WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, "Realistic Loss-Off-Coolant Accident [LOCA] Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM^{TM} LOCA [FSLOCA] Methodology)"

REQUEST FOR ADDITIONAL INFORMATION (RAI)

SIXTH SET OF RAI QUESTIONS

RAI Questions 78 through 106

ENCLOSURE 1

Proprietary Attachment to the transmittal package of the RAI sets 6, 7, and 8 contains the most current **Table 1**.

Table 2: List of Abbreviations

Abbreviation	Meaning	Note
1D	One Dimensional	
ADAMS	Agencywide Documents Access and Management System	
ASTRUM	Automated Statistical Treatment of Uncertainty Method	
BAF	Bottom of Active Fuel	
BNWL	Battelle Northwest Laboratories	
CCFL	Counter-Current Flow Limitation	
CFD	Computational Fluid Dynamics	
CHF	Critical Heat Flux	
COBRA	Coolant Boiling in Rod Arrays	
COCO	Containment Pressure Analysis Code	
COSI	Condensation on Safety Injection	
CQD	Code Qualification Document	
CSAU	Code Scaling, Applicability, and Uncertainty	
CSE	Containment Systems Experiment	
CT	Churn-Turbulent	
DC	Downcomer	
DEG	Double Ended Guillotine	
EM	Evaluation Model	
ECCS	Emergency Core Cooling System	
EOP	Emergency Operating Procedures	
EPRI	Electric Power Research Institute	
FD	Film/Drop	
FLECHT	Full Length Emergency Cooling Heat Transfer	
FSLOCA	Full Spectrum Loss-of-Coolant Accident	
GE	General Electric	
HL	Hot Leg	
HPTF	High Pressure Test Facility	
HTSTR	Heat Structure	
IAEA	International Atomic Energy Agency	
ID	Inner Diameter	
ISP	International Standard Problem	
JAERI	Japan Atomic Energy Research Institute	
LB	Large Bubble	
IBLOCA	Intermediate Break Loss-of-Coolant Accident	
IET	Integral Effects Test	
LBLOCA	Large Break Loss-of-Coolant Accident	
LHGR	Linear Heat Generation Rate	
LOCA	Loss-of-Coolant Accident	
LSTF	Large Scale Test Facility	

Table 2: List of Abbreviations (Continued)

Abbreviation	Meaning	Note
MLO	Maximum Local Oxidation	
NRC	U. S. Nuclear Regulatory Commission	
OD	Outer Diameter	
ORNL	Oak Ridge National Laboratory	
PCT	Peak Cladding Temperature	
PDF	Probability Density Function	
PIRT	Phenomena Identification and Ranking Table	
PKL	Primärkreislauf (German for Primary Coolant Circuit)	
PWR	Pressurized Water Reactor	
PIRT	Phenomena Identification and Ranking Table	
RBHT	Rod Bundle Heat Transfer Test	
RCP	Reactor Coolant Pump	
RCS	Reactor Coolant System	
RELAP	Reactor Excursion Leak Analysis Program	
RG	Regulatory Guide	
ROSA	Rig-of-Safety Assessment	
RPV	Reactor Pressure Vessel	
SB	Small Bubble	
SBLOCA	Small Break Loss-of-Coolant Accident	
SEASET	Separate Effects and System Effects Test	
SG	Steam Generator	
SI	Safety Injection	
SLB	Small-to-Large Bubble	
TAF	Top of Active Fuel	
TC	Thermocouple	
TEE	T-Junction	
TF	Three-Field	
TF	Two-Fluid	
TF2	Three-Field and Two-Fluid	
THTF	Thermal Hydraulic Test Facility	
TPTF	Two-Phase Flow Test Facility	
TR	Topical Report	
TRAC	Transient Reactor Analysis Code	
TRAC-M	Transient Reactor Analysis Code - Modernized	

Question #78: 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 LSTF as part of the ROSA 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. The LSTF had an overall volumetric scaling ratio of 1/48 and featured two equal-volume primary loops. The hot and cold legs had an 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/√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 RCP and the 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 ºF (190 K). PCT of approximately 872 ºF (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 TR WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, 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 **[** **]** 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 #79: 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 percent 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 Accession and Management System (ADAMS) 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 about 72 ºF (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 percent 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 #80: 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 percent 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/WCAP-16996-NP, Volumes I, II, and III, 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/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 presentation and documentation of results and findings from specific assessment studies. Include results and summarize outcomes from such modifications and revisions of the TR WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 0, as appropriate.

