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Addendum 3-A, Revision 1

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Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)

Westinghouse

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Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)

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October 2007

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Section A

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

September 17, 2007

Mr. James A. Gresham, Manager
Regulatory Compliance and Plant Licensing
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: FINAL SAFETY EVALUATION FOR WESTINGHOUSE ELECTRIC COMPANY (WESTINGHOUSE) TOPICAL REPORT (TR) WCAP-10266-P, REVISION 2, ADDENDUM 3, REVISION 1, "INCORPORATION OF THE LOCBART [LOSS-OF-COOLANT] (LOC), BEST ESTIMATE ANALYSIS OF REFLOOD TRANSIENTS (BART)] TRANSIENT EXTENSION METHOD INTO THE 1981 WESTINGHOUSE LARGE BREAK LOCA [LOSS-OF-COOLANT ACCIDENT] EVALUATION MODEL WITH BASH [BART AND SYSTEM HYDRAULICS] (BASH-EM)" (TAC NO. MB7485)

Dear Mr. Gresham:

By letter dated December 18, 2002, and supplemented by letters dated November 13, 2003, January 26, 2004, April 15, 2004, January 24, 2005, August 11, 2005, March 30, 2006, April 28, 2006, and April 13, 2007, Westinghouse submitted TR WCAP-10266-P, Revision 2, Addendum 3, to the U.S. Nuclear Regulatory Commission (NRC) staff for review. Revision 1 of TR WCAP-10266-P, Revision 2, Addendum 3, was submitted by letter dated June 29, 2007, and is an update to Addendum 3 requested by the NRC staff due to the changes in Addendum 3 that occurred over the course of the review.

By letter dated August 6, 2007, an NRC draft safety evaluation (SE) regarding our approval of TR WCAP-10266-P, Revision 2, Addendum 3, Revision 1, was provided for your review and comments. By letter dated August 30, 2007, Westinghouse commented on the draft SE. The NRC staff's disposition of Westinghouse's comments on the draft SE are discussed in the attachment to the final SE enclosed with this letter.

The NRC staff has found that TR WCAP-10266-P, Revision 2, Addendum 3, Revision 1, is acceptable for referencing in licensing applications for Westinghouse-designed pressurized water reactors to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that Westinghouse publish accepted proprietary and non-proprietary versions of this TR within three months of receipt of this letter. The accepted versions shall incorporate this letter and the enclosed final SE after the title page. Also, they must contain historical review information, including NRC requests for additional information and your responses. The accepted versions shall include an "-A" (designating accepted) following the TR identification symbol.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, Westinghouse and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,

Ho K. Nieh, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 700

Enclosure: Final SE

cc w/encl:
Mr. Gordon Bischoff, Manager
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Westinghouse Electric Company
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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT (TR) WCAP-10266-P, REVISION 2, ADDENDUM 3, REVISION 1, "INCORPORATION OF THE LOCBART [LOSS OF COOLANT (LOC), BEST ESTIMATE ANALYSIS OF REFLOOD TRANSIENTS (BART)] TRANSIENT EXTENSION METHOD INTO THE 1981 WESTINGHOUSE LARGE BREAK LOCA [LOSS-OF-COOLANT ACCIDENT] EVALUATION MODEL WITH BASH [BART AND SYSTEM HYDRAULICS] (BASH-EM)"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 INTRODUCTION AND BACKGROUND

On November 2, 2000, the NRC staff informed Westinghouse Electric Company (Westinghouse) of its concern of the potential non-conservative modeling of downcomer boiling in the approved Westinghouse 1981 large-break LOCA (LBLOCA) evaluation model (EM) (Reference 1). Meetings were held to discuss the issue (References 2 and 3).

Westinghouse submitted for NRC staff review an addendum to the previously approved 1981 LBLOCA EM, WCAP-10266-P-A, Revision 2, to address the downcomer boiling issue (Reference 4), referred to as the LOCBART transient extension method. In response to NRC staff requests for additional information (RAIs), Westinghouse provided responses to the NRC staff's concerns in References 5, 6, and 7. A status meeting was held on January 25, 2005 (Reference 8). Westinghouse subsequently provided its response to an additional RAI in Reference 9.

On April 28, 2006, Westinghouse informed the NRC staff of its intent to phase out the use of the 1981 EM methodology and transition to the realistic LBLOCA analysis methodology (Reference 10). Westinghouse also identified limitations on the usage of 1981 LBLOCA EM until the transition is completed and committed to continue to work with the NRC staff to bring the concerns regarding the use of 1981 LBLOCA EM and the LOCBART transient extension method to closure.

The NRC staff requested additional clarification on the LOCBART transient extension method. Westinghouse provided responses in Reference 11, with a commitment to revise WCAP-10266-P, Revision 2, Addendum 3, accordingly.

ENCLOSURE

2.0 REGULATORY EVALUATION

The emergency core cooling system (ECCS) is designed to provide protection against postulated LOCAs caused by ruptures in the primary system piping. The functional requirements for the ECCS performance, under all LOCA conditions postulated in the design, must satisfy the requirements of Section 50.46 of Title 10 of the *Code of Federal Regulations* (10 CFR), "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors." The ECCS calculated cooling performance is based on an acceptable EM for which there is sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor coolant system during an LOCA or, in this case, an ECCS EM developed in conformance with Appendix K to 10 CFR Part 50.

The specific Appendix K requirements associated with this review are:

(1) 10 CFR Part 50, Appendix K, Section I.A.6, "Reactor Internals Heat Transfer," states: "Heat transfer from piping, vessel walls, and non-fuel internal hardware shall be taken into account."

(2) 10 CFR Part 50, Appendix K, Section I.D.3, "Calculation of Reflood Rate for Pressurized Water Reactors;" states: "The refilling of the reactor vessel and the time and rate of reflooding of the core shall be calculated by an acceptable model that takes into consideration the thermal and hydraulic characteristics of the core and of the reactor system. The primary system coolant pumps shall be assumed to have locked impellers if this assumption leads to the maximum calculated cladding temperature; otherwise the pump rotor shall be assumed to be running free. The ratio of the total fluid flow at the core exit plane to the total liquid flow at the core inlet plane (carryover fraction) shall be used to determine the core exit flow and shall be determined in accordance with applicable experimental data.... The effects on reflooding rate of the compressed gas in the accumulator which is discharged following accumulator water discharge shall also be taken into account."

(3) 10 CFR Part 50, Appendix K, Section I.D.4, "Steam Interaction with Emergency Core Cooling Water in Pressurized Water Reactors," states: "The thermal-hydraulic interaction between steam and all emergency core cooling water shall be taken into account in calculating the core reflooding rate. During refill and reflood, the calculated steam flow in unbroken reactor coolant pipes shall be taken to be zero during the time that accumulators are discharging water into those pipes unless experimental evidence is available regarding the realistic thermal-hydraulic interaction between the steam and the liquid. In this case, the experimental data may be used to support an alternate assumption."

(4) 10 CFR Part 50, Appendix K, Section I.D.5, "Refill and Reflood Heat Transfer for Pressurized Water Reactors," states: "a. For reflood rates of one inch per second or higher, reflood heat transfer coefficients shall be based on applicable experimental data for unblocked cores including Full Length Emergency Cooling Heat Transfer (FLECHT) results.... New correlations or modifications to the FLECHT heat transfer correlations are acceptable only after they are demonstrated to be conservative, by comparison with FLECHT data, for a range of parameters consistent with the transient to which they are applied. b. During refill and during reflood when reflood rates are less than one inch per second, heat transfer calculations shall be based on the assumption that cooling is only

by steam, and shall take into account any flow blockage calculated to occur as a result of cladding swelling or rupture as such blockage might affect both local steam flow and heat transfer."

(5) 10 CFR Part 50, Appendix K, Section II.2 states: "For each computer program, solution convergence shall be demonstrated by studies of system modeling or noding and calculational time steps."

(6) 10 CFR Part 50, Appendix K, Section II.3 states: "Appropriate sensitivity studies shall be performed for each evaluation model, to evaluate the effect on the calculated results of variations in noding, phenomena assumed in the calculation to predominate, including pump operation or locking, and values of parameters over their applicable ranges. For items to which results are shown to be sensitive, the choices made shall be justified."

(7) 10 CFR Part 50, Appendix K, Section II.4 states: "To the extent practicable, predictions of the evaluation model, or portions thereof, shall be compared with applicable experimental information."

3.0 TECHNICAL EVALUATION

The TR WCAP-10266-P, Revision 2, Addendum 3, Revision 1 (Reference 12) describes the incorporation of the LOCBART transient extension method into the 1981 Westinghouse LBLOCA EM with BASH (BASH-EM). The LOCBART transient extension method was developed to extend the analysis of BASH-EM transients beyond the point at which downcomer boiling occurs in BASH. This was achieved by correlating the boiling-induced reduction in the downcomer driving head to a corresponding reduction in the core inlet flooding rate. This approach is to be used to ensure adequate termination of the fuel rod cladding temperature and oxidation transients as required to demonstrate compliance with the acceptance criteria of 10 CFR 50.46.

3.1 Description of the BASH-EM

The SATAN-VI computer program (Reference 13) is used to evaluate the blowdown thermal-hydraulic portion of the LBLOCA transient. The reactor core is modeled using a hot channel and an average channel, with radial flow paths simulating the crossflow between the channels. The fluid conditions in the hot channel are transferred to LOCBART and define the thermal-hydraulic boundary conditions for the fuel rod heatup during the blowdown phase of the transient.

The BASH computer program (Reference 14) is used to compute the refill and reflood thermal-hydraulic portions of the LBLOCA transient. The refill module models the transport of water from the ECCS injection points to the reactor vessel lower plenum. The reflood module models the integrated system response during reflood, including the core pressure, core inlet flooding rate, and core inlet enthalpy. These values are supplied to LOCBART as boundary conditions for the fuel rod heatup during this phase of the transient.

The minimum containment pressure transient is computed using the interactive Containment Pressure Analysis Code (COCO) module (Reference 15) for dry containment plants, or the stand-alone Long Term Ice Condenser Containment (LOTIC) computer program (Reference 16) for ice condenser containment plants. The minimum containment pressure defines the system pressure boundary condition for the refill and reflood portions of the thermal-hydraulic calculations.

The SMUUTH computer program (see Reference 14) is used to smooth the core inlet flooding rate and enthalpy during reflood. The smoothing procedure yields a core inlet flooding rate that is piecewise constant over three segments, and was designed to reduce the reflood oscillations predicted by BASH while preserving the net mass flow into the core.

The LOCBART computer program is used to compute the cladding temperature and oxidation transients for the highest-powered fuel rod in the core during the blowdown, refill, and reflood phases of the LBLOCA transient. LOCBART provides a mechanistic treatment of core heat transfer during reflood, which represents a significant improvement relative to prior application of the FLECHT correlation. The mechanistic models calculate the heat transfer coefficients appropriate to the flow and heat transfer regimes that develop axially in the hot channel, with a detailed spacer grid heat transfer model used to account for the effects of local flow acceleration and improved interfacial heat transfer.

3.2 LOCBART Transient Extension Model

BASH-EM uses a simple model to represent the downcomer and the calculation stops shortly after the downcomer fluid reaches saturation. However, downcomer boiling leads to a reduced driving head and subsequently a reduced reflood rate. BASH-EM cannot account for this reduction in the reflood rate.

A method has been proposed by Westinghouse to extend the LOCBART calculation beyond the point at which downcomer boiling is predicted to occur in BASH. This approach uses a void fraction correlation proposed by Sudo (References 17 and 18) to estimate the average void fraction in the downcomer during boiling, which is then converted to an equivalent void height. The corresponding reduction in downcomer driving head is used to calculate the core inlet flooding rate for use in the LOCBART calculation.

In response to the NRC staff's comments on the use of the proposed Sudo void fraction correlation, Westinghouse revised the proposed method to be consistent with the parameter definitions in the Sudo papers and to account for the uncertainty in the correlation. Westinghouse also revised the method used to calculate the void fraction during downcomer boiling. In addition, Westinghouse included the region below the bottom of the active core to the bottom of the downcomer in the determination of the core inlet reflood rate.

Sensitivity studies performed by Westinghouse (Reference 11) for a large, dry containment design showed the impact of reflooding rate, resulting from these changes, for the LOCBART transient extension method on the hot rod peak cladding temperature (PCT) and the maximum local oxidation. It was shown that the changes to the reflooding rate have a second order impact on these values for a large, dry containment design. Sensitivity studies for an ice-condenser containment design (Section 5.6, Reference 4) showed a measurable difference in the PCT and maximum local oxidation as a function of the reflooding rate. Ice-condenser designs typically have lower containment pressures than large, dry designs.

Westinghouse revised the method to address the containment back pressure, to be consistent with the guidance provided in Standard Review Plan 6.2.1.5, "Minimum Containment Pressure

Analysis for Emergency Core Cooling System Performance Capability Studies." The revised method includes running BASH past the point of downcomer boiling to calculate the lower containment pressure later in the transient. In addition, the revision includes a time-dependent calculation to capture the change in the wall heat release rate, the cold leg pressure, and the core collapsed liquid level.

