6, "Best-Estimate Analysis," in NUREG-0623.

Section 3.15, "Special Considerations for a Small-Break Loss-of-Coolant Accident in Pressurized Water Reactors," in U.S. NRC RG 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance," May 1989, recognizes that "break flow may be greatly influenced by the location and specific geometry of the break." Accordingly, "small-break loss-of-coolant accident calculations should, therefore, include various assumed break locations in the spectrum of breaks analyzed."

Please provide the following additional information regarding WCOBRA/TRAC-TF2 analyses performed to examine sensitivity of code predictions to break location as part of substantiating and confirming the approach for treatment of break location for small break LOCA analyses implemented in the FULL SPECTRUM™ LOCA methodology.

(1) Please identify best-estimate studies performed with WCOBRA/TRAC-TF2 to analyze the effect of break location in small break LOCAs. Provide a list of references that identify the source documents containing these analyses.

(2) Please provide and describe WCOBRA/TRAC-TF2 prediction results for a spectrum of break sizes that analyze small breaks occurring in a cold leg piping between the RCP and the reactor pressure vessel as well as in a hot leg. For breaks located in a hot leg, please consider possible sensitivity with regard to the location of the pressurizer vessel connection. Include description of relevant modeling assumptions and the computer code versions used.

(3) Present direct comparisons of prediction results for key parameters from small break LOCA analyses simulating transients with the same break sizes and different break locations. Present such comparison plots for different PWR plant types that will be analyzed with the FULL SPECTRUM™ LOCA methodology.

(4) Provide and describe WCOBRA/TRAC-TF2 prediction results that examine the impact of RCPs trip delay with offsite power available on the limiting break location

for small break LOCAs. Include analyses of small break LOCA sequences with RCPs tripped early in the transient and such with prolonged RCPs operation.

RAI Question #132: Steam Generator Decay Heat Removal during Small Break Loss-of-Coolant Accidents

The main steam safety valves (MSSVs) are direct-acting valves (actuated only by pressure) that provide overpressure design protection and backup decay heat removal capability when the steam dumps and secondary atmospheric dump valves can not be used. Each main steam line has several safety valves with staggered set pressures to provide an increased relieving capacity with an increasing overpressure. As described by T. E. Wierman et al., "Industry Performance of Relief Valves at U.S. Commercial Nuclear Power Plants through 2007," NUREG/CR-7037, March 2011, the set pressures for these valves are a nominal 1170, 1200, 1210, 1220, and 1230 psig with the highest setpoint being less than 110% of the SG design pressure.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.3, "Reactor Accident Boundary Conditions," in summarizing the modeling approach with regard to the SG secondary side boundary conditions, states that [

]a,c Specifically, it is explained that [

]a,c

Please provide additional information related to the modeling of SG secondary conditions in WCOBRA/TRAC-TF2 plant analyses to predict decay heat removal via primary to secondary heat transfer in the SGs during small break LOCAs as follows.

(1) State the method of decay heat removal due to heat transfer from the RCS to the SG secondary sides in small break LOCA analyses with WCOBRA/TRAC-TF2 as credited in the FULL SPECTRUM™ LOCA methodology. Identify the credited systems, conditions for their operation, and introduced assumptions as applied in modeling decay heat removal via the SGs in small break LOCA analyses.

(2) Describe the approach to determine the set pressures for the MSSVs. In particular, please explain how the implemented approach takes into consideration and models the following factors: (a) uncertainty in the setpoint characteristics of the safety valves, (b) pressure drop from the SG to the safety valves, (c) uncertainty in rated relief capacities of the safety valves, and (d) criteria for using the next highest pressure setpoint. For example, Section 7.2.2, "Westinghouse-Designed Plants," in NUREG-0623 (see B. Sheron, "Generic Assessment of Delayed Reactor Coolant Pump Trip during Small Break Loss-of-Coolant Accidents in Pressurized Water Reactors," NUREG-0623, November 1979), in discussing the system pressure for manual pump trip, describes that the next highest pressure setpoint for the secondary system safety valves is used when the calculated relief flow is greater than 60 percent of the rated valve capacity at the previous pressure setpoint.