Question #81: LSTF Test SB-CL-14 Data Qualification

WCAP-16996-P/WCAP-16996-NP, Volumes I, I,I 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 Accession 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 percent 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 assess 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 #82: 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 NRC 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 #83: 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 ID 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 #84: 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 **[**

] 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 **[**

] 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 **[**
]

(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 **[** **]** 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/WCAP-16996-NP, Volumes I, II, and III, 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 **[**
] 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 one-dimensional 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 one-dimensional 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 #85: 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 $0 \le W_{st} \le 1$. 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 $0 \le W_{st} \le 1$ and provide the corresponding expressions in such a case.

(2) Besides the interpolation of the interfacial flow area, performed when $0 \le W_{st} \le 1$, 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 one-dimensional 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 #86: 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 **[ ]** 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 **[ ]** 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 one-dimensional 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 one-dimensional 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 one-dimensional 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 modeled flow piping inclination 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 #87: 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, provides 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, shows that specific values of STRTX linked to the common interface between the two adjacent cells used to model each of the 90º 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.

(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 #88: 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. 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, and (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 #89: Large Scale Test Facility 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 one-dimensional 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 one-dimensional nodalization of the loop seal region in the pressurizer loop modeled by Component No. 13 with **[ ]** 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 SDS3l6L-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/WCAP-16996-NP, Volumes I, II, and III, 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 #90: Modeling of LSTF Loop Seal Horizontal Section and Bend Regions

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

] 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 **[ ]** 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 90º bends connecting the cross-over leg horizontal section to the downhill and uphill sides of the loop seal are modeled by **[ ]** 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 90º bend.

Question #91: 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 one-dimensional nodalization of the loop seal region in the LSTF pressurizer loop. The overall one-dimensional 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 were accounted for of the differential pressure tap locations, including the one in the horizontal section of the loop seal cross-over leg.

(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 #92: 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 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, 23, and 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, 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 #93: 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 **[ ]** 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 **[**

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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 **[ ]** 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 ID 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 SBLOCAs and LBLOCAs.

Question #94: 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 **[ ]** and minimum **[ ]** 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 #95: 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: **[ ]** 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 **[ ]**

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

[ ]

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 **[ ]** 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 **[ ]**

As seen from the results provided in Table 1 and the curves presented in Figure 1 above, the interpolation range $0 \leq W_{st} \leq 1$ 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 **[ ]** when HS_SLUG varies between **[ ]** with C_{stfru} being set at its default value of **[ ]**

Please explain the significant disparity between the proposed HS_SLUG sampling range from **[ ]** and the relative velocity ratio range from **[ ]** that corresponds to W_{st} values being $0 \leq W_{st} \leq 1$ when C_{stfru} is set equal to its proposed default value of **[ ]** When $0 \leq W_{st} \leq 1$, 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 **[**

]

Question #96: 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 $0 \leq W_{st} \leq 1$ 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 **[ ]** The allowable input range of C_{stfru} is from **[ ]** 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 **[ ]** and the lower and upper limiting values for the range of allowable input values for C_{stfru}, **[ ]** For the curves shown in Figure 1, the second adjustable constant, C_{hs_slug}, was set equal to its default value of 1.0.

[

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Please explain the rationale for selecting **[**2.0**]** as the default value for the C_{stfru} parameter. In addition, explain the reasons for defining a range from **[ ]** 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 #97: 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 FSLOCA methodology in this regard.

Question #98: 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 **[ ]** 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 **[ ]** of the desired value, established for each plant.”

(1) Please explain how “the bypass flow through the spray nozzle is adjusted to be within **[ ]** 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 if 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 **[ ]** Clarify how this statement relates to the criterion that the “calculated value” of the “Upper Head Nozzle Flow/Vessel Flow” parameter is within **[ ]** 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 #99: 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 **[ ]** 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 **[ ]** 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 #100: 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, Section 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 described 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 **[ ]** 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 #101: 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 ID, 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 #102: 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 **[ ]** 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 **[ ]** 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 "percent 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 "percent 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 #103: 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 #104: 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 March 27, 1986 and November 9, 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/WCAP-16996-NP, Volumes I, II, and III, 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 "percent 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 #105: 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. 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) × (2 loops)] / (48.7 kg/s) = 0.0020 = 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 #106: 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: **[**

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Discussing WCOBRA/TRAC-TF2 calculation results for ROSA-IV LSTF Test ST-NC-02, WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, 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: **[**

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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.