Sensitivity studies performed by Westinghouse (Reference 11) for a large, dry containment design showed the impact of these changes on the LOCBART transient extension reflood rate and the resulting hot rod peak cladding temperature and the maximum local oxidation. It was shown that the impact from the reduced containment pressure change has an impact on these values for a large, dry containment design, with increases in both the hot rod PCT and the maximum local oxidation values.

The NRC staff finds the revised modeling method acceptable for use with the LOCBART transient extension method because it results in a conservative evaluation of the PCT and local oxidation and addresses the downcomer boiling concern.

3.3 Validation of LOCBART Transient Extension Method

Westinghouse augmented the model validation to compare its implementation of the Sudo void fraction correlation to five Japan Atomic Energy Research Institute (JAERI) experiments (References 19 and 20). These tests modeled a 16 foot downcomer length and a width of 2 or 8 inches. With one exception, the initial conditions were representative of a pressurized water reactor (PWR) at the onset of downcomer boiling. The comparisons showed that the implementation adequately predicted the steady-state collapsed liquid level, which is representative of the conditions expected in the PWR downcomer.

3.4 Evaluation of 10 CFR Part 50, Appendix K, Requirements

3.4.1 10 CFR Part 50, Appendix K, Section I.A.6

The energy transfer between most of the metal structures in the primary system and the fluid has little effect on the system thermal-hydraulic transient, and a single metal node temperature is calculated using the slab heat transfer model described in Section 3.13 of Reference 14. However, for the lower plenum and downcomer, a detailed simulation is required for the resolution of internal temperature gradients, and a metal node temperature profile is calculated using the more detailed model.

The LOCBART transient extension method uses the downcomer metal-to-fluid heat flow rate at the onset of downcomer boiling to start the calculation of the reduction in the core inlet flooding rate. The NRC staff finds that there is reasonable assurance that Westinghouse has accounted for the effects of structures on the reflooding calculations after the onset of downcomer boiling, when coupled with the implementation of the Sudo void fraction correlation, in a conservative manner appropriate for an Appendix K-based EM.

The NRC staff finds the treatment of metal structures acceptable for use with the LOCBART transient extension method because it results in a conservative evaluation of the reflooding rate.

3.4.2 10 CFR Part 50, Appendix K, Section I.D.3

Three issues need to be considered for the LOCBART transient extension method: (1) locked rotor assumption, (2) carryover fraction, and (3) accumulator nitrogen discharge.

Locked Rotor Assumption

The reactor coolant pump is modeled in BASH as a resistance in the cold leg based on a locked rotor assumption. This yields the maximum resistance through the pump, which was shown to reduce the flooding rate and increase the PCT (Reference 25). Westinghouse did not change the locked rotor assumption after the onset of downcomer boiling.

The NRC staff finds the locked rotor assumption acceptable for use with the LOCBART transient extension method because it results in a conservative evaluation of the reflooding rate.

Carryover Fraction

Comparisons against experimental data were made directly against the measured flooding rate, the integral flooding rate, and the total carryover fraction (Reference 14). These comparisons showed that BASH provides a reasonable-to-conservative prediction of the carryover fraction, and conservatively predicts the flooding rate and integral flooding rate. The flooding rates directly influence the PCT and the flooding rates are supplied to LOCBART as a boundary condition.

The NRC staff finds the calculation of the carryover fraction acceptable for use with the LOCBART transient extension method because it results in a conservative evaluation of the reflooding rate.

Accumulator Nitrogen Discharge

Previous studies performed by Westinghouse (Reference 22) showed that accumulator nitrogen discharge pressurizes the downcomer and increases the flooding rate. This behavior is supported by experimental results (e.g., Loss of Fluid Test (LOFT)), and was used to conclude that accumulator nitrogen discharge could be conservatively neglected in BASH. As discussed in Reference 21, Semiscale tests indicated a long-term increase in system pressure due to accumulator nitrogen discharge. This would produce an increase in the flooding rate, which is conservatively neglected, and a decrease in pumped injection flow, which is a very small effect over the pressure range of interest and is also neglected. There is no change to the treatment of accumulator nitrogen discharge after downcomer boiling.

The NRC staff finds treatment of the accumulator nitrogen discharge acceptable for use with the LOCBART transient extension method because it results in a conservative evaluation of the reflooding rate.

3.4.3 10 CFR Part 50, Appendix K, Section I.D.4

BASH assumes equilibrium behavior in the reactor cold legs (Reference 14). This assumption maximizes the condensation of steam flowing from the intact cold legs to the downcomer, which minimizes the pressurization of the downcomer due to steam flowing through the broken nozzle and reduces the flooding rate. This assumption also minimizes the subcooling of the ECCS fluid entering the downcomer, which reduces the time required for the downcomer to reach saturation and leads to an earlier reduction of the flooding rate using the LOCBART transient extension method.

An additional pressure drop is applied in the cold legs to account for pressure oscillations during accumulator injection. As discussed in Reference 22, this pressure drop bounds the steam/water mixing data and was approved for licensing application as being sufficiently conservative. In a BASH-EM calculation, the accumulators are predicted to empty before the onset of downcomer boiling, and this requirement is not pertinent to the LOCBART transient extension method.

During the LOCBART transient extension, the effects of downcomer boiling and entrainment are considered in the calculation of the reduced flooding rate. Vertical entrainment effects due to steam escaping from the downcomer are reflected through use of the Sudo void fraction correlation.

The NRC staff finds the treatment of steam interaction with emergency core cooling water acceptable for use with the LOCBART transient extension method because it results in a conservative evaluation of the reflooding rate.

3.4.4 10 CFR Part 50, Appendix K, Section I.D.5

Compliance of BASH-EM with Section I.D.5 of 10 CFR Part 50, Appendix K, was demonstrated in Section 11.0 of Reference 14, and was supplemented by the validation of the LOCBART reflood heat transfer models as described in Reference 23. When the flooding rate is less than or equal to 1 inch per second, direct heat transfer to liquid is ignored, and assembly blockage is modeled if the hot assembly average rod has been predicted to burst. There is no change to the modeling of reflood heat transfer during the LOCBART transient extension.

The NRC staff finds the treatment of refill and reflood heat transfer acceptable for use with the LOCBART transient extension method because no changes to the previously accepted models were needed.

3.4.5 10 CFR Part 50, Appendix K, Section II.2

Section II.2 requires that for each computer program, solution convergence be demonstrated by studies of system modeling or noding and calculational time steps.

The simplified modeling approach used in BASH was not intended to be used to perform evaluations past downcomer boiling. To address downcomer boiling, Westinghouse proposed the LOCBART transient extension method. The method uses conditions during downcomer boiling to obtain the reduced reflood rate resulting from the decreased pressure head in the downcomer. The revised method includes running BASH past the point of downcomer boiling to calculate the lower containment pressure later in the transient.

The previous nodal studies remain applicable to the LOCBART transient extension method. Solution convergence was demonstrated for BASH in Reference 14. Solution convergence for LOCBART was based on the axial node spacing and time step selection. The axial node spacing was determined by the maximum allowable value from Reference 24 (6"), the value required to adequately resolve the axial blockage profile (3"), and the minimum value implied by Section I.A.5 of 10 CFR Part 50, Appendix K (3").

A time step sensitivity analysis using the LOCBART transient extension method, performed by Westinghouse, showed the effect of reducing the maximum allowable time step value on the cladding temperature and oxidation. The calculation showed a minimal effect on the results for the sample case.

The NRC staff finds the nodal and time step sensitivity studies performed by Westinghouse acceptable to justify the LOCBART transient extension method.

3.4.6 10 CFR Part 50, Appendix K, Section II.3

Section II.3 requires that sensitivity studies be performed to evaluate the effect on results of "phenomena assumed in the calculation to predominate."

Sensitivity calculations were performed to demonstrate the effect of assembly blockage, maximum reflood time step size, and flooding rate after downcomer boiling on the hot rod PCT and the maximum local oxidation (Section 6.4 and 6.5, Reference 12). Additional sensitivity calculations were performed to demonstrate the effect of pumped safety injection flows and downcomer metal heat release on the hot rod peak cladding temperature and the maximum local oxidation.

Pumped Safety Injection Flows

The 1981 LBLOCA EM method (Reference 14) requires consideration of both minimum and maximum pumped safety injection (SI) flows. A sensitivity calculation was performed by Westinghouse for a 4-loop ice condenser plant using maximum pumped SI flows in BASH, to demonstrate how this change affected the calculated results when downcomer boiling was considered in the analysis. A comparison of the downcomer liquid temperature and containment pressure, for the BASH calculations modeling minimum and maximum pumped SI flows, showed the downcomer temperature was reduced for the maximum SI case which more than offset the small decrease in saturation temperature due to the reduced containment pressure, and produces a substantial delay in downcomer boiling.

The NRC staff finds the treatment of pumped SI flows acceptable for use with the LOCBART transient extension method because it results in a conservative evaluation of the reflooding rate.

Downcomer Metal Heat

A sensitivity calculation was also performed by Westinghouse in which the downcomer heat links in BASH were turned off just prior to downcomer boiling. This caused the downcomer liquid temperature to remain just below saturation, and allowed the BASH calculation to be extended beyond the point at which downcomer boiling would otherwise have occurred. The results indicated that BASH was capable of extended simulations when downcomer boiling does not occur. However, the LOCBART transient extension method was developed to address the effects of the downcomer metal heat on the reflooding rate to conservatively evaluate the PCT and maximum local oxidation after downcomer boiling occurs. The downcomer is modeled with a sufficient number of nodes for use with the Sudo void fraction correlation to account for the decreased driving head following the onset of downcomer boiling.

The NRC staff finds the treatment of the downcomer metal heat acceptable for use with the LOCBART transient extension method because it results in a conservative evaluation of the reflooding rate.

3.4.7 10 CFR Part 50, Appendix K, Section II.4

Westinghouse provided comparisons of the LOCBART extension method to appropriate experimental data, as discussed in Section 3.3 of this safety evaluation (SE). The comparisons showed the implementation reasonably predicted the steady-state collapsed liquid level.

The NRC staff finds the model validation acceptable for use in justifying the LOCBART transient extension method.

3.4.8 Summary of 10 CFR Part 50, Appendix K, Requirements

Westinghouse has addressed the NRC staff concerns identified in Reference 1. The NRC staff finds there is reasonable assurance that the LOCBART transient extension method, incorporated into the 1981 LBLOCA EM, complies with the relevant requirements of 10 CFR Part 50, Appendix K and that the LOCBART transient extension method results in a conservative evaluation of the hot rod PCT and the maximum local oxidation.

4.0 LIMITATIONS AND CONDITIONS

The NRC staff's position is that BASH-EM may not adequately address some current plant configurations and that a realistic LBLOCA analysis will be required. These configurations include designs with large obstructions in the downcomer region, for example thermal shields, or designs with atypical ECCSs. In addition, Westinghouse, in correspondence regarding the review of TR WCAP-10266-P, Revision 2, Addendum 3, Revision 1, has previously committed to limitations on the use of this TR (e.g. Reference 10). The limitations and conditions listed below do not remove the obligation of Westinghouse to abide by any previous statements made in correspondence to the NRC staff as part of the review for this TR.

Licensees referencing TR WCAP-10266-P, Revision 2, Addendum 3, Revision 1, must ensure compliance with the following conditions and limitations:

1. Future usage of BASH-EM will be limited to (a) assessments pursuant to the reporting requirements of 10 CFR 50.46; and, (b) evaluations to support minor plant, fuel design, or other input changes that would normally be handled under 10 CFR 50.46 and/or 10 CFR 50.59.

2. BASH-EM shall not be used for any future LBLOCA evaluations for changes that would be expected to significantly exacerbate downcomer boiling (for example closure of the residual heat removal discharge crosstie valves, early initiation of the recirculation sprays, a significant increase in downcomer metal heat capacity, etc.).

In addition, for plants with large obstructions in the downcomer region, for example thermal shields, the downcomer cross sectional area used in the Sudo void fraction correlation should be justified.

5.0 CONCLUSION

Westinghouse provided the revised version of Addendum 3 of the TR on June 29, 2007 (Reference 12). The LOCBART transient extension model is based on experimental data, the Sudo correlation, and conservatively adjusts the reflooding rate during downcomer boiling to account for the reduced downcomer driving head. The LOCBART transient extension method results in a conservative evaluation of the hot rod PCT and the maximum local oxidation. Future analyses based on the 1981 LBLOCA BASH-EM should be conducted with the accepted LOCBART transient extension method to account for downcomer boiling, subject to the limitations discussed in Section 4.0 of this SE. The NRC staff concludes that the LOCBART transient extension method developed to account for downcomer boiling, and incorporated into the 1981 LBLOCA EM, complies with the relevant requirements of 10 CFR Part 50, Appendix K, as discussed in Section 3.4 of this SE.

6.0 REFERENCES

1. S. Dembek, US NRC, letter to H. A. Sepp, Westinghouse Electric Company, "Potential Non-Conservative Modeling in Approved Evaluation Models," November 2, 2000 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML003765667).

2. J. S. Galembush, Westinghouse Electric Company, letter to S. Dembek, US NRC, "Proprietary Presentation Material for March 6, 2001 Meeting to Discuss Downcomer Boiling," March 1, 2001 (ADAMS Package No. ML010640233).

