Summary of July 2013 NRC Code Workshop and August 2013 NRC Audit of the FULL SPECTRUM LOCA (FSLOCA) Evaluation Model (Non-Proprietary)

October 2013

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

1.0 Introduction

In July 2013, a workshop was held between Westinghouse and the Nuclear Regulatory Commission (NRC) to allow the NRC to specify WCOBRA/TRAC-TF2 cases to be executed as well as to examine the results of existing code cases. In August 2013, the NRC performed an audit of the FULL SPECTRUM™ LOCA (FSLOCA™) evaluation model (EM) submittal.

During the workshop, the NRC reviewed the results of many different level swell calculations. The results from Oak Ridge National Lab (ORNL) level swell and core uncovery test simulations were plotted, and additional noding and timestep studies were executed. These investigations revealed some anomalous behavior at gridded elevations in the G2 level swell test simulations, and also identified an apparent large sensitivity of ORNL Test CC to the [ ]^{a,c}. These items were investigated by Westinghouse and discussed during an NRC audit in August 2013. The NRC also noted the lack of sensitivity for FLECHT SEASET test 31504 to YDRAG, suspicious void fraction dipping in the ORNL simulations, and that the WCOBRA/TRAC-TF2 prediction of the two-phase level for the G2 simulations degraded with additional core noding. The FLECHT YDRAG sensitivity is discussed later in this summary, and the other two items are still under investigation.

A series of Beaver Valley parametric studies were executed. The results of these studies were presented to the NRC in the August 2013 audit, and additional discussion regarding the studies is included later in this summary.

The NRC discussed concerns with the decay heat sampling, and with the use of the Forslund-Rohsenow model for direct wall-to-droplet heat transfer in the hot wall regime. The decay heat sampling is still under consideration, but Westinghouse has agreed to remove the direct wall-to-droplet heat transfer for the hot wall regime.

The NRC also requested various large runsets with the Beaver Valley Pressurized Water Reactor (PWR) model and the ROSA SB-CL-02 model. The results of these studies were presented to the NRC in the August 2013 audit, and additional discussion regarding these studies is included later in this summary.

Finally, the NRC identified several other considerations which are discussed later in this audit summary.

Additional information to support the licensing of the FSLOCA EM is provided in this attachment. The presentations from the August 2013 NRC audit are included in following attachments.

2.0 Beaver Valley Parametric Studies

A parametric study was executed on run076 from Study C from the response to FSLOCA EM RAIs #9 and #12 (LTR-NRC-13-45 [2-1]).

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Lastly, the complete study is redone with a 25% reduction in safety injection flow. This is performed to study the impact of the parametric study under more severe accident conditions.

2.1 Nominal Safety Injection Cases

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2.2 Reduced Safety Injection Cases

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2.3 Nominal Safety Injection Case with Increase in Decay Heat versus the Reduced Safety Injection Base Case

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2.4 References

2-1) LTR-NRC-13-45, "Submittal of Westinghouse Responses to 'WCAP-16996-P, 'Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)' Request for Additional Information – RAIs 9 and 12' (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244," June 26, 2013.

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3.0 Beaver Valley Steady-State Runset

The purpose of the study is to show that there is no large variation in the parameters of interest used for demonstrating a converged steady-state. Section 26.4 of WCAP-16996-P [3-1] discusses the steady-state calculation/calibration process. The distributions of the parameters in Table 26.4-1 of WCAP-16996-P are of interest for this study. The parameters are repeated here in Table 3-1.

Table 3-1: Parameters Checked for Steady-State Convergence

Parameter		Parameter
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In addition, the distributions of the parameters used as part of the automated steady-state process are of interest. These parameters are provided in Table 3-2.

Table 3-2: Parameters Used by Automated Process to Obtain Converged Steady-State

Parameter		Parameter
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Lastly, the parameters in Table 3-3 are also of interest, because of their influence on select parameters used to determine if a steady-state has converged.

Table 3-3: Additional Parameters of Interest for Steady-State Convergence		
Parameter		Parameter
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To present the results, data tables and figures are generated. The values for the parameters of interest from the 93 runs were averaged, and the standard deviation was calculated. Table 3-4 includes the values from the nominal case, as well as the values from the 93 runs.

Table 3-5 contains the sampled attribute sets; these are the target values for each of the 93 cases.

Table 3-6 is a summary of the calculated versus target values from the last iteration step output from the automated steady-state process (several parameters in Table 3-1). In addition, the table contains the values for the parameters that are used to obtain the desired steady-state tuned parameters at their target values (parameters in Table 3-2).

Table 3-7 is a listing of the parameters in Table 3-4 at the last time step in each of the 93 steady-state runs.

In addition to extracting the data from the 93 run set, the data was extracted from the Nominal case as well. The data tables (note that there is only one run in these tables) are included as Tables 3-8, 3-9, and 3-10.

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3.1 References

3-1) WCAP-16996-P, Volumes I, II and III, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)," November 2010.

Table 3-4: List of Values Extracted at the End of the Nominal Case Steady-State Run and the Average of the 93 Cases			
Parameter	Nominal Case Value[1]	93 Run Set	
		Average[1]	Standard Deviation[1]

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Table 3-4: List of Values Extracted at the End of the Nominal Case Steady-State Run and the Average of the 93 Cases			
Parameter	Nominal Case Value[1]	93 Run Set	
		Average[1]	Standard Deviation[1]

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[1] Values are presented for loop 1, loop 2 and loop 3 where appropriate.

Table 3-5: Sampled Attribute Sets for the Beaver Valley Steady-State Runset

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Table 3-5: Sampled Attribute Sets for the Beaver Valley Steady-State Runset

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Table 3-5: Sampled Attribute Sets for the Beaver Valley Steady-State Runset

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Table 3-5: Sampled Attribute Sets for the Beaver Valley Steady-State Runset

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Table 3-5: Sampled Attribute Sets for the Beaver Valley Steady-State Runset

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Table 3-6: Calculated and Calibrated Parameter Values for the Beaver Valley Steady-State Runset

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Table 3-6: Calculated and Calibrated Parameter Values for the Beaver Valley Steady-State Runset

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Table 3-6: Calculated and Calibrated Parameter Values for the Beaver Valley Steady-State Runset

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Table 3-7: Table 3-4 Parameters from Last Timestep of Steady-State Calculation for the Beaver Valley Steady-State Runset

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Table 3-7: Table 3-4 Parameters from Last Timestep of Steady-State Calculation for the Beaver Valley Steady-State Runset

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Table 3-7: Table 3-4 Parameters from Last Timestep of Steady-State Calculation for the Beaver Valley Steady-State Runset

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Table 3-7: Table 3-4 Parameters from Last Timestep of Steady-State Calculation for the Beaver Valley Steady-State Runset

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Table 3-7: Table 3-4 Parameters from Last Timestep of Steady-State Calculation for the Beaver Valley Steady-State Runset

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Table 3-7: Table 3-4 Parameters from Last Timestep of Steady-State Calculation for the Beaver Valley Steady-State Runset

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Table 3-7: Table 3-4 Parameters from Last Timestep of Steady-State Calculation for the Beaver Valley Steady-State Runset

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Table 3-7: Table 3-4 Parameters from Last Timestep of Steady-State Calculation for the Beaver Valley Steady-State Runset

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Table 3-8: Attribute Set for the Beaver Valley Steady-State Nominal Case

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Table 3-9: Calculated and Calibrated Parameter Values for the Beaver Valley Steady-State Nominal Case

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Table 3-10: Table 3-4 Parameters from Last Timestep of Steady-State Calculation for the Beaver Valley Steady-State Nominal Case

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Figure 3-1: Distribution of Hot Leg Temperature (°F)

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Figure 3-2: Distribution of Cold Leg Temperature (°F)

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Figure 3-3: Distribution of Vessel Average Temperature (°F)

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Figure 3-4: Distribution of SG Secondary Side Pressure (psia)

a,c

Figure 3-5: Distribution of Liquid Mass Flowrate in SG Downcomer (lbm/s)

a,c

Figure 3-6: Distribution of Initial Upper Head Enthalpy (BTU/lbm)

a,c

Figure 3-7: Distribution of Initial Pressurizer Liquid Volume (ft^3)

a,c

Figure 3-8: Distribution of Peak Linear Heat Rate (kW/ft)

a,c

Figure 3-9: Distribution of Fuel Rod Gap Thickness (in) for Rod #3

a,c

Figure 3-10: Distribution of Fuel Rod Gap Thickness (in) for Rod #6

a,c

Figure 3-11: Distribution of Fuel Average Temperature at Peak Power Location on Rod #3 (°F)

a,c

Figure 3-12: Distribution of Fuel Average Temperature at Peak Power Location on Rod #6 (°F)

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Figure 3-13: Distribution of Pressurizer Pressure (psia)

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Figure 3-14: Distribution of Core Power (MWt)

4.0 ROSA SB-CL-02 Transient Runset

The FSLOCA uncertainty methodology was applied against Cylindrical Core Test Facility (CCTF) Run 62, which is a prototypical Large Break LOCA (LBLOCA) Integral Effects Test (IET), to demonstrate the code calculations against known, experimental data. It is desirable to do the same for a prototypical Small Break LOCA (SBLOCA) IET. Rig-of-Safety Assessment (ROSA) Large Scale Test Facility (LSTF) test SB-CL-02 was selected since it produces a more significant heatup than many other of the ROSA tests.