(3) Present a table that documents the parameters identified in Item (2) above and used in the demonstration plant small break LOCA analyses for the FULL SPECTRUM™ LOCA methodology presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 28, "Scoping And Sensitivity Studies," and in Section 31, "Full Spectrum LOCA Demonstration Analysis." Subsection 31.1.1, "Break Area Ranges," identifies only a quantity described as "the lowest MSSV set pressure" and provides its value as [ ]a,c for the V. C. Summer case analysis.

RAI Question #133: Steam Generator Heat Transfer Modeling

According to Section 3.2.7, "Primary to Secondary Heat Transfer (Not Applicable to Boiling Water Reactors)," in U.S. NRC Regulatory Guide 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance," May 1989, "heat transferred between the primary and secondary systems through the steam generators should be considered in the calculation and should be calculated in a best-estimate manner."

(1) Please describe the mechanisms that participate in the primary to secondary heat transfer through the SG heat exchange tubes. Identify factors that can have an impact on the primary to the secondary heat transfer mechanisms during normal plant operation and under LOCA conditions. Include consideration of deposits fouling of SG heat transfer tubes and supporting structures and associated effects on the overall heat resistance and thermal performance degradation.

(2) Please present a table that identifies the correlations used in WCOBRA/TRAC-TF2 to model the heat transfer mechanisms on the outer side of the SG heat transfer tubes. Identify the experimental database for each provided correlation and provide its applicability range. Compare the applicability ranges for the correlations against typical conditions expected during LOCAs. Explain how the factors affecting the heat transfer mechanisms as identified in Item (1) above are accounted for in the implemented heat transfer models. Summarize the technical basis for these models along with the supporting data and analyses. In particular, consider the effect of thermal performance degradation due to deposits fouling.

(3) Please present a table that identifies the correlations used in WCOBRA/TRAC-TF2 to model the heat transfer mechanisms on the inner side of the SG heat transfer tubes. Identify the experimental database for each provided correlation and provide its applicability range. Compare the applicability ranges for the correlations against typical conditions expected during LOCAs. Explain how the factors affecting the heat transfer mechanisms as identified in Item (1) above are accounted for in the implemented heat transfer models. Summarize the technical basis for these models along with the supporting data and analyses. In particular, consider the effect of non-condensable gas on heat transfer inside the SG tubes.

RAI Question #134: Steam Generator Tube Plugging Levels

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.1, "Plant Physical Configuration," in summarizing the modeling approach with regard to SG tube plugging, states that [

]a,c

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 28, "Scoping and Sensitivity Studies," Subsection 28.1.6, "Steam Generator Hydraulics: Tube Plugging – LBLOCA," present results for tube plugging levels of 0%, 10%, and 20% for a nominal double-ended guillotine break demonstration plant analyses for V. C. Summer, a three-loop Westinghouse PWR plant.

Please provide the following additional information regarding the approach to SG tube plugging modeling implemented in the FULL SPECTRUM™ LOCA methodology for performing LOCA analyses.

(1) Please explain how the [ ]a,c SG tube plugging fraction is established and used in determining relevant boundary conditions for performing LOCA analyses using the FULL SPECTRUM LOCA methodology.

(2) WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 28, "Scoping and Sensitivity Studies," referring to [ ]a,c discussed in Section 28.1.6 and in Section 28.2.9 respectively, states that [ ]a,c Please identify and describe the type of plant-specific information that is considered in determining "a plant-specific [ ]a,c for the SG tube plugging used in LOCA and associated uncertainty analyses. In particular, please explain SG design-specific information and SG operational history are taken into account when determining the [ ]a,c SG tube plugging fraction on a plant-specific basis.

(3) Please provide the information identified in Item (2) above and the plant-specific [ ]a,c for the SG tube plugging levels used in the demonstration plant analyses for the FULL SPECTRUM™ LOCA methodology presented in WCAP-16996-P Revision 0 Section 28, "Scoping And Sensitivity Studies," and in Section 31, "FULL SPECTRUM™ LOCA Demonstration Analysis." Describe the introduced assumptions, explain and discuss the applicability of the analysis results, and compare the assessments.