3. H. A. Sepp, Westinghouse Electric Company, letter to J. S. Wermiel, US NRC, "Proprietary Presentation Material for July 11th Meeting to Discuss Downcomer Boiling," July 10, 2002 (ADAMS Package No. ML022130129).

4. Westinghouse Electric Company, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)," WCAP-10266-P, Revision 2, Addendum 3, December 2002 (ADAMS Package No. ML050060358).

5. J. S. Galembush, Westinghouse Electric Company, letter to US NRC, "Response to NRC Request for Additional Information on Addendum 3 to WCAP-10266-P, Rev. 2 (Proprietary) and WCAP-11524-A, Rev. 2 (Non-Proprietary), "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)," [Responses to RAIs 2d, 3a, 3b, 3c, 4a, 4b, 4c, 4d, and 4f] November 13, 2003, LTR-NRC-03-66 (ADAMS Package No. ML033230526).

6. J. A. Gresham, Westinghouse Electric Company, letter to US NRC, "Response to NRC Request for Additional Information on Addendum 3 to WCAP-10266-P-A, Rev. 2 (Proprietary) and WCAP-11524-A, Rev. 2 (Non-Proprietary), "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)," [Responses to RAIs: 1b, 2a, 2b, 2c and 4c] January 26, 2004, LTR-NRC-04-4 (ADAMS Package No. ML040330189).

7. J. A. Gresham, Westinghouse Electric Company, letter to US NRC, "Response to NRC Request for Additional Information on Addendum 3 to WCAP-10266-P-A, Rev. 2 (Proprietary) and WCAP-1 1524-A, Rev. 2 (Non-Proprietary)," April 15, 2004, LTR-NRC-04-20 (ADAMS Accession No. ML041130209).

8. J. A. Gresham, Westinghouse Electric Company, letter to US NRC, "Presentation Material for January 25, 2005 Meeting Regarding WCAP-10266-P, Revision 2, Addendum 3 (Proprietary/Non-Proprietary)," January 24, 2005, LTR-NRC-05-2 (ADAMS Package No. ML050330489).

9. J. A. Gresham, Westinghouse Electric Company, letter to US NRC, "Response to NRC Request for Additional Information on WCAP-10266-P, Revision 2, Addendum 3, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)" (Proprietary/Non-Proprietary)," August 11, 2005, LTR-NRC-05-45 (ADAMS Package No. ML052300278).

10. B. F. Maurer, Westinghouse Electric Company, letter to US NRC, "Response to NRC Request for Additional Information on WCAP-10266-P, Revision 2, Addendum 3, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)", and Transmittal of Slide Package Entitled "Update on Large Break LOCA Evaluation Model Issue" (Proprietary/Non-Proprietary)," April 28, 2006, LTR-NRC-06-23 (ADAMS Accession No. ML061290471).

11. B. F. Maurer, Westinghouse Electric Company, letter to US NRC, "Response to NRC Request for Additional Information on WCAP-10266-P, Revision 2, Addendum 3, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)" (Proprietary/Non-Proprietary)," April 13, 2007, LTR-NRC-07-21 (ADAMS Accession No. ML071140206).

12. J. A. Gresham, Westinghouse Electric Company, letter to US NRC, "Submittal of WCAP-10266-P, Revision 2, Addendum 3, Revision 1 (Proprietary) and WCAP-11524, Revision 2, Addendum 3, Revision 1 (Non-Proprietary), "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)" June 29, 2007, LTR-NRC-07-32 (ADAMS Package No. ML071840041).

13. Westinghouse Electric Company, "SATAN VI Program: Comprehensive Space-Time Dependent Analysis of Loss-of-Coolant," WCAP-8302, June 1974. (Approved in WCAP-8471-P-A, "The Westinghouse ECCS Evaluation Model: Supplementary Information," April 1975).

14. Westinghouse Electric Company, "The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code," WCAP-10266-P-A, Revision 2, March 1987.

15. Westinghouse Electric Company,"Containment Pressure Analysis Code (COCO)," WCAP-8327, July 1974. (Approved in WCAP-8471-P-A, "The Westinghouse ECCS Evaluation Model: Supplementary Information," April 1975).

16. Westinghouse Electric Company, "Long Term Ice Condenser Containment Code - LOTIC Code," WCAP-8354-P-A, Supplement 1, April 1976.

17. Y. Sudo, "Estimation of Average Void Fraction in Vertical two-phase Flow Channel Under Low Liquid Velocity," *Journal of Nuclear Science and Technology*, 17(1), pp 1-15, January 1980.

18. Y. Sudo and H. Akimoto, "Downcomer Effective Water Head During Reflood in Postulated PWR LOCA," *Journal of Nuclear Science and Technology*, 19(1), pp 34-45, January 1982.

19. Y. Sudo and Y. Murao, "Experiment of the Downcomer Effective Water Head During a Reflood Phase of PWR LOCA," JAERI-M 7978, October 27, 1978.

20. Y. Sudo, Y. Murao, and H. Akimoto, "Experimental Results of the Effective Water Head in Downcomer During Reflood Phase of a PWR LOCA (2nd report, 50 mm Gap Size)," JAERI-M 8978, July 7, 1980.

21. US NRC, "Summary of the Semiscale Program (1965-1986)," NUREG/CR-4945, EGG-2509, July 1987.

22. Westinghouse Electric Company, "The Westinghouse ECCS Evaluation Model: Supplementary Information," WCAP-8471-P-A, April 1975.

23. Westinghouse Electric Company, "Spacer Grid Heat Transfer Effects During Reflood," WCAP-10484-P-A, Addendum 1, September 1993.

24. Westinghouse Electric Company, "BART-A1: A Computer Code for the Best Estimate Analysis of Reflood Transients," WCAP-9561-P-A, March 1984.

25. Westinghouse Electric Company, "Calculational Model for Core Reflooding After a Loss of Coolant Accident (WREFLOOD Code)," WCAP-8170, June 1974.

Principle Contributor: E. Throm

Date: September 17, 2007

RESOLUTION OF WESTINGHOUSE ELECTRIC COMPANY (WESTINGHOUSE)

COMMENTS ON DRAFT SAFETY EVALUATION (SE) FOR TOPICAL REPORT (TR)

WCAP-10266-P, REVISION 2, ADDENDUM 3, REVISION 1,

"INCORPORATION OF THE LOCBART [LOSS-OF-COOLANT (LOC), BEST ESTIMATE

ANALYSIS OF REFLOOD TRANSIENTS (BART)] TRANSIENT EXTENSION METHOD INTO

THE 1981 WESTINGHOUSE LARGE BREAK LOCA [LOSS-OF-COOLANT ACCIDENT]

EVALUATION MODEL WITH BASH [BART AND SYSTEM HYDRAULICS] (BASH-EM)"

(TAC NO. MB7485)

By letter dated August 30, 2007, Westinghouse provided seventeen comments on the draft SE for TR WCAP-10266-P, Revision 2, Addendum 3, Revision 1, "Incorporation of the LOCBART Transient Extension Method Into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)" and three comments on the cover letter associated with this draft SE. No information in the draft SE for this TR was identified as proprietary; therefore, the draft SE will be made publicly available. The following are the U.S. Nuclear Regulatory Commission (NRC) staff's resolution of these comments:

Cover Letter comments for TR WCAP-10266, Revision 2, Addendum 3, Revision 1:

1. Add "-A" following "WCAP-10266-P" (3 places).

   NRC Resolution for Comment 1 on Cover Letter:

   The cover letter cites TR WCAP-10266-P, Revision 2, Addendum 3, Revision 1, which is the subject of this SE and for which a "-A" version has not yet been issued. Therefore, the title of the TR in the cover letter (3 places) should not include the "-A." In general, whenever the subject is a previously approved and published TR (e.g., TR WCAP-10266-P-A, Revision 2) the "-A" is appropriate.

2. Change "Best Estimate Analysis Reflood Transient" to "Best Estimate Analysis of Reflood Transients" and BART System Hydraulics" to "BART and System Hydraulics" (Page 1, Subject line).

   NRC Resolution for Comment 2 on Cover Letter:

   The proposed change is adopted.

3. Add November 13, 2004, and April 13, 2007, to the list of supplemental letter dates (Page 1, 1st paragraph, 1st sentence).

   NRC Resolution for Comment 3 on Cover Letter:

   The proposed change is adopted.

ATTACHMENT

Draft SE comments for TR WCAP-10266, Revision 2, Addendum 3, Revision 1:

1. Add "-A" following "WCAP-10266-P" (Multiple Pages).

   NRC Resolution for Comment 1 on Draft SE:

   The proposed change is adopted in all instances where TR WCAP-10266-P, Revision 2, or earlier approved versions of TR WCAP-10266-P, are cited. The instance where TR WCAP-10266-P, Revision 2, Addendum 3, is cited is not adopted because TR WCAP-10266-P, Revision 2, Addendum 3, was never approved by the NRC staff. In addition, the proposed change is not adopted in instances where TR WCAP-10266-P, Revision 2, Addendum 3, Revision 1, is cited, because Westinghouse has not yet published the "-A" version.

2. Change "Best Estimate Analysis Reflood Transient" to "Best Estimate Analysis of Reflood Transients" and "BART System Hydraulics" to "BART and System Hydraulics" (Title).

   NRC Resolution for Comment 2 on Draft SE:

   The proposed change is adopted.

3. Add "Revision 2," after "WCAP-10266-P-A," (Page 1, line 9).

   NRC Resolution for Comment 3 on Draft SE:

   The proposed change is adopted.

4. Change "References 5 and 6" to "References 5, 6 and X", where X is the reference number for LTR-NRC-04-20 (Page 1, line 12).

   NRC Resolution for Comment 4 on Draft SE:

   The proposed change is adopted. However, "Reference X" is "Reference 7" in the Final SE.

5. Change to "Westinghouse subsequently provided its response to an additional request for information in Reference 8 (Page 1, lines 13-15).

   NRC Resolution for Comment 5 on Draft SE:

   The proposed change is adopted. However, "Reference 8" of the Draft SE is "Reference 9" in the Final SE.

6. Delete "in Reference 10" and the corresponding citation (not applicable to TR Revision 1) (Page 1, lines 24-25, and page 11, lines 39-44).

NRC Resolution for Comment 6 on Draft SE:

The proposed change is adopted.

7. Delete the following sentence for consistency with the original BASH-EM methodology: "At that point the reflood rate, from SMUUTH, is used to continue the hot rod heat up calculation in LOCBART" (Page 4, lines 25-26).

NRC Resolution for Comment 7 on Draft SE:

The proposed change is adopted.

8. Change "at the onset of" to "during" for consistency with TR Revision 1 (Page 4, line 40; Page 8, line 3; Page 10, line 23).

NRC Resolution for Comment 8 on Draft SE:

The proposed change is adopted.

9. Change "range of widths, from 2 to 8 inches" to "width of 2 or 8 inches" (Page 5, lines 28-29).

NRC Resolution for Comment 9 on Draft SE:

The proposed change is adopted.

10. Delete Reference 21 (repeated reference) and replace with Reference 14 (Page 5, line 40; Page 6, line 27; Page 7, lines 7 and 34; Page 8, line 9; Page 12, lines 42-43).

NRC Resolution for Comment 10 on Draft SE:

The proposed change is adopted.

11. Replace Reference 21 with a reference for WCAP-8170 (Reference 6-4 of TR Revision 1) (Page 6, line 17).

NRC Resolution for Comment 11 on Draft SE:

The proposed change is adopted. The reference for WCAP-8170 is Reference 25.

12. Replace Reference 21 with Reference 23 (Page 6, line 39).

NRC Resolution for Comment 12 on Draft SE:

The proposed change is adopted. Reference 23 in the Draft SE is Reference 22 in the Final SE.

13. Delete the first sentence and the word "also" from the second sentence (corresponding sensitivities removed in TR Revision 1), and change (Section 5.4 and 5.5, Reference 4)" to "(Sections 6.4 and 6.5, Reference 12)" (Page 8, line 28-33).

    NRC Resolution for Comment 13 on Draft SE:

    The proposed change is adopted.

14. Change "As such" to "In addition" to distinguish between the affected/unaffected plant designations provided in Reference 9 and the configurations identified in lines 42-44 (Page 9, line 44).

    NRC Resolution for Comment 14 on Draft SE:

    The proposed change is adopted.

15. Change "March 6" to "March 1" (Page 10, line 42).

    NRC Resolution for Comment 15 on Draft SE:

    The proposed change is adopted.

16. Change the title of Reference 20 to "Experimental Results of the Effective Water Head in Downcomer During Reflood Phase of a PWR LOCA (2nd report, 50 mm Gap Size)" (Page 12, lines 39-40).

    NRC Resolution for Comment 16 on Draft SE:

    The proposed change is adopted.

17. Change "BART-AI" to "BART-A1" (Page 13, line 7).

    NRC Resolution for Comment 17 on Draft SE:

    The proposed change is adopted.