Two sets of 311 simulations was executed varying all the experimental uncertainties which could be ranged within a transient runset, as well as all the applicable model uncertainties. These runsets are discussed in Sections 4.1 and 4.2.

4.1 Transient Runset with Full Uncertainty Sampling

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4.2 Transient Runset without Break Discharge Coefficient Sampling

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Figure 4-1: Cladding Temperature at the Maximum Measured Cladding Temperature Elevation for the 311 Case ROSA SB-CL-02 Runset

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Figure 4-2: Predicted Minus Measured Cladding Temperature at the Maximum Measured Cladding Temperature Elevation for the 311 Case ROSA SB-CL-02 Runset

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Figure 4-3: Vapor Temperature at the Maximum Measured Cladding Temperature Elevation for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset

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Figure 4-4: Pressurizer Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset

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Figure 4-5: Core Differential Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset

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Figure 4-6: Downcomer Differential Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset

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Figure 4-7: Loop Seal A Pump-Side Differential Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset

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Figure 4-8: Loop Seal B Pump-Side Differential Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset

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Figure 4-9: Cladding Temperature at the Maximum Measured Cladding Temperature Elevation for the 311 Case ROSA SB-CL-02 Runset without CD Sampling

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Figure 4-10: Predicted Minus Measured Cladding Temperature at the Maximum Measured Cladding Temperature Elevation for the 311 Case ROSA SB-CL-02 Runset without CD Sampling

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Figure 4-11: Vapor Temperature at the Maximum Measured Cladding Temperature Elevation for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset without CD Sampling

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Figure 4-12: Core Exit Temperatures for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset without CD Sampling

a,c

Figure 4-13: Vapor Heat Transfer Coefficient at the Maximum Measured Cladding Temperature Elevation for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset without CD Sampling

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Figure 4-14: Pressurizer Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset without CD Sampling

a,c

Figure 4-15: Core Differential Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset without CD Sampling

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Figure 4-16: Downcomer Differential Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset without CD Sampling

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Figure 4-17: Loop Seal A Pump-Side Differential Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset without CD Sampling

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Figure 4-18: Loop Seal B Pump-Side Differential Pressure for the First 100 Cases of the 311 Case ROSA SB-CL-02 Runset without CD Sampling

5.0 Updated Region I Break Sampling Approach

5.1 Background

LTR-NRC-13-45 [5-1] provided the response to RAIs 9 and 12 on the FULL SPECTRUM LOCA methodology topical report [5-2]. During the August 2013 NRC Audit on the FSLOCA methodology, a draft revision to the Region I break area sampling method was presented. The following subsections present the finalized revision to the Region I break area sampling method, which is modified from the approach presented in August 2013.

5.2 Revised Region I Break Area Sampling Method

Section 29.2 of WCAP-16996-P discusses the break area uncertainty treatment for Region I, whereby the break area is sampled [ ]^{a,c} from $A_{I,min}$ to $A_{II,min}$, where $A_{I,min}$ is the smallest break area that the charging pumps can make-up the mass lost out of the break, and $A_{II,min}$ is [ ]^{a,c} As discussed in RAI 9, there exists a small segment (resonance region) between $A_{I,min}$ and $A_{II,min}$ where the core may uncover. The resonance region exists because the transient behavior of a SBLOCA is the result of a race between mass lost out the break and the depressurization of the reactor coolant system (RCS), which results in increased safety injection flow. For the smallest breaks, the mass lost out the break is low, such that the safety injection at the higher pressure (due to the slower depressurization rate) is adequate for keeping the core covered with a two-phase mixture level and mitigating the accident. Likewise, for the larger small breaks, the depressurization rate is fast enough that the increase in safety injection (due to lower pressure) and accumulator actuation are adequate for replenishing the higher mass lost out the break and keeping the core covered with a two-phase mixture level. For the breaks in between (generally 0.0218 ft^2 (2 inch) to 0.1963 ft^2 (6 inch)), the depressurization rate is slow enough that the safety injection flow may not be sufficient to keep the core covered with a two-phase mixture level, and core uncovery is observed. Since these break areas are most likely to become limiting in Region I, attention should be given to this resonance range within the Region I uncertainty analysis. As such, the Region I break area sampling method, as described in WCAP-16996-P, is revised to [

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The revised Region I break area sampling method is divided into two main steps:

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The following provides further details for each step.

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5.3 Example Demonstration of the Revised Region I Break Area Sampling Method

The following provides a sample demonstration of the revised Region I break area sampling method with the Beaver Valley Unit 1 plant model.

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Table 5-2: Results from Step 1 Cases

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Figure 5-1: Peak Cladding Temperature vs. Effective Break Area for Step 1 Cases

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Figure 5-2: Peak Cladding Temperature vs. Effective Break Area for Step 1 and Step 2 Cases

5.4 Conclusions

The revised Region I break area sampling method [

]^{a,c} In addition, the revised approach adequately captures the large change in PCT with a small change in break area that occurs in the resonance region, and has the ability to demonstrate that the acceptance criteria are met with high probability.

5.5 References

5-1) LTR-NRC-13-45, "Submittal of Westinghouse Responses to 'WCAP-16996-P, 'Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)' Request for Additional Information – RAIs 9 and 12' (Proprietary/Non-Proprietary), Project 700, TAC No. ME5244," June 26, 2013.

5-2) WCAP-16996-P, Volumes I, II and III, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)," November 2010.

5-3) WCAP-12945-P-A, Volume 1, Revision 2, and Volumes 2 through 5, Revision 1, "Code Qualification Document for Best Estimate LOCA Analysis," March 1998.

6.0 Impact of YDRAG on FLECHT SEASET Test 31504

6.1 Background

A question was raised by the NRC Staff during the July 2013 code workshop regarding why the FLECHT-SEASET 31504 case was insensitive to changes in the interfacial drag multiplier (YDRAG). The study's results were examined, and an explanation to the Staff's question is provided below.

6.2 Investigation

Per Section 29.1.5 of WCAP-16996-P [6-1], YDRAG is applied to the [ ]^{a,c}, and is ramped out as the flow transitions to [ ]^{a,c}. As such, YDRAG is not applied when a cell is determined to be in [ ]^{a,c} flow regime.

During reflood (which is at a low system pressure), a cell is determined to be in the hot wall flow regime if any heat transfer node wall temperature in that cell is [ ]^{a,c} above the saturation temperature (Equation 4-1 in WCAP-16996-P). In the FLECHT-SEASET 31504 simulations, the temperature used to determine if a cell is in the hot wall flow regime is [ ]^{a,c} (per Table 14.1-6 of WCAP-16996-P, FLECHT-SEASET 31504 was conducted at a pressure of 40 psia). Since this temperature is lower than the typical quench temperature ([ ]^{a,c}, Figures 29.1.8-8 to 29.1.8-10 of WCAP-16996-P), a cell is not likely to be in a cold wall flow regime until all the heat transfer nodes in that cell have quenched. This means that the quench front has passed through the cell prior to YDRAG being applied.