RAI Question #135: SG Tube Plugging Impact on Core Flow Stagnation for Large Break Loss-of-Coolant Accidents

Considering the modeling approach with regard to SG tube plugging, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements," Subsection 29.3.1, "Bounded Parameters," explains that [

]a,c

Recognizing an additional phenomenon of importance for large break LOCA analyses, Subsection 29.3.1, "Bounded Parameters," acknowledges that [

]a,c Specifically, Subsection 29.3.1 explains that [

]a,c

(1) Please identify and describe the deterministic studies of SG tube plugging level that are referred to in the above provided citation from Subsection 29.3.1. Summarize and present results from such analyses that examine the impact of the assumed SG tube plugging level on large break LOCA predictions with a focus on core flow stagnation and possible flow reversal. Include plots that capture such predicted conditions for the core and the hot channel in particular. Analyze and show identified effects of flow stagnation on prediction results taking into consideration applicable safety criteria.

(2) Please identify best-estimate studies that have been performed with WCOBRA/TRAC-TF2 to analyze the effect of SG tube plugging on large break LOCA predictions associated with core flow stagnation and possible flow reversal in the core. Provide a list of references that identify the source documents containing these analyses. In addition to the analyses discussed in Subsection 28.1.6, "Steam Generator Hydraulics: Tube Plugging – LBLOCA," please present results from calculations obtained with WCOBRA/TRAC-TF2 that examine the impact of SG tube plugging on large break LOCA predictions due to core flow stagnation and possible flow reversal in the core.

(3) In presenting the analyses requested in Item (2) above, please provide additional information addressing the following items: (a) the analyses should cover a spectrum of large break sizes over which the examined effect takes place and code predictions show most sensitivity to break change, if so observed, and (b) the analyses should cover the entire range of possible SG tube plugging levels. Please provide consideration of different PWR plant types and show predictions results for a PWR plant design for which the sensitivity to SG tube plugging due to core flow stagnation is expected to be most pronounced, as applicable. Show the impact on prediction results with relevance to the safety criteria and include zoomed plots of computed results over a time window during which the stagnation effect is predicted to occur, as applicable.

RAI Question #136: Reactor Coolant Pump Trip Impact on Core Initial Thermal-Hydraulic Response for Large Break Loss-of-Coolant Accidents

The time of RCP trip following a large break LOCA can have an impact on the initial thermal-hydraulic response in the reactor pressure vessel and in the reactor core region in particular. Among others, processes such as flow stagnation and possible flow reversal in the core can be affected by RCPs operation and time of RCP trip. WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 28, "Scoping and Sensitivity Studies," Subsection 28.1.2, "Offsite Power Availability – LBLOCA," presents large break LOCA analyses performed with WCOBRA/TRAC-TF2 for the reference V. C. Summer (CGE) and Beaver Valley Unit 1 (DLW) plants. The analyses examine the impact of offsite power availability on large break LOCA results.

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.5.2, "Variability of Plant Conditions Due to Operation Actions," states that [

]^{a,c}

Please provide the following additional information regarding WCOBRA/TRAC-TF2 analyses performed to examine sensitivity of the initial reactor core thermal-hydraulic response to RCP trip time with offsite power available.

(1) Please identify best-estimate studies that have been performed with WCOBRA/TRAC-TF2 to analyze sensitivity of large break LOCA predictions to RCP trip time with offsite power available with a focus on the initial thermal-hydraulic response in the reactor pressure vessel and in the reactor core region. Provide a list of references that identify the source documents containing these analyses. In addition to the analyses discussed in Subsection 28.1.2, "Offsite Power Availability – LBLOCA," please present results from WCOBRA/TRAC-TF2 calculations to examine sensitivity to RCP trip time following a large break LOCA.

(2) Please provide WCOBRA/TRAC-TF2 prediction results analyzing sensitivity of large break LOCA predictions to RCP trip time with offsite power available with a focus on the effect of core flow stagnation and possible flow reversal in the core.

(3) In presenting the analyses requested in Item (1) above, please provide additional information addressing the following items: (a) the analyses should cover a spectrum of large break sizes over which the examined effect takes place and code predictions show most sensitivity to break change, if so observed, and (b) the analyses should cover a range of RCPs trip times that reflects the uncertainty associated with the pump trip event. Please provide consideration of different PWR plant types and show predictions results for a PWR plant design for which the sensitivity of examined parameters to RCPs trip time is most pronounced, as applicable. Show the impact on prediction results with relevance to the applicable safety criteria and include zoomed plots of computed results over a time window during which the stagnation effect is predicted to take place, as applicable.