Section B

Westinghouse

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Nuclear Services
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USA

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555-0001

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Direct fax: (412) 374-4011
e-mail: greshaja@westinghouse.com

Our ref: LTR-NRC-07-32

June 29, 2007

Subject: Submittal of WCAP-10266-P-A, Revision 2, Addendum 3, Revision 1 (Proprietary) and WCAP-11524-A, Revision 2, Addendum 3, Revision 1 (Non-Proprietary), "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)"

References:
1. Letter from S. Dembek (NRC) to H. Sepp (Westinghouse), "Potential Non-Conservative Modeling of Downcomer Boiling in the Approved Westinghouse 1981 Evaluation Model Using BASH," March 27, 2002.
2. Letter from H. A. Sepp (Westinghouse) to J. S. Wermiel (NRC), "Submittal of Addendum 3 to WCAP-10266-P-A, Rev. 2 (Proprietary) and WCAP-11524-A, Rev. 2, (Non-Proprietary), 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM),'" December 18, 2002.
3. Letter from B. F. Maurer (Westinghouse) to NRC Document Control Desk, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)' (Proprietary/Non-Proprietary)," April 13, 2007.

Enclosed are copies of:

1. WCAP-10266-P-A, Revision 2, Addendum 3, Revision 1, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)" (Proprietary).
2. WCAP-11524-A, Revision 2, Addendum 3, Revision 1, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)" (Non-Proprietary).

Also enclosed are:

1. One (1) copy of the Application for Withholding, AW-07-2297 (Non-Proprietary) with Proprietary Information Notice.
2. One (1) copy of Affidavit (Non-Proprietary).

This information is being submitted by Westinghouse Electric Company LLC for NRC review and approval in accordance with Reference 1; Revision 0 was previously submitted in Reference 2 and has been revised to incorporate various changes, including the responses to NRC requests for additional information transmitted in Reference 3.

This submittal contains proprietary information of Westinghouse Electric Company, LLC. In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Commission's regulations, we are enclosing with this submittal an Application for Withholding from Public Disclosure and an affidavit. The affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the affidavit or Application for Withholding should reference AW-07-2297 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Enclosures

cc: Jon Thompson (NRC O-7E1A)

Westinghouse

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Our ref: AW-07-2297

June 29, 2007

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: WCAP-10266-P-A, Revision 2, Addendum 3, Revision 1, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)" (Proprietary)

Reference: Letter from J. A. Gresham to NRC, LTR-NRC-07-32, dated June 29, 2007.

The Application for Withholding is submitted by Westinghouse Electric Company LLC (Westinghouse), pursuant to the provisions of Paragraph (b) (1) of Section 2.390 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.390, Affidavit AW-07-2297 accompanies this Application for Withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to this Application for Withholding or the accompanying affidavit should reference AW-07-2297 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Enclosures

cc: Jon Thompson (NRC O-7E1A)

AW-07-2297

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared J. A. Gresham, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

PATRICIA L. CROWN COMMONWEALTH OF PENNSYLVANIA NOTARY PUBLIC

J. A. Gresham

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Sworn to and subscribed before me
this 29th day of JUNE, 2007

Patricia L Crown
Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Patricia L. Crown, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Feb. 7, 2009
Member, Pennsylvania Association of Notaries

(1) I am Manager, Regulatory Compliance and Plant Licensing, in Nuclear Services, Westinghouse Electric Company LLC (Westinghouse), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse "Application for Withholding" accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in WCAP-10266-P-A, Revision 2, Addendum 3, Revision 1, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)" (Proprietary), dated June 2007, for submittal to the Commission, being transmitted by Westinghouse letter (LTR-NRC-07-32) and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse is that associated with Westinghouse's request for NRC approval of WCAP-10266-P-A, Revision 2, Addendum 3, Revision 1, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)."

This information is part of that which will enable Westinghouse to:

(a) Obtain NRC approval of WCAP-10266-P-A, Revision 2, Addendum 3, Revision 1, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)."

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for licensing documentation.

(b) Westinghouse can sell support and defense of the use of large break LOCA analysis predictions including the LOCBART Transient Extension Method.

(c) The information requested to be withheld reveals the distinguishing aspects of a methodology which was developed by Westinghouse.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar calculations and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

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1 INTRODUCTION

The 1981 Westinghouse Large Break LOCA (LBLOCA) Evaluation Model with BASH (BASH Evaluation Model or BASH-EM) is used to perform LBLOCA simulations in accordance with the requirements of 10 CFR 50 Appendix K. Westinghouse has developed a method to extend BASH-EM transients beyond the point at which downcomer boiling is predicted to occur in BASH by correlating the boiling-induced reduction in downcomer driving head to a corresponding reduction in the core inlet flooding rate. This approach is denoted as the LOCBART Transient Extension Method and is used to ensure adequate termination of the fuel rod cladding temperature and oxidation transients, as required to demonstrate compliance with the acceptance criteria of 10 CFR 50.46.

This report describes the incorporation of the LOCBART Transient Extension Method into the BASH-EM. Section 2 provides a brief description of the main computer codes that comprise the BASH-EM. Section 3 provides an overview of the Sudo Correlation, which is used to calculate the axial void profile in the downcomer during downcomer boiling. Section 4 describes the LOCBART Transient Extension Method, including the procedure used to calculate the core inlet flooding rate during downcomer boiling. Section 5 describes the validation of the Sudo Correlation against experiments conducted in the Japan Atomic Energy Research Institute (JAERI) downcomer boiling test facility. Section 6 demonstrates compliance with the 10 CFR 50 Appendix K requirements cited in the Nuclear Regulatory Commission (NRC) letter of 27 March 2002 (Reference 1-1). Section 7 identifies limitations that will be applied to the future usage of BASH-EM until the transition to realistic LBLOCA methods is complete.

This report has been prepared as an addendum to WCAP-10266-P-A, Revision 2 (Reference 1-2), in which the BASH-EM was originally approved for licensing applications by an NRC Safety Evaluation Report (SER) of 13 November 1986. Addendum 1 was approved by an NRC SER of 15 September 1987 (Reference 1-3), and Addendum 2 was approved by an NRC SER of 20 January 1988 (Reference 1-4), so the present report is denoted as Addendum 3 to WCAP-10266-P-A, Revision 2. This revision reflects the responses to NRC requests for additional information (RAIs) transmitted in Reference 1-5 and incorporates various updates to use more recent information and enhance readability.

1.1 REFERENCES FOR SECTION 1

1-1. Letter from S. Dembek (NRC) to H. Sepp (Westinghouse), "Potential Non-Conservative Modeling of Downcomer Boiling in the Approved Westinghouse 1981 Evaluation Model Using BASH," March 27, 2002.

1-2. WCAP-10266-P-A, Revision 2, "The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code," March 1987.

1-3. WCAP-10266-P-A, Revision 2, Addendum 1, "The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code; Addendum 1: Power Shape Sensitivity Studies," December 1987.

1-4. WCAP-10266-P-A, Revision 2, Addendum 2, "The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code; Addendum 2: BASH Methodology Improvements and Reliability Enhancements," May 1988.

1-5. LTR-NRC-07-21, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)' (Proprietary/Non-Proprietary)," April 13, 2007.

2 OVERVIEW OF BASH EVALUATION MODEL

This section provides a brief description of the main computer codes that comprise the BASH-EM.

The SATAN-VI code (Reference 2-1) calculates the blowdown thermal-hydraulic portion of the transient. The system response is determined by solving the conservation equations of mass, energy and momentum, with a constitutive drift flux model allowing for relative motion between the liquid and vapor phases. SATAN-VI models the core using hot and average channels, with radial flow paths used to account for crossflow between the channels. Fluid conditions in the hot channel are transferred to LOCBART and are used to define the thermal-hydraulic boundary conditions during the blowdown phase of the transient.

The BASH and SMUUTH codes (Reference 2-2) calculate the refill and reflood thermal-hydraulic portions of the transient. The refill module of BASH contains the models that describe the transport of water from the emergency core cooling system (ECCS) injection points to the reactor vessel lower plenum. The reflood module of BASH contains the models that compute the integrated system response following bottom-of-core recovery, using a minimum containment pressure transient calculated using the interactive COCO module (Reference 2-3) for dry containment plants or the stand-alone LOTIC2 code (Reference 2-4) for ice condenser containment plants. The SMUUTH code smoothes the core inlet flooding rate and enthalpy during reflood for use in LOCBART, eliminating the reflood oscillations predicted by BASH while preserving the net mass flow into the core.

The LOCBART code (Reference 2-2) calculates the cladding temperature and oxidation transients for the highest-powered fuel rod in the core during all three phases of the transient. LOCBART was developed by merging the LOCTA-IV (Reference 2-5) fuel rod heat conduction code with the BART-A1 (Reference 2-6) core reflood heat transfer code and replaces the prior application of the FLECHT Correlation (Reference 2-7) with a mechanistic treatment of core heat transfer during reflood. The mechanistic models calculate the heat transfer coefficients appropriate to the flow and heat transfer regimes that develop axially in the hot channel, with a detailed spacer grid heat transfer model (References 2-8 and 2-9) used to account for the effects of local flow acceleration and improved interfacial heat transfer.

2.1 REFERENCES FOR SECTION 2

2-1. WCAP-8302, "SATAN VI Program: Comprehensive Space-Time Dependent Analysis of Loss-of-Coolant," June 1974. *(Approved in Reference 2-10.)*

2-2. WCAP-10266-P-A, Revision 2, "The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code," March 1987.

2-3. WCAP-8327, "Containment Pressure Analysis Code (COCO)," July 1974. *(Approved in Reference 2-10.)*

2-4. WCAP-8354-P-A, Supplement 1, "Long Term Ice Condenser Containment Code - LOTIC Code," April 1976.

2-5. WCAP-8301, "LOCTA-IV Program: Loss-of-Coolant Transient Analysis," June 1974. *(Approved in Reference 2-10.)*

2-6. WCAP-9561-P-A, "BART-A1: A Computer Code for the Best Estimate Analysis of Reflood Transients," March 1984.

2-7. WCAP-9220-P-A, Revision 1, "Westinghouse ECCS Evaluation Model, 1981 Version," February 1982.

2-8. WCAP-10484-P-A, "Spacer Grid Heat Transfer Effects During Reflood," March 1991.

2-9. WCAP-10484-P-A, Addendum 1, "Spacer Grid Heat Transfer Effects During Reflood," September 1993.

2-10. WCAP-8471-P-A, "The Westinghouse ECCS Evaluation Model: Supplementary Information," April 1975.

3 DISCUSSION OF SUDO CORRELATION

As discussed in Section 4, the LOCBART Transient Extension Method uses a void fraction correlation developed by Sudo (Reference 3-1) to calculate the axial void profile in the downcomer during downcomer boiling. The Sudo Correlation relates the average void fraction (α) to the characteristic diameter, fluid saturation properties and vapor superficial velocity using the following equation:

$$\alpha = \frac{Y}{AX^m}$$

where:

$$X = \left(\frac{\mu_g j_g}{\sigma g_c}\right)\left(\frac{\mu_f}{\mu_g}\right)^{.82}\left(\frac{\rho_g}{\rho_f}\right)^{.2}$$

$$Y = \left(\frac{\sigma g_c}{\rho_f g D^2}\right)^{.064}\left(\frac{\mu_g}{\mu_f}\right)^{.125}$$

Regime	A	m
X ≤ .0005	.00523	-.704
.0005 < X ≤ .004	.093	-.325
X > .004	.54	0

and where:

D	=	characteristic diameter (ft)
g	=	32.2 ft/s^2
g_c	=	32.2 ft-lbm/lbf-s^2
j_g	=	vapor superficial velocity (ft/s)
μ_f	=	saturated liquid viscosity (lbm/s-ft)
μ_g	=	saturated vapor viscosity (lbm/s-ft)
ρ_f	=	saturated liquid density (lbm/ft^3)
ρ_g	=	saturated vapor density (lbm/ft^3)
σ	=	liquid surface tension (lbf/ft)

The tabulated values for A and m correspond to the bubbly/bubbly-slug, fully-developed slug and annular flow regimes. [