This is demonstrated by looking at the void fraction of a cell near the middle of the bundle along with the cladding temperatures near the bottom and top of that cell. Figure 6-1 provides the noding diagram for the FLECHT-SEASET 31504 cases, and Figure 6-2 shows the void fraction for Cell 7 of Channel 2 (inner bundle channel) as well as the cladding temperatures for the heat transfer nodes near the bottom and top of that cell. As seen from the figure, there is [

]^{a,c}

Figure 24.6.4-7 of WCAP-16996-P compares the void fraction profile of the FLECHT-SEASET 31504 base simulation to test data when the quench front is at 60 inches (5 feet). As seen in Figure 6-2, this also occurs near [ ]^{a,c} in all three YDRAG simulations. A comparison of the void fraction profile at [ ]^{a,c} for the three YDRAG simulations is presented in Figure 6-3, which shows [

]^{a,c}

Figure 6-4 compares the flow regime through the bundle at [ ]^{a,c}, and shows that [

]^{a,c}

It is noted that while the void distribution is affected by YDRAG, the [

]a,c As shown in Figure 6-2, the void fraction in the cell [

]a,c

Figure 6-5 provides a comparison of the entrained liquid generation rate for cells 6, 7 and 8 of Channel 2. As seen in Figure 6-5, [

]a,c Based on Figures 6-3 and 6-5, it is concluded that [

]a,c

6.3 Conclusion

YDRAG is applied to cells which are in [

]a,c

6.4 References

6-1) WCAP-16996-P, Volumes I, II and III, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)," November 2010.

a,c

Figure 6-1: FLECHT-SEASET 31504 Noding Diagram

a,c

Figure 6-2: Void Fraction and Cladding Temperature for Cell 7 of Channel 2

a,c

Figure 6-3: Void Fraction Profile for Channel 2 at [ ]a,c

a,c

Figure 6-4: Flow Regime Profile for Channel 2 at [ ]a,c

a,c

Figure 6-5: Entrained Liquid Generation Rate for Cells 6, 7 and 8 of Channel 2

a,c

Figure 6-6: Total Vessel Mass and PCT

a,c

Figure 6-7: Carryover Fraction (Equation 19.5-6 of WCAP-16996-P)

7.0 Crossover Leg Re-Plugging Under LBLOCA Conditions

During the August 2013 NRC audit of the FSLOCA EM, a concern was expressed that the loop seal region could re-plug in the short term under LBLOCA conditions, especially if the break was located at the top of the cold leg piping.

A large split break spectrum was executed for Beaver Valley (presented in Section 27.1.2.1 of WCAP-16996-P [7-1]) with the break oriented at the bottom of the cold leg. This study was then rerun with the break oriented on the top of the pipe.

The resulting split break spectrum studies consider break areas ranging from 1.0 ft^2 to twice the flow area of the cold leg, with upward and downward oriented breaks. The void fraction at the bottom of the loop seal for all of the base and sensitivity cases was inspected. The figures from the top-oriented break studies with a break area of twice the cold leg area (Figures 7-1 through 7-3) and with a break area of 1.0 ft^2 (Figures 7-4 through 7-6) are included in this summary.

[

]a,c

7.1 References

7-1) WCAP-16996-P, Volumes I, II and III, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)," November 2010.

a,c

Figure 7-1: Void Fraction in the Loop 1 Loop Seal Region for an Upward Oriented Break with a Break Area of Twice the Cold Leg Area

a,c

Figure 7-2: Void Fraction in the Loop 2 Loop Seal Region for an Upward Oriented Break with a Break Area of Twice the Cold Leg Area

[ ] a,c

Figure 7-3: Void Fraction in the Loop 3 Loop Seal Region for an Upward Oriented Break with a Break Area of Twice the Cold Leg Area

a,c

Figure 7-4: Void Fraction in the Loop 1 Loop Seal Region for an Upward Oriented Break with a Break Area of 1 Square Foot

a,c

Figure 7-5: Void Fraction in the Loop 2 Loop Seal Region for an Upward Oriented Break with a Break Area of 1 Square Foot

[ ] a,c

Figure 7-6: Void Fraction in the Loop 3 Loop Seal Region for an Upward Oriented Break with a Break Area of 1 Square Foot

8.0 Downcomer Steam-Water Interaction under Intermediate Break LOCA (IBLOCA) and SBLOCA Conditions

The calculation of liquid entrainment and sweepout in the downcomer is important in the simulation of LOCA transients since the downcomer provides the driving head to reflood the core. If the amount of entrainment or liquid sweepout is under-predicted, it could result in increased downcomer inventory, which could lead to an artificially increased liquid level in the core.

Upper Plenum Test Facility (UPTF) Test 25A was designed to study steam-water interaction in the downcomer under LBLOCA reflood conditions. The test was run in four phases, and the test conditions for each phase are presented in Table 19.3-17 of WCAP-16996-P [1]. The test conditions were compared to the conditions for the Beaver Valley Unit 1 SBLOCA and IBLOCA break spectrum cases (Section 27.1.2 of WCAP-16996-P), which covers from 2-inch to 16-inch break diameters. This comparison is presented in Table 8-1.

[

]a,c

The simulation of UPTF Test 25A with WCOBRA/TRAC-TF2 is discussed in Section 19.3.11 of WCAP-16996-P. [

]a,c

Some additional information regarding the steam-water interaction in the downcomer under SBLOCA conditions can be extracted from IET facility simulations. For IET facilities, it is recognized that there are a number of phenomena interacting to produce the test data and the simulated result. However, the simulation results can be inspected for indications of an under-prediction of entrainment in the downcomer.

ROSA Test SB-CL-05 is an integral effects test with high head safety injection and a 5% cold leg break. The downcomer differential pressure for the simulation of this experiment is presented as Figure 21.5-15 in WCAP-16996-P. [

]a,c

ROSA Test SB-CL-14 is an integral effects test without high head safety injection and a 10% cold leg break (no 10% cold leg break test with HHSI was simulated). The downcomer differential pressure cannot be obtained from the available experimental data for this simulation;

however, a comparison of core liquid levels is presented as Figure 21.6-14 in WCAP-16996-P. The concern with excess liquid in the downcomer is that it would provide additional driving head to push liquid into the core. [

]^{a,c}

8.1 References

8-1) WCAP-16996-P, Volumes I, II and III, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)," November 2010.

8-2) Yoon, S. H., et. al., "An Experimental Study of Sweepout and Entrainment in the Advanced Reactor Downcomer," *Proceedings of International Congress on Advanced Nuclear Power Plants (ICAPP)*, Embedded Topical Meeting, June 9-13, 2002.

8-3) Yoon, S. H. and Suh, K. Y., "Investigation of Sweepout Mechanism and Critical Void Height in Annular Downcomer," *Journal of Nuclear Science and Technology*, Vol. 40, No. 10, pp. 834-844, October 2003.

Table 8-1: Comparison of Steam Mass Flow Rates, Steam Kinetic Energy, and Kutateladze Numbers between a PWR and UPTF Test 25A

Facility	Intact Loop Steam Flow Rate (lbm/s)	Intact Loop Steam Kinetic Energy (lbm/ft-s^2)	Kutateladze Number (-)	Broken Loop Steam Flow Rate (lbm/s)
[				
				]^{a,c}

Presentations from the August NRC Audit

FULL SPECTRUM LOCA (FSLOCA) Plant Scoping Studies

Aaron Everhard
Westinghouse Electric Company
August 2013

Westinghouse

Background

- Plant studies were performed to demonstrate code capability
  - List includes studies presented in topical report and response to RAIs

Offsite Power Availability	Break Orientation (SB)
Power Shape	Loop Seal Clearing as function of break size (SB)
Time Step Size	Core Interfacial Drag (YDRAG) (SB)
SG Tube Plugging	Stratification Criterion (HS_SLUG) (SB)
Break Spectrum	Decay Heat (SB)
Accumulator Line Break	Lower SI Flow (SB)
Accumulator Elevation	SG Interfacial Drag (SB)
Break Path Resistance (LB)	Safety Injection Condensation (KCOSI) (SB)
Numerical Perturbations (SB)	SB Limiting Break Size

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Studies with V. C. Summer

- [ ][a,c] documents the model development

Document	Study Performed
[ ][a,c]	Break Spectrum (LB, IB, SB)
[ ][a,c]	Power Shape Offsite Power Availability Time Step Size Accumulator Elevation SG Tube Plugging Break Path Resistance (LB) Lower SI Flow (SB) Break Orientation (SB) Stratification Criterion (HS_SLUG) (SB) Safety Injection Condensation (KCOSI) (SB) Core Interfacial Drag (YDRAG) (SB) Loop Seal Clearing with Break Size (SB) SG Interfacial Drag (SB)
[ ][a,c]	Demonstration Analysis

Studies with Beaver Valley Unit 1 (1/2)

- [ ]a,c documents the model development

Document	Study Performed
[ ]a,c	Break Spectrum (LB, IB, SB)
[ ]a,c	Power Shape Offsite Power Availability Time Step Size Accumulator Line Break Break Path Resistance (LB) Break Orientation (SB) Stratification Criterion (SB) Safety Injection Condensation (SB) Core Interfacial Drag (SB) Loop Seal Clearing with Break Size (SB) SG Interfacial Drag (SB)

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Studies with Beaver Valley Unit 1 (2/2)

Document	Study Performed
[ ]a,c	Numerical Perturbations on stratification criterion and wall drag (SB)
[ ]a,c	SB limiting break size
[ ]a,c	Parametric study on select parameters (SB) Conservative case (SB)
[ ]a,c	Steady-State