RAI Question #137: Steam Generator Tube Plugging Impact on Steam Generator Reversed Heat Transfer for Large Break Loss-of-Coolant Accidents

Considering the modeling approach with regard to SG tube plugging, WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 29, "Assessment of Uncertainty Elements," Subsection 29.3.1, "Bounded Parameters," explains that
[

]a,c

Following a large break LOCA, liquid entrainment from the upper plenum through the hot legs and into the SG tube bundles can lead to significant evaporation of entrained liquid due to reversed heat transfer from the hot SG secondary systems to the primary side of the SG tubes. In turn, this process can cause a primary pressure increase thus impacting the core thermal response. Such reversed heat transfer through the SGs can be dependant on the available SG heat transfer area, which is directly affected by the assumed SG tube plugging level.

(1) Please present results from calculations obtained with WCOBRA/TRAC-TF2 that examine the effect of the assumed SG tube plugging level on large break LOCA predictions with a focus on the effect of reversed heat transfer from the hot SG secondary systems and evaporation of entrained liquid on the SG tubes primary side.

(2) In presenting the analyses requested in Item (1) above, please provide additional information addressing the following items: (a) the analyses should cover a spectrum of large break sizes over which the examined effect takes place and code predictions show most sensitivity to break change and (b) the analyses should cover the entire range of possible SG tube plugging levels. Please provide consideration of different PWR plant designs and show predictions results for a PWR plant design for which the sensitivity of primary pressure increase to SG tube plugging is expected to be most pronounced, as applicable. Show the impact on prediction results with relevance to the applicable safety criteria and include zoomed plots of computed results over a time window during which the examined effect is predicted to take place, as applicable.

RAI Question #138: Safety Injection Pump Flow during Loss-of-Coolant Accidents

WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 25, "Plant Sources of Uncertainty," Subsection 25.3, "Reactor Accident Boundary Conditions," in summarizing the modeling approach with regard to the safety injection (SI) flow, states that [ ]a,c Specifically, it is stated that "safety injection (SI) flow varies depending on the single failure assumed, and on the specific plant pump and injection line configuration. Current methods, which are also used in currently accepted evaluation models, provide conservative estimates of minimum and maximum flow, which take into account several uncertainties."

Please provide additional information related to the modeling of pumped SI flow in performing LOCA analyses using WCOBRA/TRAC-TF2 as identified below.

(1) Describe the approach to determine the [ ]^{a,c} that are assumed for LOCA analyses on a plant-specific basis. In particular, please identify and describe these "several uncertainties" that are taken into consideration by the "current methods, which are also used in currently accepted evaluation models" in order to provide conservative estimates as stated in Subsection 25.3, "Reactor Accident Boundary Conditions." In addition, please explain how the implemented approach accounts for and models the following factors: (a) uncertainties in safety injection pump characteristics, (b) injection line configuration, and (c) flow resistance and pressure drop along the injection lines.

(2) Please document the parameters identified in Item (1) above and used in the demonstration plant analyses of the FULL SPECTRUM™ LOCA methodology presented in WCAP-16996-P/WCAP-16996-NP, Volumes I, II and III, Revision 0, Section 28, "Scoping And Sensitivity Studies," and in Section 31, "Full Spectrum LOCA Demonstration Analysis." State assumptions and relevant conditions, as implemented in assessing parameters related to the SI pump flow modeling in the performed LOCA analyses. Include graphs of all pump flow characteristics and tables documenting assessments for other relevant parameters, as appropriate.

RAI Question #139: Asymmetrical Predictions in Modeling of Parallel Flow Configurations

Thermal hydraulic system codes, such as RELAP5, have been found to predict asymmetrical results when modeling parallel flow configurations, usually under low-flow conditions. Recognition of such modeling difficulties is presented by G. W. Johnsen, "RELAP5-3D Development & Application Status," Presentation at the 2002 RELAP5 International User's Seminar, September 4-6, 2001, Park City, Utah. In PWR plant analysis, such flow configurations can be related to parallel flow paths representing the cold legs in the same primary coolant loop of a Combustion Engineering (CE) PWR plant, parallel flow channels representing different azimuthal sections of a reactor vessel downcomer, such representing steam generator secondary side volumes or other regions of the reactor system. A possible solution approach in modeling a simple flow problem between parallel pipes is discussed by D. Lucas, "Recirculating Flow Anomaly Problem Solution Method," Proceedings of 8th International Conference on Nuclear Engineering ICONE8, Paper ID 8479, April 2-6, 2000, Baltimore, Maryland.