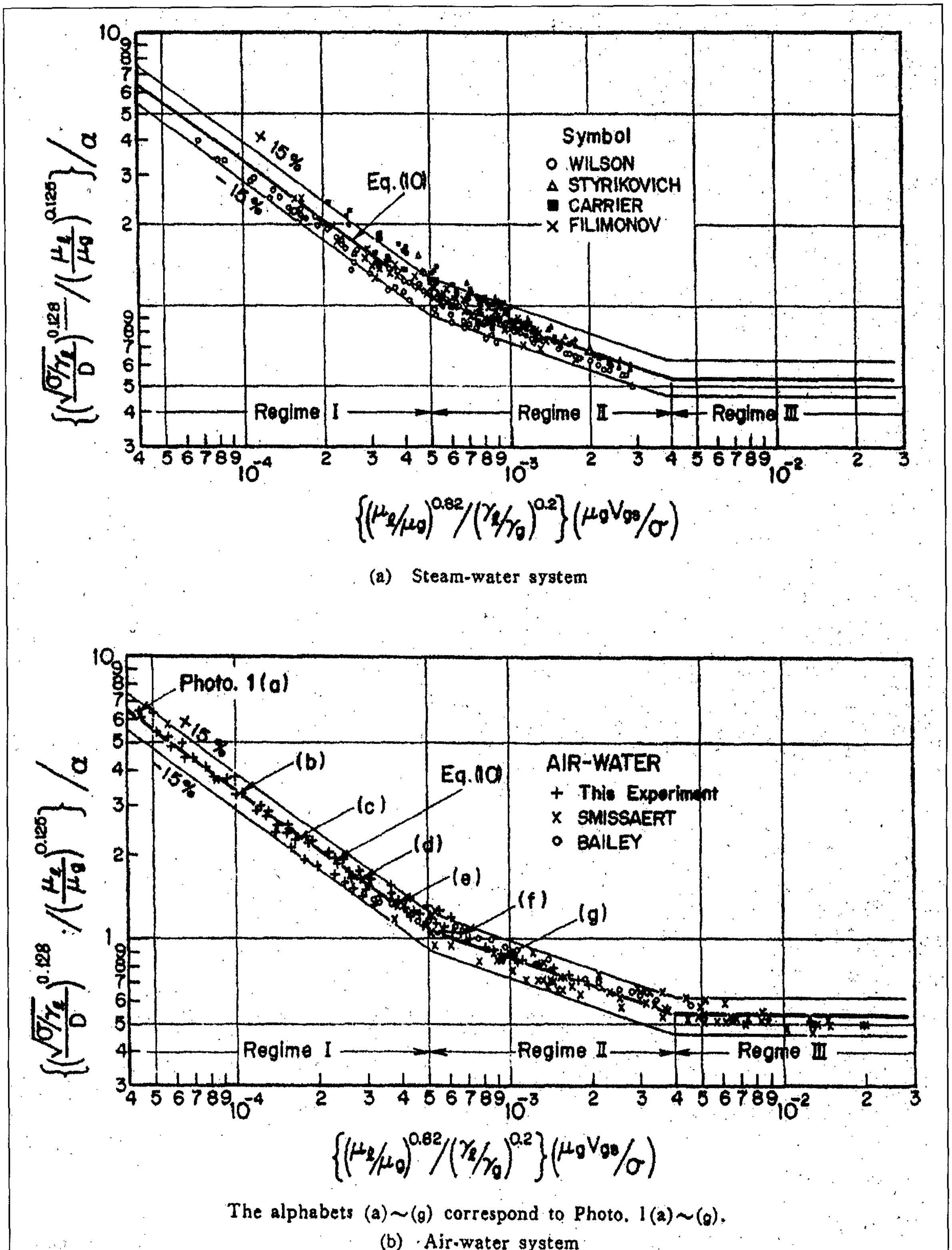
]^{a,c}

The Sudo Correlation was developed using dimensional analysis considering data from both steam-water and air-water systems. The steam-water data span tube diameters from 2.5 to 19 in, pressures from 90 to 1630 psia and liquid superficial velocities from 0 to 12 in/s. The air-water data span tube diameters from 2.1 to 6 in, with a pressure of 14.7 psia and a liquid superficial velocity near zero. [

]a,c Figure 3-1 (Reference 3-1) shows an error band of approximately ±15%, indicating a reasonably accurate prediction of the average void fraction under a fairly wide range of conditions.

3.1 REFERENCES FOR SECTION 3

3-1. Sudo, Y., "Estimation of Average Void Fraction in Vertical Two-Phase Flow Channel under Low Liquid Velocity," Journal of Nuclear Science and Technology, 17(1), pp. 1-15, January 1980.



(a) Steam-water system

The alphabets (a)~(g) correspond to Photo. 1(a)~(g).
(b) Air-water system

Figure 3-1: Comparison of Sudo Correlation to Experimental Data

4 DESCRIPTION OF LOCBART TRANSIENT EXTENSION METHOD

The LOCBART Transient Extension Method is based on a method developed by MPR (Reference 4-1) and uses the Sudo Correlation (Section 3) to calculate the average void fraction in the downcomer during downcomer boiling. The axial void profile is integrated to calculate an equivalent void height, and the corresponding reduction in downcomer driving head is used to calculate a reduction in the core inlet flooding rate. The core inlet flooding rate, core inlet enthalpy and core pressure are specified as boundary conditions in the LOCBART input and are used to extend the calculation as required to demonstrate termination of the hot rod cladding temperature and oxidation transients.

Reference 4-2 proposed several changes to the methodology described in Sections 3 and 4.4 of Revision 0 of this report to address the technical questions identified in NRC RAIs 1 and 3-5. Following is a revised methodology description reflecting the changes identified in Reference 4-2.

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2. [

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4. [

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Reference 4-2 describes sensitivity calculations that were completed to demonstrate the effect of the proposed changes to the LOCBART Transient Extension Method on the core inlet flooding rate during downcomer boiling, the peak cladding temperature (PCT) and the maximum local oxidation (MLO) for a sample plant with a neutron pad design. The flooding rate multiplier calculated using the revised methodology (i.e., Case G of Reference 4-2) [

]a,c. A further reduction would be expected for a plant with a thermal shield design, due primarily to the increased wall heat release rate and the decreased flow area and characteristic diameter in the thermal shield region.

4.1 REFERENCES FOR SECTION 4

4-1. MPR-1163, "Summary of Results from the UPTF Downcomer Separate Effects Tests, Comparison to Previous Scaled Tests, and Application to U. S. Pressurized Water Reactors," July 1990.

4-2. LTR-NRC-07-21, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)' (Proprietary/Non-Proprietary)," April 13, 2007.

4-3. WCAP-9561-P-A, "BART-A1: A Computer Code for the Best Estimate Analysis of Reflood Transients," March 1984.

5 VALIDATION AGAINST EXPERIMENTAL DATA

This section describes the validation of the Sudo Correlation against experiments conducted in the JAERI downcomer boiling test facility (References 5-1 and 5-2). The experiments were conducted in a full-scale rectangular downcomer simulator under atmospheric pressure, with heated walls to simulate the metal heat release that occurs during a pressurized water reactor (PWR) LBLOCA reflood transient. Section 5.1 describes the test facility and experimental procedure, and Section 5.2 describes the simulation of selected experiments using the Sudo Correlation.

5.1 FACILITY DESCRIPTION AND EXPERIMENTAL PROCEDURE

Figure 5-1 (Reference 5-3) provides a schematic of the JAERI downcomer boiling test facility. The downcomer simulator consisted of two heated carbon steel plates with a thickness of 50 mm, arranged in parallel to form a rectangular flow channel with a height of 6.5 m, heated length of 5 m, width of 1 m and gap width of 200 mm. (Note that the lower and upper plenum heights in Figure 5-1 appear to be reversed; see Figures 4 and 5 of Reference 5-1 and Figures 2 and 3 of Reference 5-2.) The inner surfaces were lined with stainless steel with a thickness of 6 mm, simulating the cladding in a PWR reactor vessel. A removable insert with a thickness of 100 mm was used in some experiments to form two parallel flow channels with a 50 mm gap width. Water was supplied to the downcomer simulator by one of two injection modes: Mode A, which used the bottom injection port for a rapid initial filling representative of accumulator injection flow rates, or Mode B, which used the top injection port for a gradual initial filling representative of pumped safety injection flow rates. Both modes used the top injection port after the initial filling, with excess water removed through an overflow line. An extraction line at the bottom of the downcomer simulator was used in some experiments to remove water at a velocity of 0.5, 1 or 2 cm/s, simulating the net loss of downcomer inventory resulting from the core reflooding process. According to Reference 5-3, "[t]he results show no significant effect of extracted water velocity on effective water head in the range of 0 to 2 cm/s downward".

Thermocouples and differential pressure cells were placed at various locations along the heated length and were used to determine the wall surface heat flux (by the method of inverse heat conduction) and the downcomer collapsed liquid levels. Measurements of temperatures and differential pressures began after the downcomer walls and injection fluid were heated to the desired temperature. The initial wall temperature was between 200°C and 300°C for all tests except one, representative of the average vessel wall temperature at the beginning of a simulated PWR reflood transient. The injection temperature was between 96°C and 100°C for all tests except two, representative of the temperature of liquid entering the downcomer during a simulated PWR reflood transient after the accumulators have emptied.

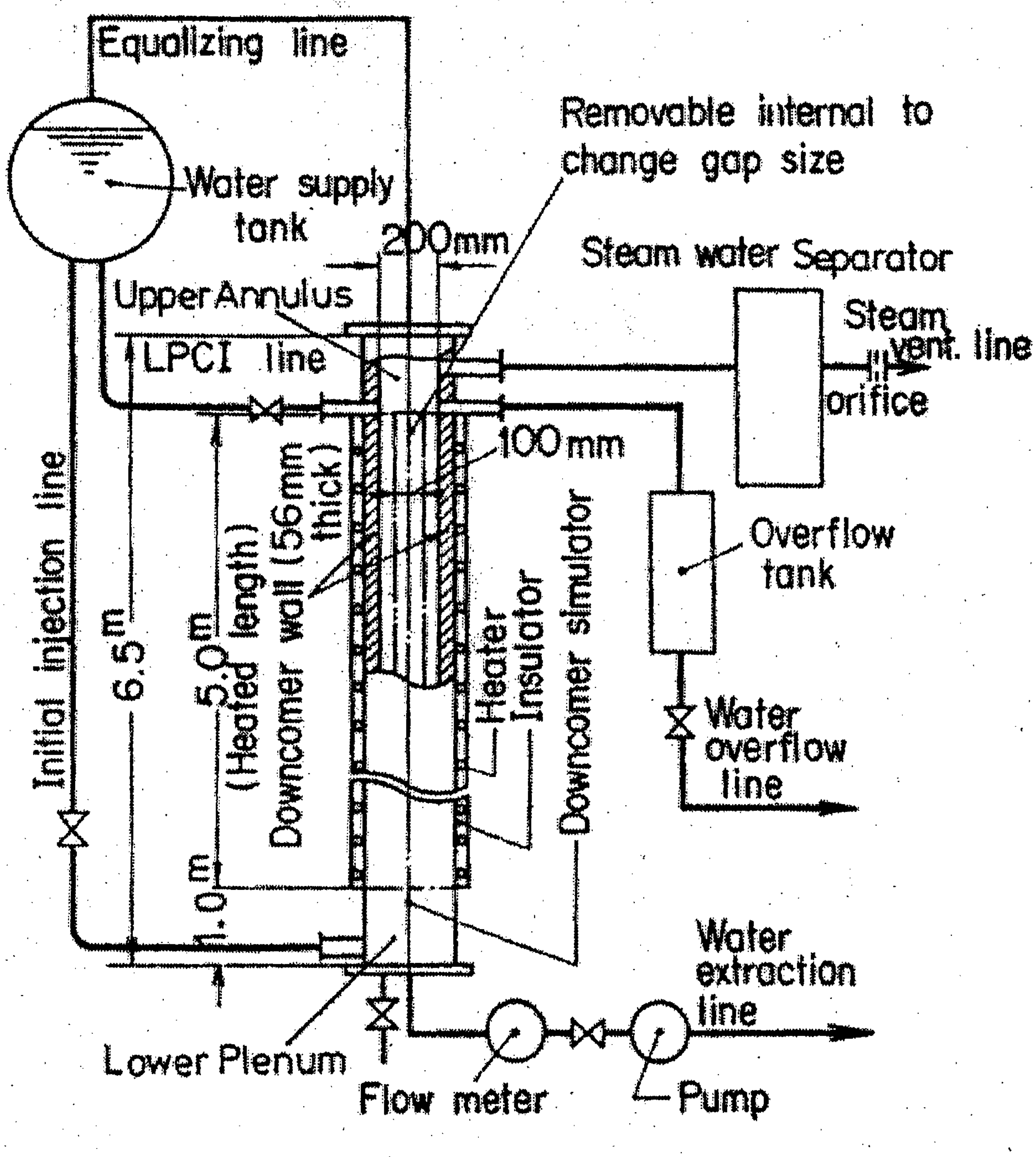

Fig. 1 Schematic of test apparatus

Figure 5-1: Schematic of JAERI Downcomer Boiling Test Facility

5.2 SIMULATION OF SELECTED EXPERIMENTS

Several experiments from the JAERI downcomer boiling test facility have been simulated to demonstrate the predictive capability of the Sudo Correlation for the conditions of interest. The simulations incorporated the applicable changes from the response to RAI 1 (Reference 5-4) except for the [

]a,c. Table 5-1 is based primarily on Table 2 of Reference 5-1 and Table 1 of Reference 5-2 and shows the gap width (S), number of heated walls (N_{WALLS}), initial wall temperature (T_W), extracted water velocity (V_{EX}), injection temperature (T_{INJ}) and injection mode (Mode) for the experiments that have been simulated as part of the present effort.