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Questions

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Full Spectrum LOCA (FSLOCA) Development and Validation of High Importance Phenomena

Jeffrey Kobelak
Westinghouse Electric Company
August 2013

Westinghouse

Background

- Models were added and/or validation was completed for WCOBRA/TRAC-TF2 to capture several new key phenomena relative to SBLOCA Analysis
  - Mixture Level Swell
  - Loop Seal Clearing
  - Horizontal Stratification
  - Cold Leg Condensation

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Mixture Level Swell

- Prediction of two-phase mixture level in the core is significant for the analysis of the SBLOCA transient
- [ ]^{a,c} as described in the response to RAI #17 (LTR-NRC-13-37)
- Code validated against Oak Ridge National Lab (ORNL), G1, G2, Two-Phase Test Facility (TPTF), and Semiscale facilities

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Mixture Level Swell

- Facility Models
  - G1 Facility: [ ]a,c
  - G2 Facility: [ ]a,c
  - ORNL Facility: [ ]a,c
  - TPTF Facility: [ ]a,c

- Level Swell Test Simulations and Results
  - All Facilities except Semiscale: [ ]a,c
  - Semiscale SET: [ ]a,c

- Sensitivity Study
  - ORNL/PWR Axial Noding: [ ]a,c
  - ORNL Timestep Size: [ ]a,c

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Loop Seal Clearing

- Timing of loop seal clearing, the number of loop seals that clear, and the residual liquid in the loops that clear impact the core uncovery progression for a SBLOCA transient
- [ ][a,c]
- Code validated against Upper Plenum Test Facility (UPTF) loop seal experiments

Loop Seal Clearing

- [ ]a,c

- Facility Model and Test Simulations
  - UPTF: [ ]a,c

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Cold Leg Condensation

- Amount of condensation in the cold leg can influence de-pressurization and core uncovery behavior for SBLOCA transients
- Cold leg condensation model added to WCOBRA/TRAC-TF2
- Code validated against COSI and UPTF cold leg condensation experiments
- Details provided in later presentation

Horizontal Stratification

- Model Development
  - Horizontal Stratification Model: [ ]a,c
- Implementation of Model into Code
  - Horizontal Stratification Model: [ ]a,c
- Facility Model and Test Simulations
  - TPTF: [ ]a,c

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Conclusions

- Models for High Importance Phenomena have been included in the WCOBRA/TRAC-TF2 code
- Validation of code predictions against experimental data performed for the High Importance Phenomena
  - Confirmed code model performance is acceptable
  - Investigating a few remaining items as part of RAI responses

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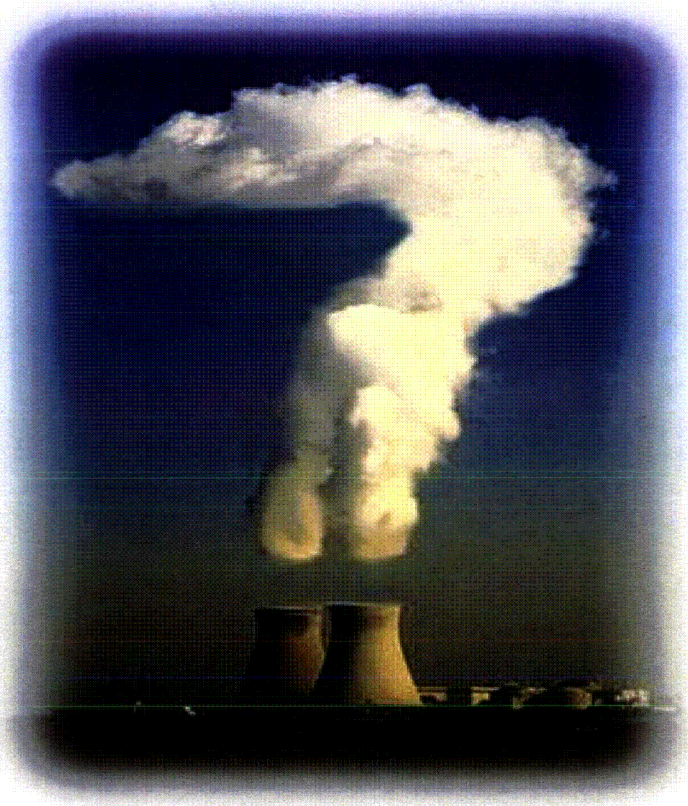
Questions



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Full Spectrum LOCA (FSLOCA) Modeling Guidance

Jeffrey Kobelak
Westinghouse Electric Company
August 2013

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Background

- Noding Philosophy
- Model Development
  - Vessel Model
  - Loop Model
  - Containment Model

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Noding Philosophy

- [

  ]a,c

- Overall noding scheme was confirmed to be acceptable and consistent

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Production WCOBRA/TRAC Noding

- Evaluation Model Topicals: WCAP-12945-P-A, WCAP-16009-P-A
- Safeguards Engineering Standards

Vessel	Loop
[	
]a,c	

FSLOCA Noding / Model Development

- During the development of FSLOCA, [ ]a,c
- The TF2 User's Manual, [ ]a,c was also maintained
- Test Facility and PWR Noding is described in the Evaluation Model Topical: WCAP-16996-P
- [ ]a,c describes the conversion of a production code PWR model to a model for FSLOCA

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FSLOCA PWR Models

- Beaver Valley
  - [ ]a,c Production Code Vessel Model
  - [ ]a,c Production Code Loop Model
  - [ ]a,c Model Updates for FSLOCA
- V. C. Summer
  - [ ]a,c Production Code Vessel and Loop Model
  - [ ]a,c Modifications for Upflow Conversion
  - [ ]a,c Model Updates for FSLOCA

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Containment Model

- COCO Separate from WCOBRA/TRAC for Production Analyses
  - [ ]a,c COCO_A User's Manual
  - [ ]a,c COCO Input for BASH
  - [ ]a,c Updates to COCO Input for BELOCA

- COCO was incorporated into WCOBRA/TRAC-TF2 for FSLOCA
  - Input Differences Described in the TF2 User's Manual [ ]a,c

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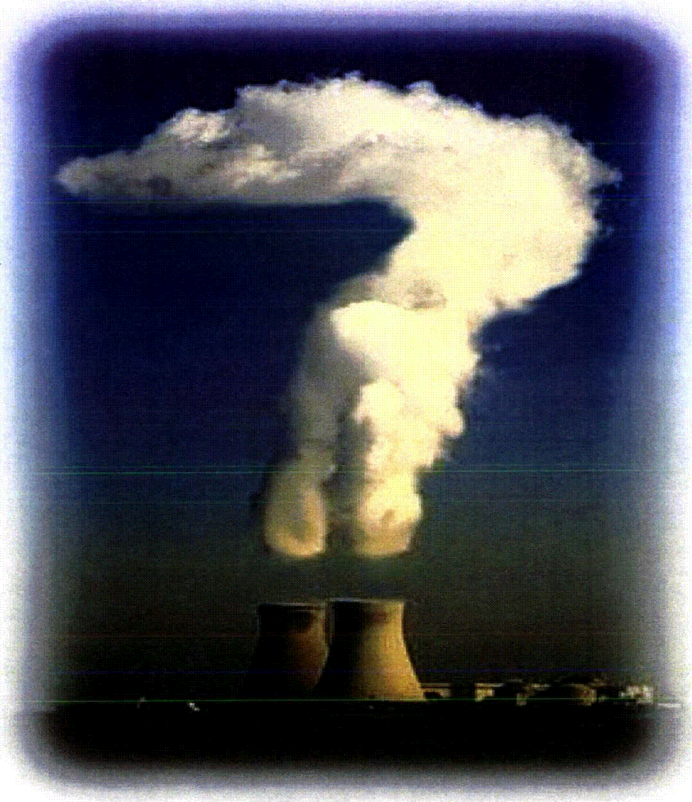
Questions



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FULL SPECTRUM LOCA (FSLOCA)
Region I Break Sampling

Aaron Everhard
Westinghouse Electric Company
August 2013

Westinghouse

Outline

- Background
- Previous Region I Break Area Sampling Method
- Revised Region I Break Area Sampling Method

Background (1/2)

- Historically, break size is a legitimate variable during a LOCA event

- Sampling methodology is selected to adequately bound realistic break frequencies
  - A 'realistic' break area sampling would give much more probability weight to smaller break sizes, and this reality is not credited in defining the event

