Westinghouse Non-Proprietary Class 3

WCAP-14747 & WCAP-14450-NP-A
Addendum 1-A, Revision 0

December 2004

Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best Estimate LOCA Evaluation Models

Westinghouse

WCAP-14747 & WCAP-14450-NP-A

Addendum 1-A, Revision 0

Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models

Mitchell E. Nissley
LOCA Integrated Services

December 2004

Westinghouse Electric Company LLC
P.O. Box 355
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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 11, 2004

Mr. John Gresham, Manager
Regulatory and Licensing Engineering
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: FINAL SAFETY EVALUATION FOR WESTINGHOUSE TOPICAL REPORT, "ADDENDUM 1 TO WCAP-12945-P-A AND WCAP-14449-P-A, METHOD FOR SATISFYING 10 CFR 50.46 REANALYSIS REQUIREMENTS FOR BEST-ESTIMATE LOCA EVALUATION MODELS" (TAC NO. MB6803)

Dear Mr. Gresham:

By letter dated October 9, 2002, the Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A, Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," to the staff for review. Westinghouse supplemented the information in the above TR in a letter dated December 16, 2003, which provided clarifying details regarding process controls that would be implemented in performing reanalyses using the proposed addendum methodology. On January 23, 2004, an NRC draft safety evaluation (SE) regarding our approval of the TR was provided for your review and comments. By e-mail dated February 11, 2004, Westinghouse agreed with the content of the SE.

The staff has found that the TR is acceptable for referencing as an approved methodology in plant licensing applications. The enclosed SE documents the staff's evaluation of Westinghouse's justification for the improved methodology.

Our acceptance applies only to the 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's TR website, we request that Westinghouse publish an accepted version of this TR within three months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed SE between the title page and the abstract. It must be well indexed such that information is readily located. Also, it must contain in appendices historical review information, such as questions and accepted responses, draft SE comments, and original report pages that were replaced. The accepted version shall include a "-A" (designating "accepted") following the report identification symbol.

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If the NRC's criteria or regulations change so that its conclusions in this letter, that the TR is acceptable, is invalidated, Westinghouse and/or the licensees referencing the TR will be expected to revise and resubmit its respective documentation, or submit justification for the continued applicability of the TR without revision of the respective documentation.

Sincerely,

Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 700

Enclosure: Safety Evaluation

cc w/encl:
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

"ADDENDUM 1 TO WCAP-12945-P-A AND WCAP-14449-P-A, METHOD FOR SATISFYING 10 CFR 50.46 REANALYSIS REQUIREMENTS FOR BEST-ESTIMATE LOCA EVALUATION MODELS"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 INTRODUCTION

By letter dated October 9, 2002, the Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A, Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," to the NRC for review and approval. The TR describes a proposed methodology to perform best-estimate large break (LB) loss-of-coolant accident (LOCA) reanalyses for plants already licensed with LBLOCA analyses performed using the methodology described in either of the Westinghouse LBLOCA TRs identified in the Addendum title. The proposed reanalysis methodology would implement an abbreviated calculational approach which would preserve the characteristic plant-specific LBLOCA transient while implementing changes or correcting errors in accordance with 10 CFR 50.46(a)(3). Westinghouse proposed this abbreviated methodology to reduce unnecessary regulatory burden. The staff reviewed the proposal and found it acceptable, as discussed below.

Westinghouse supplemented the information in the above TR in a letter dated December 16, 2003, which provided clarifying details regarding process controls that would be implemented in performing reanalyses using the proposed addendum methodology.