Please show that WCOBRA/TRAC-TF2 does not predict anomalous behaviors as described above for other codes when using three- and one-dimensional components. As part of the response, present predictions for an illustrative parallel pipe flow problem as implemented in the RELAP5 dual pipe flow input model presented below.

```
=Flow Anomaly Test Problem
*
*-------------------------------------------------------------
*crdno       problem type    problem option
0000100         new          transnt
*-------------------------------------------------------------
*crdno       input units      output units
```

```
0000102          british          british
*------------------------------------------------------------------
*crdno   time 1    time 2
0000105  10.       40.    10000.
*------------------------------------------------------------------
0000110  nitrogen
*------------------------------------------------------------------
*crdno end time  min dt   max dt  control  minor ed  major ed  restart
0000201  5000.  1.0e-6  2.0     3   1      250       500
***************************************************************************
***************************************************************************
* minor edit requests
***************************************************************************
***************************************************************************
*
*crdno      variable      parameter
*
301  count   0
302  dt      0
303  dtcrnt  0
304  cputime  0
305  errmax   0
306  emass    0
307  tmass   0
310  mflowj  145010000
311  mflowj  145020000
312  mflowj  716000000
313  mflowj  711000000
314  mflowj  175010000
315  mflowj  175020000
316  tempf   130010000
317  tempf   160010000
318  cntrlvar 1
319  cntrlvar 2
320  testda  2
321  testda  3
322  testda  4
20800001 testda 2
20800002 testda 3
20800003 testda 4
*
*********************************************************************
*********************************************************************
* hydrodynamic components
*********************************************************************
*********************************************************************
1300000  pmpsuca2       pipe  * loop a2 rc pump suction
1300001  1
1300101  4.2761  1
1300301     25.956   1
1300401     0.0   1
```

```
1300601        -90.  1
1300701    -25.956  1
1300801  .00030       0.   1
1301001   00    1
1301201  3  2200.0  550.0    0.0          0.0      0.0      1
*
1450000  clbrcha2       branch
1450001  2       0
1450101  10.0 5.4064     0.     0. -90.0  -5.4064 .00015     0. 00
1450200  3  2200.0   550.0
1451101  160010000 145000000  4.2761   1.0    1.0   0100
1452101  130010000 145000000  4.2761   1.0    1.0   0100
1451201  0.0      0.0      0.0
1452201  0.0      0.0      0.0
*
1600000  pmpsuca1         pipe
1600001  1
1600101   4.2761  1
1600301     25.956   1
1600401      0.0   1
1600601        -90.  1
1600701    -25.956   1
1600801  .00030       0.    1
1601001   00    1
1601201  3  2200.0   550.0  0.0            0.0      0.0      1
*
1750000  clbrcha1       branch
1750001  2       0
*1750101  10.0 5.4064     0.     0. -90.0  -5.4064 .00015     0. 00
1750101  10.0 5.4064     0.     0. -90.0  -5.4064 .01000     0. 00
1750200  3  2200.0   550.0
1751101  175010000 160000000  4.2761   1.0    1.0   0100
1752101  175010000 130000000  4.2761   1.0    1.0   0100
1751201  0.0      0.0      0.0
1752201  0.0      0.0      0.0
*
*
7100000  lpa1hpit     tmdpvol
7100101  1.0e6    10.0 0.0    0.    -90.0  -10.0   0.    0.    00
7100200    3
7100201     0.      2200.0         90.
*
*
7110000  lpa1hpif   tmdpjun
7110101  710010000  175000000       .0246
7110200   1
7110201   0.0    0.0     0.0      0.0
7110202   10.0   96.0     0.0      0.0
*
*
7150000  lpa2hpit      tmdpvol
```

```
7150101  1.0e6  10.0 0.0   0.  -90.0 -10.0  0.    0.   00
7150200   3
7150201    0.      2200.0        550.
*
*
7160000  lpa2hpif   sngljun
7160101  145010000 715000000    10.0   1.0 1.0 0
7160201 0   0.0    0.0     0.0
*
20500100  dtempf  sum  1.0 0.0 1
20500101  0.0  1.0 tempf  160010000  -1.0  tempf  130010000
*
20500200  dtempf  sum  1.0 0.0 1
20500201  0.0  1.0 tempf  130010000  -1.0  tempf  160010000
*
.   * end of input stream
```