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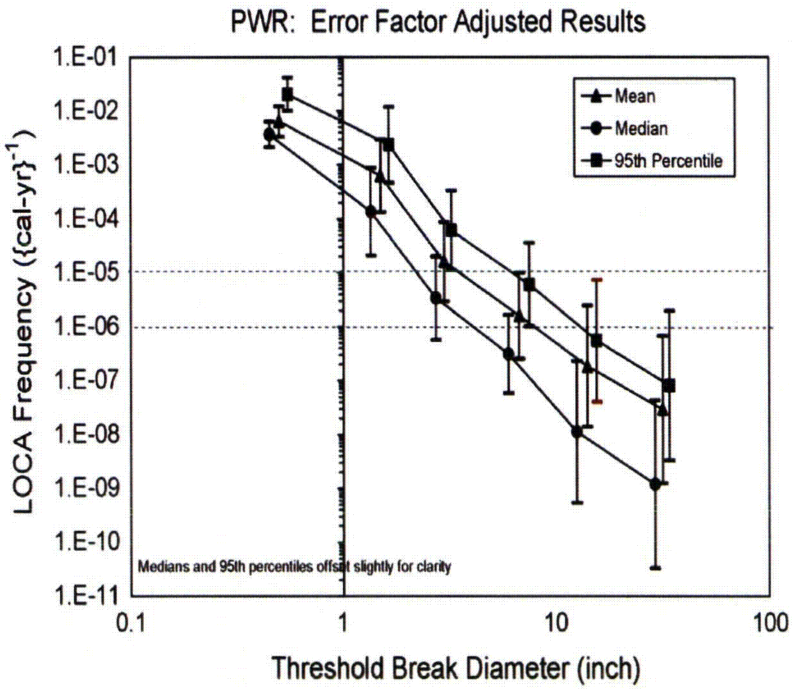
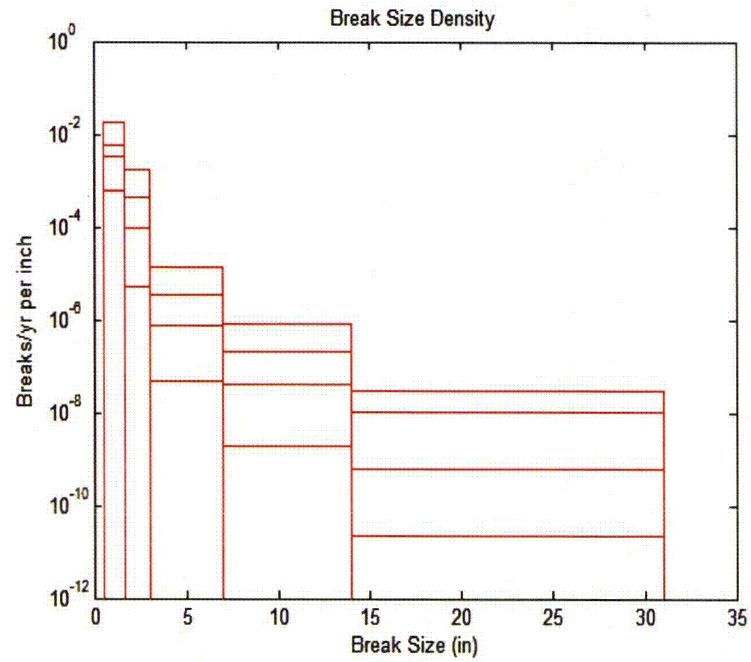
Background (2/2)



(Figure 7.37 of NUREG-1829 V1)



(from Los Alamos National Lab presentation, May 9, 2012 ACRS transcripts)

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Previous Region I Break Area Sampling Method

- Minimum break area defined as the break area where safety injection is adequate to make up loss of mass out the break
  - A_{MIN} , see Section 31.1.1 of WCAP-16996-P for an example

- [

]a,c

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Revised Region I Break Area Sampling Method

- [

]a,c

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[

]a,c

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[

]a,c

[

]a,c

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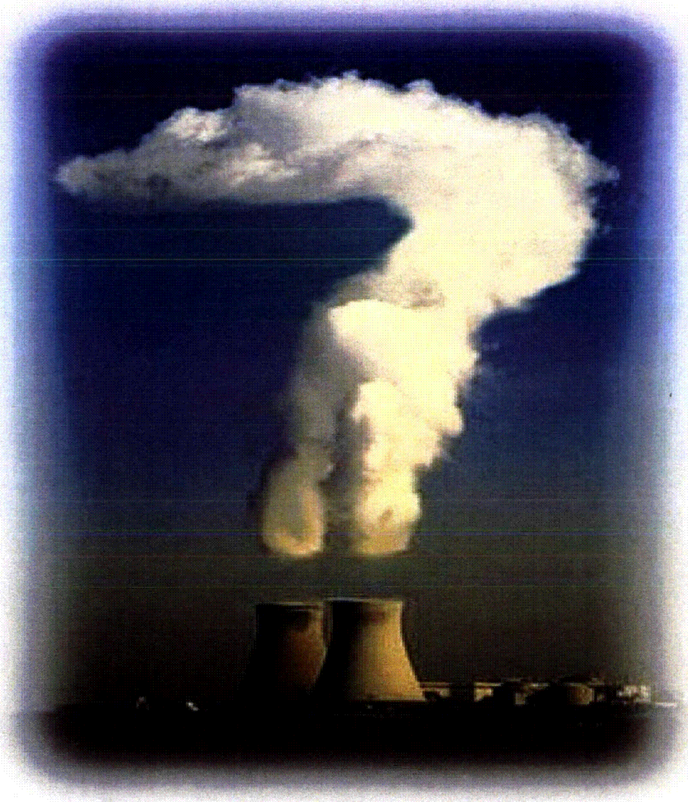
Conclusions

- [

]a,c

- Revised method considered adequate for demonstrating that the acceptance criteria are met with a high probability

Questions



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Roadmap of ROSA Large Scale Test Facility Test Simulations for the Westinghouse Full Spectrum LOCA (FSLOCA) Methodology

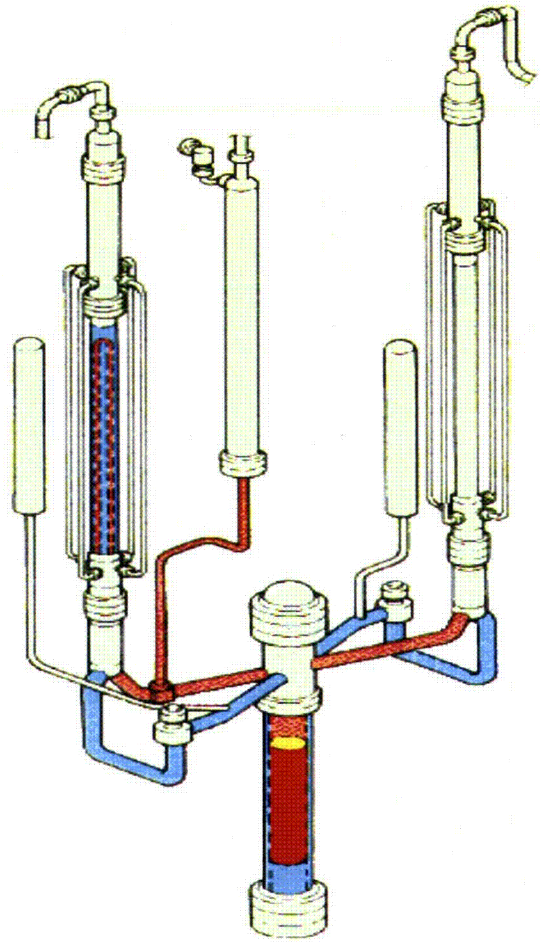
Nikolay Petkov
Westinghouse Electric Company
August 2013

Westinghouse

JAERI ROSA-IV Large Scale Test Facility

Objectives:

- Conduct large scale integral simulations of PWR SBLOCA and operational transients.
- Provide data to support development and verification of advanced computer codes for PWR accident and transient simulations.
- Investigation of plant recovery methods – operator procedures and equipment to be used on the plant to mitigate SBLOCA transients.



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JAERI ROSA-IV Large Scale Test Facility

Design Philosophy:

- Elevations preserved, i.e., one-to-one match to 4-loop Westinghouse PWR.
- Volumes scaled to 1/48 of the PWR volume.
- Flow areas are scaled to 1/48 in the vessel and 1/24 in the steam generators.
- Hot and cold legs scaled to conserve the $L/(D)^{1/2}$ ratio (which is in essence a Froude number) for better manifestation of the flow regime transition in the primary loop.