Table 5-1: Test Conditions for JAERI Run Nos. 115, 116, 120, 211 and 213

Run No.	S, mm (in)	N_{WALLS}	T_W, °C (°F)	V_{EX}, cm/s (in/s)	T_{INJ}, °C (°F)	Mode
115	200 (7.9)	2	250 (482)	0 (0)	98 (208)	A
116	200 (7.9)	2	275 (527)	0 (0)	100 (212)	A
120	200 (7.9)	2	300 (572)	2 (0.8)	100 (212)	A
211	50 (2.0)	1	250 (482)	0 (0)	99 (210)	A
213	50 (2.0)	1	250 (482)	0 (0)	97 (207)	B

The wall surface heat flux histories used in the simulations of Run Nos. 115, 116, 120, 211 and 213 are based on [

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Figures 5-3 to 5-5 provide sample results from the simulations of Run Nos. 115, 116, 120, 211 and 213 including the vapor superficial velocity and void fraction at the top of the heated length and the collapsed liquid level across the heated length. Review of these figures leads to the following observations:

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- [

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- [

]^{a,c}

Figures 5-6 to 5-9 compare the measured and predicted collapsed liquid levels for Run Nos. 115, 116, 120 and 211, using measured values based on [

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Figure 5-11 compares the measured and predicted collapsed liquid levels for Run No. 213, using measured values based on [

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[

]a,c

Figure 5-2: Average Wall Surface Heat Flux vs. Time for Run Nos. 115, 116, 120, 211 and 213

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Figure 5-3: Vapor Superficial Velocity at 5 m for Run Nos. 115, 116, 120, 211 and 213

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Figure 5-4: Void Fraction at 5 m for Run Nos. 115, 116, 120, 211 and 213

[

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Figure 5-5: Collapsed Liquid Level Between 0 and 5 m for Run Nos. 115, 116, 120, 211 and 213

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Figure 5-6: Comparison of Measured and Predicted Collapsed Liquid Levels for Run No. 115

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Figure 5-7: Comparison of Measured and Predicted Collapsed Liquid Levels for Run No. 116

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]a,c

Figure 5-8: Comparison of Measured and Predicted Collapsed Liquid Levels for Run No. 120

[

]a,c

Figure 5-9: Comparison of Measured and Predicted Collapsed Liquid Levels for Run No. 211

[

]a,c

Figure 5-10: Comparison of Downcomer Volumetric Heat Load Transients for JAERI Run Nos. 115, 116, 120 and 211 and Sample BASH PWR Calculation

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]a,c

Figure 5-11: Comparison of Measured and Predicted Collapsed Liquid Levels for Run No. 213

5.3 REFERENCES FOR SECTION 5

5-1. JAERI-M 7978, "Experiment of the Downcomer Effective Water Head during a Reflood Phase of PWR LOCA," October 1978.

5-2. JAERI-M 8978, "Experimental Results of the Effective Water Head in Downcomer during Reflood Phase of a PWR LOCA (2nd Report, 50 mm Gap Size)," July 1980.

5-3. Sudo, Y., and Akimoto, H., "Downcomer Effective Water Head during Reflood in Postulated PWR LOCA," Journal of Nuclear Science and Technology, 19[1], pp. 34-45, January 1982.

5-4. LTR-NRC-07-21, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)' (Proprietary/Non-Proprietary)," April 13, 2007.

6 COMPLIANCE WITH 10 CFR 50 APPENDIX K

This section demonstrates compliance with the 10 CFR 50 Appendix K requirements cited in Reference 6-1. Plant designations "A" and "B" are retained from Revision 0 of this report and represent the 3-loop dry containment and 4-loop ice condenser containment plants used in the comparisons of BASH-EM and Best Estimate LOCA (BELOCA) results. Plant designation "C" is added for Revision 1 to identify the 4-loop ice condenser containment plant used for most of the other sensitivity studies reported in this section. (Note that the LOCBART calculations shown in Figures 6-3, 6-5, 6-6 (Curve "C"), 6-7 (Curve "C"), 6-10, 6-14 (Curves "A" and "C"), 6-16 (solid curve) and 6-17 used the original LOCBART Transient Extension Method as described in Revision 0 of this report; see Reference 6-2 for sensitivity calculations comparing the original and revised methods.)

6.1 SECTION I.A.6 - REACTOR INTERNALS HEAT TRANSFER

10 CFR Part 50, Appendix K, Section I.A.6 requires that heat transfer from the reactor vessel walls and non-fuel internal hardware be taken into account. [Westinghouse] must demonstrate how this is accomplished in the 1981 EM using BASH and with the LOCBART extension method after the onset of downcomer boiling.

In the BASH code, fluid nodes and metal nodes account for mass and energy content, and flow links and heat links account for mass, energy and momentum transfer. For most of the metal structures in the reactor coolant system, a single metal node temperature is calculated using the slab heat transfer model described in Section 3.13 of Reference 6-3. For the lower plenum and downcomer, internal metal temperature profiles are calculated using the detailed heat transfer model described in Section 3.14 of Reference 6-3. The detailed model uses an implicit finite-difference method that considers plate, cylindrical or spherical geometry in a uniform or composite structure and provides a reasonably accurate calculation of the internal temperature distribution.

The metal-to-fluid heat transfer calculations use the heat link models described in Section 3.20 of Reference 6-3. These models consider subcooled, saturated and superheated fluid states and maximize the energy transfer by using the maximum heat flux from various heat transfer regimes. Figure 6-1 shows the heat transfer regime selection logic for subcooled fluid, which is applied to the downcomer in standard PWR licensing calculations. The heat transfer regimes considered for subcooled fluid include natural convection (SNC), forced convection (SFC), nucleate boiling (SNB), transition boiling (STB) and film boiling (SFB), with the critical heat flux (CHF) evaluated using the MacBeth Correlation. (Note that q", SC, T_W and T_{SAT} denote heat flux, subcooled convection, wall temperature and saturation temperature, respectively.) Figure 6-2 shows the downcomer metal-to-fluid heat flow rate prior to downcomer boiling from a sample BASH PWR calculation. Subcooled transition boiling exists very early in reflood, followed by subcooled nucleate boiling until the bulk downcomer fluid reaches saturation.

As discussed in Section 4, the LOCBART Transient Extension Method uses the
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]^{a,c} and therefore complies with the cited requirement of 10 CFR 50 Appendix K.

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Figure 6-1: BASH Heat Transfer Regime Selection Logic for Subcooled Fluid

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Figure 6-2: Downcomer Metal-to-Fluid Heat Flow Rate Prior to Downcomer Boiling for 4-Loop Ice Condenser Plant "C"

6.2 SECTION I.D.3 - CALCULATION OF REFLOOD RATE

10 CFR Part 50, Appendix K, Section I.D.3 requires that "[t]he refilling of the reactor vessel and the time and rate of reflooding of the core be calculated by an acceptable model that takes into consideration the thermal and hydraulic characteristics of the core and of the reactor system. ... The effects on reflooding rate of the compressed gas in the accumulator which is discharged following accumulator water discharge shall also be taken into account." [Westinghouse] must demonstrate how this is accomplished in the 1981 EM using BASH and with the LOCBART extension method after the onset of downcomer boiling.

Section I.D.3 of 10 CFR 50 Appendix K pertains to the calculation of the reflood rate and identifies three considerations (locked-rotor assumption, carryover fraction and accumulator nitrogen discharge) that must be specifically addressed.

Locked-Rotor Assumption
In BASH, the reactor coolant pump is modeled as a resistance in the cold leg based on a locked-rotor assumption. This maximizes the resistance through the pump, which was shown in a prior Evaluation Model study (Reference 6-4, Section 4.4.8) to reduce the flooding rate. There is no change to the locked-rotor assumption during downcomer boiling.

Carryover Fraction
In Reference 6-3, the comparisons of BASH against experimental data were made directly against the measured flooding rate and integral flooding rate, in addition to the total carryover fraction. The flooding rate and integral flooding rate are more readily defined for gravity reflood simulations and more directly influence the peak cladding temperature since the flooding rate is supplied to LOCBART as a boundary condition. These comparisons showed that BASH provides a representative-to-conservative prediction of the carryover fraction and conservatively predicts the flooding rate and integral flooding rate. The flooding rate is reduced during downcomer boiling to account for the loss of driving head between the downcomer and core, in the manner described in Section 4.

Accumulator Nitrogen Discharge
As discussed in Appendix F of Reference 6-3, a prior Evaluation Model study (Reference 6-5, Section 3.8 and Appendix C) showed that accumulator nitrogen discharge pressurizes the downcomer and increases the flooding rate. This behavior is supported by experimental results (e.g., LOFT) and was used to conclude that accumulator nitrogen discharge could be conservatively neglected in BASH. (Note that accumulator nitrogen discharge is modeled in the minimum containment pressure calculations.) As discussed in Reference 6-6, Semiscale tests indicated a long-term increase in system pressure due to accumulator nitrogen discharge. This would produce an increase in the flooding rate, which is conservatively neglected, and a decrease in pumped injection flow, which is a very small effect over the pressure range of interest and is also neglected. There is no change to the treatment of accumulator nitrogen discharge during downcomer boiling.

6.3 SECTION I.D.4 - STEAM INTERACTION WITH EMERGENCY CORE COOLING WATER

10 CFR Part 50, Appendix K, Section I.D.4 requires that "[t]he thermal-hydraulic interaction between steam and all emergency core cooling water shall be taken into account in calculating the core reflooding rate." ... [Westinghouse] must demonstrate how this is accomplished in the 1981 EM using BASH and with the LOCBART extension method after the onset of downcomer boiling.

As discussed in Section 11.0 of Reference 6-3, BASH assumes equilibrium behavior in the cold legs. This assumption maximizes the condensation of steam flowing from the intact cold legs to the downcomer, minimizing the pressurization of the downcomer due to steam flowing through the broken nozzle and reducing the flooding rate. This assumption also minimizes the subcooling of the emergency core cooling (ECC) fluid entering the downcomer, reducing the downcomer saturation time and leading to an earlier reduction of the flooding rate.

As discussed in Section 11.0 of Reference 6-3, an additional pressure drop is applied in the cold legs to account for pressure oscillations during accumulator injection. As discussed in Section 2.2.1 of Reference 6-5, this pressure drop reflects steam/water mixing data for injection angles of 90° (1.8 psi) and 45° (0.6 psi) and was approved for licensing application as being sufficiently conservative. BASH-EM predicts accumulator emptying to occur well before downcomer boiling, so this requirement is not pertinent to the LOCBART Transient Extension Method.

During the transient extension, the effects of downcomer boiling and entrainment are considered in calculating the reduced flooding rate. Vertical entrainment effects due to steam escaping from the downcomer are reflected through use of the Sudo Correlation, [

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6.4 SECTION I.D.5 - REFILL AND REFLOOD HEAT TRANSFER

10 CFR Part 50, Appendix K, Section I.D.5 requires that (a) for reflood rates of one inch per second or higher, reflood heat transfer coefficients shall be based on applicable experimental data for unblocked cores including FLECHT results, and (b) during refill and during reflood when reflood rates are less than one inch per second, heat transfer calculations shall be based on the assumption that cooling is only by steam, and shall take into account any flow blockage calculated to occur as a result of cladding swelling or rupture as such blockage might affect both local steam flow and heat transfer. [Westinghouse] must demonstrate how this is accomplished in the 1981 EM using BASH and with the LOCBART extension method after the onset of downcomer boiling.

Compliance of BASH-EM with Section I.D.5 of 10 CFR 50 Appendix K was originally demonstrated in Section 11.0 of Reference 6-3 and is supplemented by the validation of the LOCBART reflood heat transfer models as described in Reference 6-7. When the flooding rate is less than or equal to 1 inch per second, direct heat transfer to liquid is ignored, and assembly blockage is modeled if the hot assembly average rod has been predicted to burst. There is no change to the modeling of reflood heat transfer during downcomer boiling, though the heat transfer from the rods to the coolant is generally degraded when the flooding rate is reduced. Refer to Section 6.5 for a sensitivity study demonstrating the effect of reducing the flooding rate during downcomer boiling on the hot rod peak cladding temperature and local oxidation at the limiting elevation.

During refill, LOCBART assumes an adiabatic heatup except for rod-to-rod radiation. This assumption, combined with the substantial delay that is predicted to occur between the end of bypass and the end of refill, produces a significant increase in cladding temperatures that has been estimated in Reference 6-8 as a source of about 100 K (180°F) conservatism in Appendix K Evaluation Models.

LOCBART accounts for assembly blockage by reducing the steam mass velocity in the vicinity of the burst, with no direct credit for the beneficial effects of flow acceleration, turbulence intensification and droplet atomization that have been observed experimentally (e.g., Reference 6-9). With this formulation, assembly blockage degrades heat transfer and increases cladding temperatures in the vicinity of the burst, which is conservative relative to experimental results and can represent a substantial conservatism in the analysis when the peak cladding temperature occurs late in reflood. Figure 6-3 illustrates the effect of assembly blockage on the hot rod peak cladding temperature and local oxidation at the limiting elevation for a LOCBART calculation with a late-reflood peak cladding temperature and an assembly blockage [ ]^{a,c} near the maximum value [ ]^{a,c}. As shown in Figure 6-3, decreasing the assembly blockage from [ ]^{a,c} decreases the peak cladding temperature and maximum local oxidation by about [ ]^{a,c}, respectively, for this sample calculation.