JAERI ROSA-IV Large Scale Test Facility

Design Philosophy:

- Nominal core power is 10 MW(t) - this is 14% of representative 3423 MW(t) PWR power scaled by a factor of 1/48.
- Core simulator heaters designed to represent 17x17 PWR assembly to preserve the heat transfer characteristics of the core, number of rods scaled to 1/48 of the PWR.
- Pressures (primary and secondary) are similar to PWR.
- Pressure losses designed to match the PWR for the scaled flow rates

JAERI ROSA-IV Large Scale Test Facility

Design Philosophy:

- Each steam generator (SG) has the same height and characteristic elevations as the real PWR steam generator,
- 141 U-tubes with diameter similar to the real SG
- Primary and secondary steam separators,
- SG downcomer is simulated by four pipes, sized to provide a representative downcomer volume and width of the real PWR SG.

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ROSA-IV LSTF Model Development and Test Simulations

Topic	Supporting Calcnote
Development of the ROSA-IV LSTF Steady State vessel (3-D) and loop (1-D) model.	[ ]a,c
Simulations of the ST-NC-02 natural circulation test	[ ]a,c
Various simulations of the 5% cold leg break tests SB-CL-18 and SB-CL-05	[ ]a,c
Simulations of ROSA break orientation tests (0.5% and 2.5% breaks)	[ ]a,c

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Roadmap of Section 21 of the FSLOCA Topical Report WCAP-16996-P

Topical Section	Supporting Calcnote
21.1 - Introduction	N/A
21.2 – Test Facility Description	N/A
21.3 – Description of ROSA Model	[ ]a,c
21.4 – Simulation of SB-CL-18	[ ]a,c
21.5 – Simulation of SB-CL-05	[ ]a,c
21.6 – Simulation of 10% Side Break SB-CL-14	[ ]a,c
21.7 – Break Orientation Study	[ ]a,c

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Roadmap of Section 21 of the FSLOCA Topical Report WCAP-16996-P

Topical Section	Supporting Calcnote
21.8 – Break Spectrum Study	Based on previous sections
21.9 – Simulation of ST-NC-02, 2% Power Natural Circulation Test	[ ]^{a,c}
21.10 – CCFL Results and Evaluation	Data extracted from simulations of tests documented in previous sections
21.11 – Bypass Sensitivity Calculations	SB-CL-18 simulations; [ ]^{a,c}
21.12 – CD1 Sensitivity	SB-CL-18 simulations; [ ]^{a,c}

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Roadmap of Section 21 of the FSLOCA Topical Report WCAP-16996-P

Topical Section	Supporting Calcnote
21.13 – CD2 Sensitivity	SB-CL-18 simulations; [ ]a,c
21.14 – Broken Loop Pump Resistance	SB-CL-18 simulation; transient in [ ]a,c
21.15 – YDRAG Sensitivity	SB-CL-18 simulation; [ ]a,c
21.16.1 – HS_SLUG Sensitivity with SB-CL-16	SB-CL-16 simulation; [ ]a,c
21.16.2 – HS_SLUG Sensitivity with SB-CL-18	SB-CL-18 simulation; [ ]a,c
21.16.3 – HS_SLUG Sensitivity with SB-CL-14	SB-CL-14 simulation; [ ]a,c

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Roadmap of Section 21 of the FSLOCA Topical Report WCAP-16996-P

Topical Section	Supporting Calcnote
21.17 – KCOSI Sensitivity Calculations	SB-CL-05 simulation; cases from [ ]a,c
21.18 – MSSV Setpoint Sensitivity Calculation	Comparison of 0.5% side break SB-CL-15 simulations; Cases from [ ]a,c

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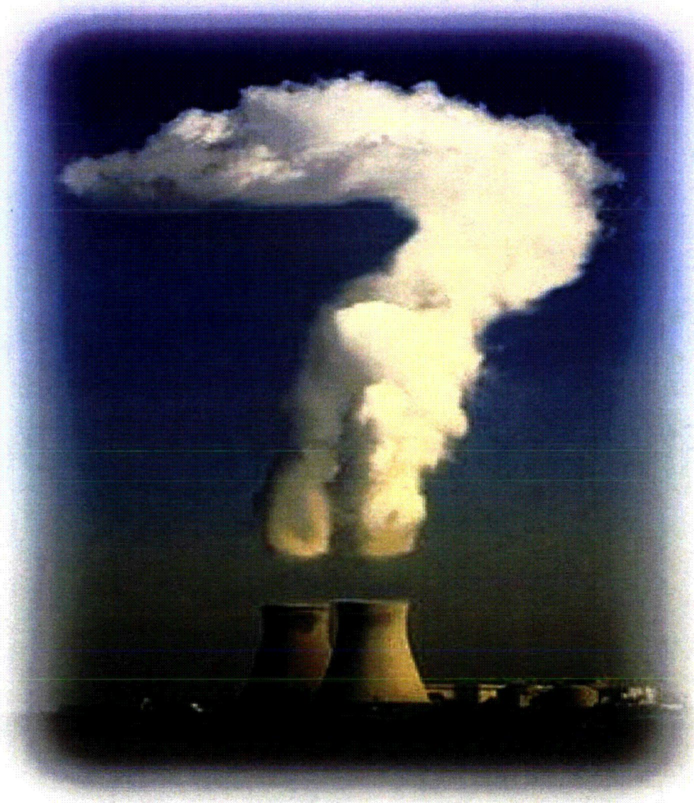
Questions



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Full Spectrum LOCA (FSLOCA) Overview

Jeffrey Kobelak
Westinghouse Electric Company
August 2013

Westinghouse

Overview

- Desired Scope of Approval
  - Technical Work for Evaluation Model (EM) Extension
  - Usage Conditions and Limitations
- Westinghouse Status of RAI Responses
- Burnup Methodology

Desired Scope of Approval

a,c

Technical Work Scope for EM Extension

- [

]a,c

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Technical Work Scope for EM Extension

- [

]a,c

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Applicability Limits

- [

]a,c

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Usage Conditions

- [

]a,c

Status of RAI Responses

- Sets 1 Through 4
  - Responses completed and formally transmitted to NRC except RAIs 36-39
    - Ongoing effort to address RAIs 36-39 necessitated changes to the burnup methodology
    - Expect EM updates to be completed along with TR Volume 3 updates by March 2014
  - RAI-45
    - CCTF-62 311-case runset previously transmitted to the NRC (part of LTR-NRC-13-40)
    - Beaver Valley Steady-State cases completed and will be discussed later in audit

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Status of RAI Responses

- Set 5 (Primarily Interfacial Drag and Level Swell)
  - Responses completed for RAIs 72 through 74 and 76
  - Developing responses for other Set 5 RAIs
    - Will include pertinent information from the July 2013 code workshop and supplemental investigations
  - RAI-76
    - [

]a,c

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Status of RAI Responses

- Set 6
  - Started developing responses to a subset of these RAIs at-risk (ROSA and loop seal clearing)
  - Waiting for formal transmittal of RAI set

- Sets 7 and 8
  - Waiting for formal transmittal of RAI sets
  - Expect subset of RAIs may no longer be relevant based on July and August NRC/Westinghouse discussions
    - E.g. Semiscale-related RAIs 109 to 111

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TCD and Burnup Methodology

- Automated Statistical Treatment of Uncertainty Method (ASTRUM) EM modeled the hot rod / hot assembly as fuel in the first cycle of irradiation

- Same modeling approach was used in FSLOCA
  - Approach was developed prior to consideration of fuel pellet TCD

- ASTRUM TCD evaluations and FSLOCA Large Break scoping results indicate that limiting results can occur during first or second cycle of irradiation

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TCD and Burnup Methodology

- Methodology updates in-progress to include TCD and revise burnup treatment
  - Use fuel rod performance data which explicitly includes the effect of TCD
  - Analyze fuel in first and second cycle of irradiation
    - [

      ]a,c
  - Neutronics and fuel rod inputs will be updated consistent with the changes to burnup methodology (e.g. peaking factor burndown)
- Limited amount of model improvements
  - e.g. power distribution modeling approach

TCD and Burnup Methodology

- Proactively adding provisions for some burnup-related cladding embrittlement mechanisms in advance of codification
  - Embrittlement mechanisms include
    - Interior cladding oxygen pickup
    - Breakaway oxidation
    - Cladding corrosion
  - Inclusion of these items can only penalize the analysis results, and provide additional assurance that cladding ductility is protected for current 10 CFR 50.46 acceptance criteria

Questions

Westinghouse

Full Spectrum LOCA (FSLOCA) Cold Leg Condensation Model

Katsuhiro Ohkawa
Westinghouse Electric Company
August 2013

Westinghouse

Background

- Amount of condensation in the cold leg can impact de-pressurization and vessel inventory which would have significant influence on core uncovery behavior for SBLOCA transients – TR-Section 2 PIRT

- Models were added in WCT-TF2 to capture condensation enhancement by Safety Injection which was identified as key phenomena relative to SBLOCA Analysis - CNs

- Validation was completed and Uncertainty Range/Distribution was identified - CNs

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Cold Leg Condensation

- Cold leg condensation model was developed based on subset of Westinghouse-COSI data and was added to WCOBRA/TRAC-TF2

- Code was validated against
  - COSI data (both Westinghouse and Framatome)
  - ROSA-IV (SET and IET modes)
  - UPTF 8A cold leg condensation experiment
  - UPTF25A cold leg condensation experiment

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Cold Leg Condensation Model related Calculation Notes

- Cold Leg Condensation Model Development – [

  ]a,c

- Implementation of Model into WCOBRA/TRAC-TF2 – [
  ]a,c

- Facility Test Simulations – [ ]a,c
  - Westinghouse Model and COSI (Vertical and Horizontal)
  - Framatome COSI (Co-current and Inverse)
  - JAERI ROSA-IV SB-CL-05 (SET)
  - Development of Uncertainty

- JAERI ROSA-IV SB-CL-05 (IET) – [ ]a,c

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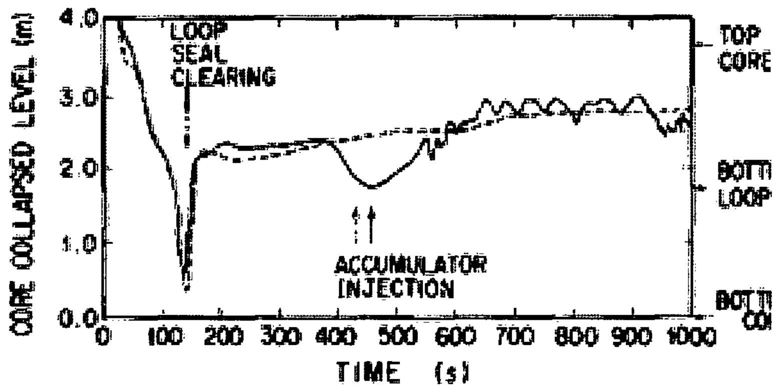
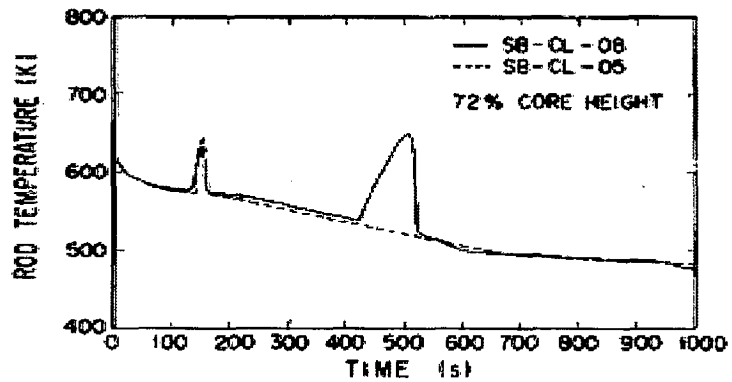
Responses to RAI-30 through 35 and Additional Information

- RAI-30 through 35 addressed additional question of the model applicability for PWR transients: [ ]a,c
  - Examination of Scaling of Geometry and other relevant parameters (Dia., Area, Length, Superficial Velocity, Reynolds number of CL and of SI line, Froude number of SI line)
  - Moderate Scale Distortion in SI jet Reynolds number – bias accounted for by the KCOSI multiplier
- Scaling analysis + Validation matrix covering wide range of CL diameter, SI flow rate, and SI Reynolds number support scalability to PWR

SI on/off - SB-CL-05 vs. SB-CL-18 in the Topical Report Section 21

- Similar Comparison seen in Tasaka (1988 NED) who compared SB-CL-08 VS. SB-CL-05





- Small impact on the depressurization

- Difference is seen in the coolant inventory in the core

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Additional KCOSI Sensitivity Runs

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Additional KCOSI Sensitivity Runs

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Additional KCOSI Sensitivity Runs

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Additional KCOSI Sensitivity Runs

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SI on/off - SB-CL-05 vs. SB-CL-18: Coolant Inventory in Core

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SI on/off - SB-CL-05 vs. SB-CL-18: Max Cladding Temperature

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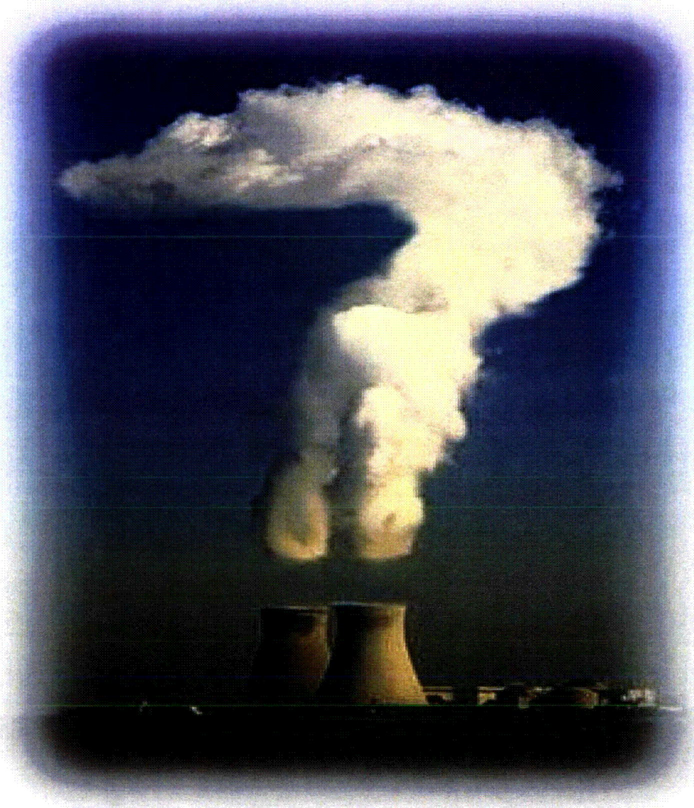
Questions



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Issues Discussed in July 2013 NRC Code Workshop

Jeffrey Kobelak
Aaron Everhard
Westinghouse Electric Company

August 2013

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Overview

- Beaver Valley SS and ROSA Transient Studies
- Anomalous Grid Behavior in G2 Level Swell Test
- [ ][a,c]
- Decay Heat Uncertainty Sampling
- Forslund-Rohsenow Model
- Beaver Valley Parametric Study
- Other Issues Still Under Investigation

Beaver Valley and ROSA Studies

- Completed runset of Beaver Valley steady-state cases
  - Results will be presented on Thursday
- Large runset of ROSA transients in-progress

Grid Behavior in G2 Level Swell

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Grid Behavior in G2 Level Swell

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[ ]a,c Impact on ORNL Test CC

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[ ]a,c Impact on ORNL Test CC

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Decay Heat Uncertainty Sampling

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Decay Heat Uncertainty Sampling

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Forslund-Rohsenow Correlation

- Direct contact heat transfer to the entrained field is based on Forslund-Rohsenow
- NRC expressed concern with modeling direct contact heat transfer with droplets
  - Model will be updated to remove the direct heat transfer to droplets
  - Heat transfer multiplier distributions will be revisited

Beaver Valley Study Background

- [ ]a,c presented in February 2013 Meeting
- Performed a parametric study on the following 4 parameters
  - Decay heat increased 20%
  - YDRAG cut in half → [ ]a,c
  - Cold leg condensation at SI location cut in half [ ]a,c
  - Cold leg condensation at SI location turned off [ ]a,c
- Ran an additional case with parameters biased in a conservative direction
- Repeated all 5 cases with the SI reduced by 25%

Main Parameters Varied (1/4)

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Main Parameters Varied (2/4)

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Main Parameters Varied (3/4)

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Main Parameters Varied (4/4)

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Results – Nominal SI Case

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Results – Nominal SI Case

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Results – Nominal SI Case

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Results – Nominal SI Case

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Results – Nominal SI Case

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Results – Nominal SI Case

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Results – Nominal SI Case

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Results – Nominal SI Case

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Results – Nominal SI Case

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[ ]a,c Nominal SI Conservative Case

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[ ]a,c Nominal SI Conservative Case

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[ ]a,c Nominal SI Conservative Case

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Results – Reduced SI Case

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Results – Reduced SI Case

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Results – Reduced SI Case

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Results – Reduced SI Case

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Results – Reduced SI Case

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Results – Reduced SI Case

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Results – Reduced SI Case

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Results – Reduced SI Case

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Results – Reduced SI Case

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[ ]a,c Reduced SI Conservative Case

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[ ]a,c Reduced SI Conservative Case