Reference 6-7 describes the validation of the LOCBART reflood heat transfer models against FLECHT Low Flooding Rate Cosine, FLECHT SEASET and G2 experiments. For the simple egg-crate grids used in the FLECHT experiments, LOCBART predicted peak cladding temperatures near the mean of the data with a slightly conservative capture fraction. For the production-type mixing vane grids used in the G2 experiments, LOCBART predicted peak cladding temperatures that bounded nearly all of the data. This difference in behavior was attributed to the inability of the LOCBART spacer grid heat transfer models to fully capture the heat transfer benefit of the mixing vanes and can represent a substantial conservatism in the analysis when the peak cladding temperature occurs late in reflood.

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Figure 6-3: Effect of Assembly Blockage on Hot Rod Peak Cladding Temperature and Local Oxidation at Limiting Elevation for 4-Loop Ice Condenser Plant "C"

6.5 SECTION II.2 - SOLUTION CONVERGENCE

10 CFR Part 50, Appendix K, Section II.2 requires that for each computer program, solution convergence be demonstrated by studies of system modeling or noding and calculational time steps. This requirement is not satisfied because the BASH code fails when downcomer boiling is predicted to occur. [Westinghouse] should discuss how and why the BASH code fails, and demonstrate why the 1981 BASH-EM solution converges under these conditions and is acceptable for the entire duration of its expected calculational period (entire duration of the refill and reflood portions of the transient).

As discussed in Reference 6-3, BASH models the downcomer using a lower liquid cell and an upper vapor cell with a moving interface between them. [

]^{a,c} A rigorous treatment is beyond the capability of an Appendix K code such as BASH and would require a level of detail similar to WCOBRA/TRAC, which models downcomer boiling and entrainment explicitly using a two-fluid representation and multidimensional noding.

BASH solution convergence was originally demonstrated in Section 11.0 of Reference 6-3 and was subsequently improved by reducing the minimum and maximum time step sizes (Reference 6-10). LOCBART solution convergence is based primarily on the axial node spacing and time step selection. The axial node spacing is determined by the maximum allowable value from Reference 6-11 (6″), the value required to resolve the axial blockage profile (3″) and the minimum value implied by Section I.A.5 of 10 CFR 50 Appendix K (3″). The time step size is taken as [ ]^{a,c} during refill and is calculated internally during reflood using appropriate selection criteria, with minimum and maximum values of [ ]^{a,c}, respectively, used for standard PWR licensing calculations. Figure 6-5 shows the effect of reducing the maximum reflood time step size on the hot rod peak cladding temperature and local oxidation at the limiting elevation for a sample LOCBART calculation, indicating a minimal effect on results.

Figures 6-6 and 6-7 show the effect of varying the flooding rate during downcomer boiling on the hot rod peak cladding temperature and local oxidation at the limiting elevation for a sample LOCBART calculation. The peak cladding temperature and local oxidation at the limiting elevation increase with decreasing flooding rate during downcomer boiling, which is consistent with the expected result.

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Figure 6-4: Sample Calculations of Void Fraction vs. Increase Above Saturated Liquid Enthalpy Using Homogeneous Equilibrium Assumption

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Figure 6-5: Effect of Maximum Reflood Time Step Size on Hot Rod Peak Cladding Temperature and Local Oxidation at Limiting Elevation for 4-Loop Ice Condenser Plant "B"

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Figure 6-6: Effect of Flooding Rate During Downcomer Boiling on Hot Rod Peak Cladding Temperature for 4-Loop Ice Condenser Plant "C"

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Figure 6-7: Effect of Flooding Rate During Downcomer Boiling on Hot Rod Local Oxidation at Limiting Elevation for 4-Loop Ice Condenser Plant "C"

6.6 SECTION II.3 - SENSITIVITY STUDIES

10 CFR Part 50, Appendix K, Section II.3 requires that sensitivity studies be performed to evaluate the effect on results of "phenomena assumed in the calculation to predominate". [Westinghouse] originally assumed that downcomer boiling would not occur, and therefore sensitivity studies of this phenomenon were not performed. Based on current knowledge of downcomer boiling and its impacts on peak clad temperature (PCT), the staff requires that sensitivity studies be performed.

Sections 6.4 and 6.5 describe LOCBART sensitivity calculations demonstrating the effect of assembly blockage, maximum reflood time step size and flooding rate during downcomer boiling on the hot rod peak cladding temperature and local oxidation at the limiting elevation. Reference 6-2 describes sensitivity calculations demonstrating the effect of the proposed changes to the LOCBART Transient Extension Method on the core inlet flooding rate during downcomer boiling and the hot rod peak cladding temperature and local oxidation at the limiting elevation for a sample plant with a neutron pad design. This section describes: (a) BASH-EM sensitivity calculations demonstrating the effect of minimum vs. maximum injection flow rates and downcomer metal heat release on the hot rod peak cladding temperature and local oxidation at the limiting elevation; and, (b) comparisons of the hot rod peak cladding temperature predicted using BASH-EM to the estimated 50th and 95th percentile hot rod peak cladding temperatures based on the 1996 Westinghouse Best Estimate LBLOCA Evaluation Model (Reference 6-12).

<u>Minimum vs. Maximum Injection Flow Rates</u>
The Safety Evaluation Report for Reference 6-3 requires consideration of both minimum and maximum injection flow rates. A sensitivity calculation was completed for a 4-loop ice condenser containment plant to demonstrate the effect of using minimum vs. maximum injection flow rates on the hot rod peak cladding temperature and local oxidation at the limiting elevation. The minimum containment pressure transient from the case with minimum injection flow rates was reduced by [

]^{a,c} for the case with maximum injection flow rates, which is representative of the sensitivity of the LOTIC2 code to this change.

Figure 6-8 compares the downcomer liquid temperatures from BASH and indicates a reduction for the case modeling maximum injection flow rates, more than offsetting the small decrease in saturation temperature due to the reduced containment pressure and delaying downcomer boiling. Figure 6-9 compares the flooding rate integrals from SMUUTH and shows [

]^{a,c}

Downcomer Metal Heat Release
A sensitivity calculation was completed for a 4-loop ice condenser containment plant to demonstrate the effect of deactivating the downcomer heat links in BASH just prior to downcomer boiling. This causes the downcomer liquid temperature to remain slightly subcooled and allows the transient to proceed beyond the onset of downcomer boiling (Figure 6-11). Figure 6-12 compares the downcomer and core collapsed liquid levels from BASH and shows no apparent difficulty, indicating that BASH is generally capable of extended simulations when downcomer boiling does not occur. Figure 6-13 compares the flooding rate integrals from SMUUTH and indicates [

]^{a,c}

BASH-EM vs. BELOCA
BASH-EM calculations were completed for a 3-loop dry containment plant (Plant "A") and a 4-loop ice condenser plant (Plant "B") that have been licensed with the Reference 6-12 BELOCA methodology. These calculations used the standard BASH-EM methodology to the extent possible, with inputs selected based on the BELOCA analyses where appropriate. The calculation for Plant "A" is based on Revision 0 of this report, while the calculation for Plant "B" was revised to incorporate various plant-specific evaluations such as the fuel design and the fuel rod initial conditions. This approach allows a reasonably direct comparison between the deterministic and realistic methods and provides an assessment of the conservatism that is generally believed to exist in Appendix K LBLOCA Evaluation Models.

Figures 6-15 and 6-16 compare the hot rod peak cladding temperatures predicted by BASH-EM to the estimated BELOCA 50th and 95th percentile hot rod peak cladding temperatures for Plants "A" and "B" and demonstrate [
]^{a,c}. Reference 6-13 describes conditions where BASH-EM may not be conservative relative to a realistic methodology and identifies limitations that will be applied to the future usage of BASH-EM until the transition to realistic methods is complete; see Section 7 for related information.

Figure 6-17 shows the hot rod cladding average temperature vs. time at 3.0, 5.5, 7.25, 9.0, 10.75 and 12.0 ft from the Plant "B" calculation with a flooding rate of [ ]^{a,c} during downcomer boiling and illustrates the progression of the hot assembly quench front as a function of time. Beyond this point, continued operation of the emergency core cooling system would be expected to establish and maintain an acceptably low temperature for the initiation of long-term core cooling. See Section 2.1 of Reference 6-13 for additional information regarding the predictive capability of BASH-EM during the late-reflood portion of the transient.

[

]a,c

Figure 6-8: Effect of Minimum vs. Maximum Injection Flow on Downcomer Liquid Temperature for 4-Loop Ice Condenser Plant "C"

[

]a,c

Figure 6-9: Effect of Minimum vs. Maximum Injection Flow on Integral Flooding Rate for 4-Loop Ice Condenser Plant "C"

[

]a,c

Figure 6-10: Effect of Minimum vs. Maximum Injection Flow on Hot Rod Peak Cladding Temperature and Local Oxidation at Limiting Elevation for 4-Loop Ice Condenser Plant "C"

[

]a,c

Figure 6-11: Effect of Downcomer Metal Heat Release on Downcomer Liquid Temperature for 4-Loop Ice Condenser Plant "C"

[

]a,c

Figure 6-12: Effect of Downcomer Metal Heat Release on Downcomer and Core Collapsed Liquid Levels for 4-Loop Ice Condenser Plant "C"

[

]a,c

Figure 6-13: Effect of Downcomer Metal Heat Release on Integral Flooding Rate for 4-Loop Ice Condenser Plant "C"

[

]a,c

Figure 6-14: Effect of Downcomer Metal Heat Release on Hot Rod Peak Cladding Temperature and Local Oxidation at Limiting Elevation for 4-Loop Ice Condenser Plant "C"

[

]a,c

Figure 6-15: Comparison of BASH-EM and BELOCA Results for 3-Loop Dry Containment Plant "A"

[

]a,c

Figure 6-16: Comparison of BASH-EM and BELOCA Results for 4-Loop Ice Condenser Plant "B"

[

]a,c

Figure 6-17: Hot Rod Cladding Temperature at Selected Elevations for 4-Loop Ice Condenser Plant "B"

6.7 SECTION II.4 - COMPARISON TO APPLICABLE EXPERIMENTAL DATA

10 CFR Part 50, Appendix K, Section II.4 requires that, to the extent practicable, predictions of the evaluation model, or portions thereof, shall be compared with applicable experimental information. [Westinghouse] should provide a comparison of the LOCBART extension method to appropriate experimental data. The comparison should include appropriate scaling considerations.

Section 5 describes the validation of the Sudo Correlation against full-scale experiments conducted in the JAERI downcomer boiling test facility.

6.8 REFERENCES FOR SECTION 6

6-1. Letter from S. Dembek (NRC) to H. Sepp (Westinghouse), "Potential Non-Conservative Modeling of Downcomer Boiling in the Approved Westinghouse 1981 Evaluation Model Using BASH," March 27, 2002.

6-2. LTR-NRC-07-21, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)' (Proprietary/Non-Proprietary)," April 13, 2007.

6-3. WCAP-10266-P-A, Revision 2, "The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code," March 1987.

6-4. WCAP-8170, "Calculational Model for Core Reflooding After a Loss of Coolant Accident (WREFLOOD Code)," June 1974.

6-5. WCAP-8471-P-A, "The Westinghouse ECCS Evaluation Model: Supplementary Information," April 1975.

6-6. NUREG/CR-4945, EGG-2509, "Summary of the Semiscale Program (1965-1986)," July 1987.

6-7. WCAP-10484-P-A, Addendum 1, "Spacer Grid Heat Transfer Effects During Reflood," September 1993.

6-8. NUREG/IA-0127, GRS-101, MPR-1346, "Reactor Safety Issues Resolved by the 2D/3D Program," July 1993.

6-9. Erbacher, F. J., "Cladding Tube Deformation and Core Emergency Cooling in a Loss of Coolant Accident of a Pressurized Water Reactor," Nuclear Engineering and Design 103, pp. 55-64, 1987.

6-10. LTR-NRC-07-23, "U. S. Nuclear Regulatory Commission, 10 CFR 50.46 Annual Notification and Reporting for 2006," May 15, 2007.

6-11. WCAP-9561-P-A, "BART-A1: A Computer Code for the Best Estimate Analysis of Reflood Transients," March 1984.

6-12. WCAP-12945-P-A, Volume 1 (Revision 2) and Volumes 2-5 (Revision 1), "Code Qualification Document for Best Estimate LOCA Analysis," March 1998.

6-13. LTR-NRC-06-23, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)', and Transmittal of Slide Package Entitled 'Update on Large Break LOCA Evaluation Model Issue' (Proprietary/Non-Proprietary)," April 28, 2006.

7 LIMITATIONS ON BASH-EM USAGE

Reference 7-1 describes conditions where BASH-EM may not be conservative relative to a realistic methodology and identifies the following limitations that will be applied to the usage of BASH-EM for affected and potentially affected plants until the transition to realistic LBLOCA analysis methods is complete:

1. Affected and potentially affected licensees will complete an assessment which supplements the BASH-EM analysis and demonstrates reasonable assurance of safe operation.

2. Future usage of BASH-EM will be limited to: (a) assessments pursuant to the reporting requirements of 10 CFR 50.46; and, (b) evaluations to support minor plant, fuel design or other input changes that would normally be handled under 10 CFR 50.46 and/or 10 CFR 50.59 and that do not invalidate the demonstration of reasonable assurance of safe operation.

In addition, the following limitations will be applied to the usage of BASH-EM for other plants:

3. Future LBLOCA analyses being submitted for NRC review and approval as new analyses of record will be performed using a realistic methodology.

4. Future LBLOCA evaluations supporting plant or input changes that would be expected to significantly exacerbate downcomer boiling (e.g., closure of the residual heat removal pump discharge cross-tie valves, early initiation of the recirculation sprays, significant increase in downcomer metal heat capacity, etc.) should either utilize a realistic methodology or justify why a realistic methodology is not required.

These limitations will obviate the need to justify the conservatism of BASH-EM relative to a realistic LBLOCA analysis methodology on a plant- and analysis-specific basis.

7.1 REFERENCES FOR SECTION 7

7-1. LTR-NRC-06-23, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)', and Transmittal of Slide Package Entitled 'Update on Large Break LOCA Evaluation Model Issue' (Proprietary/Non-Proprietary)," April 28, 2006.

8 CONCLUSIONS

This report has described the incorporation of the LOCBART Transient Extension Method into the BASH-EM. Use of the Sudo Correlation has been validated against full-scale separate-effects tests, and compliance with the 10 CFR 50 Appendix K requirements cited in Reference 8-1 has been demonstrated. The method will be applied in accordance with the limitations identified in Section 7 and will be used to ensure adequate termination of the fuel rod cladding temperature and oxidation transients, as required to demonstrate compliance with the acceptance criteria of 10 CFR 50.46.

8.1 REFERENCES FOR SECTION 8

8-1. Letter from S. Dembek (NRC) to H. Sepp (Westinghouse), "Potential Non-Conservative Modeling of Downcomer Boiling in the Approved Westinghouse 1981 Evaluation Model Using BASH," March 27, 2002.

Section C

Westinghouse

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Our ref: LTR-NRC-07-21

April 13, 2007

Subject: Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)" (Proprietary/Non-Proprietary)

Enclosed are copies of the proprietary and the non-proprietary versions of "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)'."

Also enclosed are:

One (1) copy of the Application for Withholding, AW-07-2268 (Non-Proprietary) with Proprietary Information Notice.
One (1) copy of Affidavit (Non-Proprietary).

This submittal contains proprietary information of Westinghouse Electric Company LLC. In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Commission's regulations, we are enclosing with this submittal an Application for Withholding from Public Disclosure and an affidavit. The affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the affidavit or Application for Withholding should reference AW-07-2268 and should be addressed to B. F. Maurer, Acting Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

BFMaurer

B. F. Maurer, Acting Manager
Regulatory Compliance and Plant Licensing

Enclosures

cc: Jon Thompson /NRR
Ed Throm /NRR

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Our ref: AW-07-2268

April 13, 2007

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: LTR-NRC-07-21 P-Attachment, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)'," (Proprietary)

Reference: Letter from B. F. Maurer to U.S. NRC Document Control Desk, LTR-NRC-07-21, dated April 13, 2007.

The Application for Withholding is submitted by Westinghouse Electric Company LLC (Westinghouse), pursuant to the provisions of Paragraph (b) (1) of Section 2.390 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.390, Affidavit AW-07-2268 accompanies this Application for Withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to this Application for Withholding or the accompanying affidavit should reference AW-07-2268 and should be addressed to B. F. Maurer, Acting Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

BF Maurer

B. F. Maurer, Acting Manager
Regulatory Compliance and Plant Licensing

Enclosures

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared B. F. Maurer, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

B F Maurer

B. F. Maurer, Acting Manager
Regulatory Compliance and Plant Licensing

Sworn to and subscribed before me
this 13th day of April, 2007

Sharon L. Markle

Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Sharon L. Markle, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Jan. 29, 2011
Member, Pennsylvania Association of Notaries

(1) I am Acting Manager, Regulatory Compliance and Plant Licensing, in Nuclear Services, Westinghouse Electric Company LLC (Westinghouse), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse "Application for Withholding" accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in LTR-NRC-07-21 P-Attachment, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)'," (Proprietary), for submittal to the Commission, being transmitted by Westinghouse letter (LTR-NRC-07-21) and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse is that associated with Westinghouse's request for NRC approval of WCAP-10266-P-A, Revision 2, Addendum 3, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)."

This information is part of that which will enable Westinghouse to:

(a) Obtain NRC approval of WCAP-10266-P-A, Revision 2, Addendum 3, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)."

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of this information to its customers for purposes of meeting NRC requirements for licensing documentation.

(b) Westinghouse can sell support and defense of the use of large break LOCA analysis predictions including the LOCBART Transient Extension Method.

(c) The information requested to be withheld reveals the distinguishing aspects of a methodology which was developed by Westinghouse.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar calculations and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

Proprietary Information Notice

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

Copyright Notice

LTR-NRC-07-21 NP-Attachment
TAC NO. MB7485

Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, "Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)"

April 13, 2007

Westinghouse Electric Company LLC
P.O. Box 355
Pittsburgh, PA 15230-0355

1. **In light of Figure 1b-1 of Reference 1, please clarify the number of cells that Westinghouse will be using in the axial noding void fraction calculation to develop the downcomer head loss for use in LOCBART.**

<u>Reference</u>

1. **LTR-NRC-04-4, "Response to NRC Request for Additional Information on Addendum 3 to WCAP-10266-P-A, Rev. 2 (Proprietary) and WCAP-11524-A, Rev. 2 (Non-Proprietary), 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)'," January 26, 2004.**

Several changes to the LOCBART Transient Extension Method are proposed to address the technical questions identified in RAIs 1 and 3-5. Sensitivity calculations have been completed to demonstrate the effect of the proposed changes on the core inlet flooding rate during downcomer boiling, the peak cladding temperature (PCT) and the maximum local oxidation (MLO) for a sample plant with a neutron pad design. The base calculation used the LOCBART Transient Extension Method as described in the Topical Report and was modified as follows for the sensitivity calculations (note that each case builds on the preceding case):

[

]^{a,c}

[

]a,c

Figure 1-1 compares the core inlet flooding rate during downcomer boiling for the base case and Cases A to G. [

]a,c

Figures 1-2 and 1-3 compare the hot rod cladding temperature at the PCT elevation and the hot rod local oxidation at the MLO elevation, respectively, for the base case and Cases A to G. [

]a,c

Based on the preceding information, Case G is proposed for standard PWR calculations. A similar approach would apply for a plant with a thermal shield design, with the most notable differences being an increased wall heat release rate, decreased flow area and decreased characteristic diameter in the thermal shield region; these differences would be expected to reduce the core inlet flooding rate during downcomer boiling with all other things being equal. For plants of either design (i.e., neutron pads or thermal shield), the limitations identified in Section 2.4 of Reference 1-4 will continue to apply until the transition to realistic large break LOCA analysis methods is complete.

<u>References</u>

1-1. Sudo, Y., and Akimoto, H., "Downcomer Effective Water Head during Reflood in Postulated PWR LOCA," Journal of Nuclear Science and Technology, 19(1), pp. 34-45, January 1982.

1-2. LTR-NRC-04-4, "Response to NRC Request for Additional Information on Addendum 3 to WCAP-10266-P-A, Rev. 2 (Proprietary) and WCAP-11524-A, Rev. 2 (Non-Proprietary), 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)'," January 26, 2004.

1-3. LTR-NRC-04-20, "Response to NRC Request for Additional Information on Addendum 3 to WCAP-10266-P-A, Rev. 2 (Proprietary) and WCAP-11524-A, Rev. 2 (Non-Proprietary)," April 15, 2004.

1-4. LTR-NRC-06-23, "Response to NRC Request for Additional Information on WCAP-10266-P-A, Revision 2, Addendum 3, 'Incorporation of the LOCBART Transient Extension Method into the 1981 Westinghouse Large Break LOCA Evaluation Model with BASH (BASH-EM)', and Transmittal of Slide Package Entitled 'Update on Large Break LOCA Evaluation Model Issue' (Proprietary/Non-Proprietary)," April 28, 2006.

Figure 1-1

[

]a,c

Figure 1-2

[

]a,c

Figure 1-3

[

]a,c

2. In Reference 2, Sudo bounds his correlation for steam-water to pressures of 6-111 atm, tube diameters 63-486 mm and superficial liquid velocities 0-30 cm/s. The author suggests that "more experiments should be done to investigate the range in which [the Sudo correlation] is applicable". In Reference 3, the author provides very limited test data to confirm the validity of the correlation in the desired range. Please provide additional test data in the desired range of use of the correlation (i.e., the full testing report from Sudo's test) to demonstrate its adequacy for use with LOCBART.

References

2. Sudo, Y., "Estimation of Average Void Fraction in Vertical Two-Phase Flow Channel under Low Liquid Velocity," Journal of Nuclear Science and Technology, 17(1), pp. 1-15, January 1980.

3. Sudo, Y., and Akimoto, H., "Downcomer Effective Water Head during Reflood in Postulated PWR LOCA," Journal of Nuclear Science and Technology, 19(1), pp. 34-45, January 1982.

Additional simulations of experiments from the JAERI downcomer boiling test facility have been completed to demonstrate the applicability of the Sudo correlation for the conditions of interest. The simulations incorporated the applicable changes from the response to RAI 1 except for the [ ]^{a,c}. Table 2-1 is based primarily on Table 2 of Reference 2-1 and Table 1 of Reference 2-2 and shows the gap width (S), number of heated walls (N_{WALLS}), initial wall temperature (T_W), extracted water velocity (V_{EX}), injection temperature (T_{INJ}) and injection mode (Mode) for the 5 experiments that have been simulated as part of the present effort.

Table 2-1: Test Conditions for JAERI Run Nos. 115, 116, 120, 211 and 213

Run No.	S, mm (in)	N_{WALLS}	T_W, °C (°F)	V_{EX}, cm/s (in/s)	T_{INJ}, °C (°F)	Mode
115	200 (7.9)	2	250 (482)	0 (0)	98 (208)	A
116	200 (7.9)	2	275 (527)	0 (0)	100 (212)	A
120	200 (7.9)	2	300 (572)	2 (0.8)	100 (212)	A
211	50 (2.0)	1	250 (482)	0 (0)	99 (210)	A
213	50 (2.0)	1	250 (482)	0 (0)	97 (207)	B

The wall surface heat flux histories used in the simulations of Run Nos. 115, 116, 120, 211 and 213 are based on [

]a,c

Figures 2-2 to 2-4 provide sample results from the simulations of Run Nos. 115, 116, 120, 211 and 213 including the vapor superficial velocity and void fraction at the top of the heated length and the collapsed liquid level across the heated length. Review of these figures leads to the following observations:

[

]a,c

Figures 2-5 to 2-8 compare the measured and predicted collapsed liquid levels for Run Nos. 115, 116, 120 and 211, using measured values based on [

]^{a,c}

Figure 2-10 compares the measured and predicted collapsed liquid levels for Run No. 213, using measured values based on [

]^{a,c}

References

2-1. JAERI-M 7978, "Experiment of the Downcomer Effective Water Head during a Reflood Phase of PWR LOCA," October 1978.

2-2. JAERI-M 8978, "Experimental Results of the Effective Water Head in Downcomer during Reflood Phase of a PWR LOCA (2nd Report, 50 mm Gap Size)," July 1980.

Figure 2-1

[

]a,c

Figure 2-2

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]a,c

Figure 2-3

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]a,c

Figure 2-4

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]a,c

Figure 2-5

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]a,c

Figure 2-6

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]a,c

Figure 2-7

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]a,c

Figure 2-8

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]a,c

Figure 2-9

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]a,c

Figure 2-10

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]a,c

3. **In Reference 2, Sudo states that "[the Sudo correlation] can predict the experimental data referred to in [his] study within ±15%". He also explains that "the effect of [the superficial velocity] can be neglected in the velocity range of 0-30 cm/s because the difference of these tendencies is included within the same range of error of ±15%". In Reference 4, Westinghouse stated this uncertainty-based agreement between the correlation and experimental data need not be considered based on other conservatisms within the BASH Evaluation Model. Please demonstrate that the conservatisms in the BASH Evaluation Model capture the source of the ±15% uncertainty in the Sudo correlation.**

   <u>Reference</u>

   4. **LTR-NRC-04-20, "Response to NRC Request for Additional Information on Addendum 3 to WCAP-10266-P-A, Rev. 2 (Proprietary) and WCAP-11524-A, Rev. 2 (Non-Proprietary)," April 15, 2004.**

   (Please see the response to RAI #1.)

4. **In keeping with SRP 6.2.1.5, "Minimum Containment Pressure Analysis for Emergency Core Cooling System Performance Capability Studies", please clarify the pressure to be used for a licensing analysis. It would appear the minimum expected pressure over the duration of the analysis should be used to develop the downcomer head loss for use in LOCBART. As noted in References 1 and 4, the expected decrease in the system pressure following the onset of downcomer boiling would inhibit the reflood.**

   (Please see the response to RAI #1.)

5. **The downcomer extends below the bottom of the active core. It appears that the modeling approach credits no boiling in this region which would result in a larger downcomer head and better reflood than if boiling were considered. Please provide a discussion of the importance of this region and the treatment of wall heat from this region in the LOCBART analysis.**

   (Please see the response to RAI #1.)