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Reduced SI Conservative Case

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Other Issues

- Several other item identified during July code workshop are being investigated
  - G2 Noding Sensitivity Results
  - Void Fraction Dipping in ORNL Simulations

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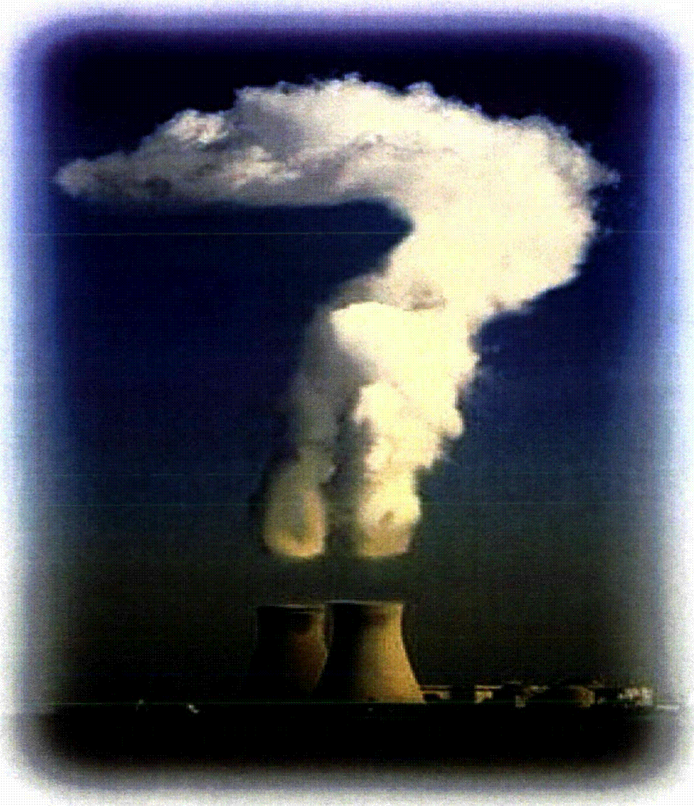
Questions



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Full Spectrum LOCA (FSLOCA) Uncertainty Contributors and Treatment

Jeffrey Kobelak
Aaron Everhard
Westinghouse Electric Company
August 2013

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Background (1/2)

- Potential Uncertainty Contributors are generally treated in one of three ways
  - **Nominal without Uncertainty**
    - Parameters which are tightly controlled
    - LOCA transient sensitivity to the parameter is negligible

Background (2/2)

- **Bounded**
  - LOCA transient sensitivity to the parameter is small
  - Effort to develop a detailed uncertainty treatment is judged to exceed the benefit of doing so
  - Intentionally add conservatism to the evaluation model

- **Sampled**
  - Uncertainties are explicitly evaluated
  - Distributions generally either well-characterize the data, or are skewed in a conservative manner

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Nominal without Uncertainty

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Bounded (1/2)

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Bounded (2/2)

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Sampled Parameters (1/3)

- Complete list of parameters and ranges provided in response to RAI-45A (from [

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Sampled Parameters (2/3)

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Sampled Parameters (3/3)

- [

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Demonstration of Parameter Ranging

- Large runset with ranging of all applicable uncertainty contributors was previously completed for CCTF Run 62
  - Transmitted to the NRC as part of the Response to RAI-45

- Follow-up demonstration was completed with the Beaver Valley PWR steady-state case

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DLW Steady-State Runs – Case Description

- [$]^{a,c}$ documents 93 steady-state runs which randomly sampled all the uncertainty attributes
  - Also includes a case which has the parameters at their nominal/unbiased values

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DLW Steady-State Runs – Attributes Sets

- List of Sampled Attribute Sets

DLW Steady-State Runs – SS Convergence

- The parameters defined in Table 26.4-1 of WCAP-16996-P are confirmed to meet the acceptable steady-state criteria

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DLW Steady-State Runs – Results (1/7)

- The following quantities are extracted for each loop from each of the 93 cases, as well as the nominal case.

Hot Leg Temperature (F)	Cold Leg Temperature (F)
Loop Mass Flow Rate (lbm/s)	SG 2nd Pressure (psia)
SG 2nd Steam Flow (lbm/s)	SG 2nd Liquid Flow (lbm/s)
SG Liquid Temperature (F)	Pump Speed (rad/s)
Pump Momentum Source (ft/s^2)	Pump Head (ft)

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DLW Steady-State Runs – Results (2/7)

- Here are the values from the Nominal case

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DLW Steady-State Runs – Results (3/7)

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DLW Steady-State Runs – Results (4/7)

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DLW Steady-State Runs – Results (5/7)

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DLW Steady-State Runs – Results (6/7)

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DLW Steady-State Runs – Results (7/7)

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DLW Steady-State Runs - Conclusions

- Steady-state criteria met for all 93 cases
- Mean values from the distributions agree very well with the nominal case.
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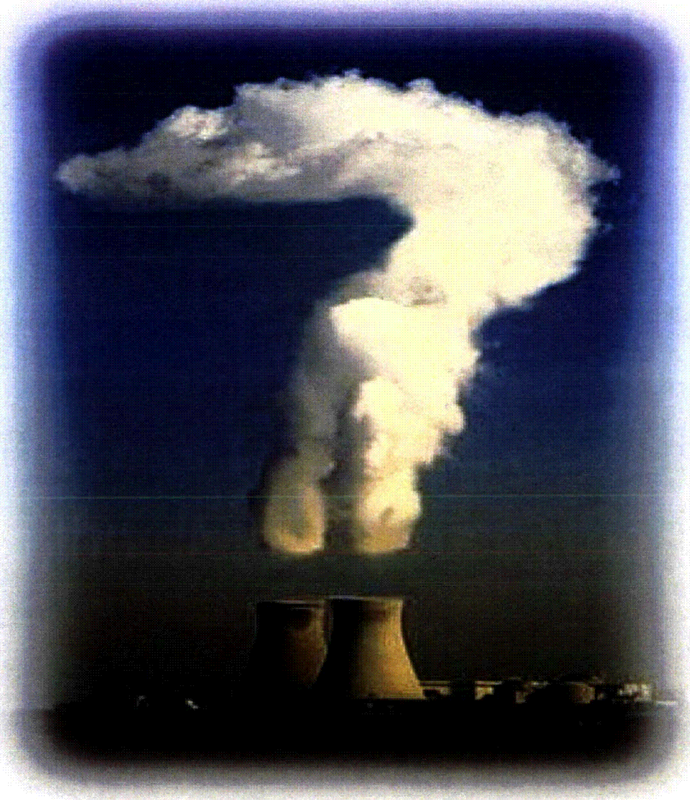
Questions



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Full Spectrum LOCA (FSLOCA) CCTF-62 and ROSA SB-CL-02 Runsets

Jeffrey Kobelak
Westinghouse Electric Company
August 2013

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Overview (1/2)

- Consistency in steady-state (SS) calculation demonstrated with Beaver Valley SS runset
- Code capability for transient calculation demonstrated against IET facilities (data)
  - CCTF Run 62 selected as prototypical LBLOCA test
  - ROSA SB-CL-02 selected as prototypical SBLOCA test

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Overview (2/2)

- **CCTF Run 62**
  - Cladding temperature at 6, 8, and 10-ft elevations selected as figures of merit
- **ROSA SB-CL-02**
  - Cladding temperature at PCT elevation selected as figure of merit
  - Plots of other key phenomena presented
- **Both Facilities**
  - Minimum, nominal and maximum code predictions compared against data
  - Distribution for full 311-case runset calculated
    - Histograms show predicted - measured

CCTF Run 62 – Tclad at 6 ft

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CCTF Run 62 – Tclad at 8 ft

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CCTF Run 62 – Tclad at 10 ft

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CCTF Run 62 - Summary

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Elevation	Number of Cases Over-Predict Maximum Tclad	Number of Cases Under-Predict Maximum Tclad
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ROSA SB-CL-02

- Executed 311 transient runset
- Ranged the following parameters
  - [

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ROSA SB-CL-02

- Results processed first 100 runs; additional cases not expected to change distribution
  - Plots provided for key parameters against data
- [

  ]a,c compared to data for full runset

ROSA SB-CL-02

- Adobe Acrobat Document

ROSA SB-CL-02 - Tclad

- Distribution of predicted cladding temperature at PCT elevation versus data for complete 311 runset

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ROSA SB-CL-02 - Observations

- Cladding temperature was [

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ROSA SB-CL-02

Adobe Acrobat Document

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ROSA SB-CL-02 - Tclad

- Distribution of predicted Tclad versus data without CD ranging

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ROSA SB-CL-02 - Observations

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Questions

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