2.0 BACKGROUND AND REGULATORY EVALUATION

The regulations specified in 10 CFR 50.46(a)(1) identify calculational methodology requirements for nuclear power plant LOCA methodologies. Section 10 CFR 50.46(c) identifies the types of processes which are required to assure that LOCA analyses performed for a given plant actually represent that plant. Section 50.46(a)(3)(i and ii) specifies criteria to be applied and actions to be taken when significant changes or errors in parts of the plant-specific LOCA methodology, defined in accordance with 10 CFR 50.46(a)(1) and (c), are found to have accumulated. When the licensee makes changes to its plant input model, or finds errors in parts of the plant-specific LOCA methodology covered by 10 CFR 50.46(a)(1) and (c) that are significant, the licensee must reanalyze the plant's LOCA response. This is usually done by repeating the plant's LOCA analyses (reanalyzing) using a LOCA methodology approved for the plant, with changes and errors updated if the base LOCA methodology remains the same. With

LOCA methodologies covered by 10 CFR Part 50, Appendix K, this reanalysis entails performing one LOCA calculation for each case analyzed. Using the best-estimate LOCA methodologies described in WCAP-12945-P-A and WCAP-14449-P-A, several LOCA calculations are required. The proposed methodology would significantly reduce the number of LOCA calculations needed to perform the reanalysis, and therefore significantly reduce unnecessary regulatory burden, while assuring plant safety.

WCAP-12945-P-A describes the approved Westinghouse best-estimate LBLOCA analysis methodology that applies to Westinghouse three- and four-loop reactor designs with conventional cold leg emergency core cooling system (ECCS) injection. WCAP-14449-P-A describes the approved Westinghouse best-estimate LBLOCA analysis methodology that applies to Westinghouse two-loop reactor designs with upper plenum ECCS injection. The proposed abbreviated best-estimate LBLOCA analysis methodology uses the same computer code, WCOBRA/TRAC, as the staff approved for use in the methodologies described in the TRs.

The Westinghouse best-estimate LBLOCA analysis methodology uses a combination of response surfaces and Monte Carlo techniques to develop a peak cladding temperature (PCT) uncertainty distribution for a plant. Westinghouse demonstrates this using the following equation:

$$PCT_i = PCT_{REF} + \Delta PCT_{PD,i} + \Delta PCT_{IC,i} + \Delta PCT_{MOD,i} + \Delta PCT_{SUP,i}$$

where:

PCT_{REF} = PCT for a fixed set of reference conditions by the approved methodology,

$\Delta PCT_{PD,i}$ = change in PCT due to the power distribution parameters sampled for iteration i,

$\Delta PCT_{IC,i}$ = change in PCT due to sampling of the initial and boundary condition uncertainty distribution for iteration i,

$\Delta PCT_{MOD,i}$ = change in PCT due to the thermal-hydraulic models sampled for iteration i,

$\Delta PCT_{SUP,i}$ = change in PCT due to application of the superposition correction factor, and sampling of the superposition correction uncertainty for iteration i,

In the proposed abbreviated reanalysis methodology, only the PCT_{REF} and $\Delta PCT_{SUP,i}$ are completely recalculated, unless the analyst determines that input changes for the reanalysis will significantly alter the characteristic profile of any of the other factors (i.e., $\Delta PCT_{PD,i}$, $\Delta PCT_{IC,i}$, and $\Delta PCT_{MOD,i}$). If the analyst does determine that one or more of the other factors, or the characteristic plant-specific LBLOCA transient profile is so altered, a decision must be made whether a full reanalysis must be performed in lieu of implementing the abbreviated reanalysis methodology.

The staff reviewed the proposed methodology using as criteria: (1) preservation of the characteristic plant-specific LBLOCA transient profile, and (2) substantial retention of the statistical process profile for the plant. Fulfilling these two objectives provides assurance that the proposed abbreviated reanalysis methodology for the Westinghouse best-estimate LBLOCA analysis methodology will be able to satisfy 10 CFR 50.46(a)(1) and applicable parts of 10 CFR 50.46(c).

3.0 TECHNICAL EVALUATION

The Westinghouse October 9, 2002, letter describes the proposed abbreviated reanalysis methodology and its implementation, as discussed in Section 2.0 above. In a letter dated December 16, 2003, Westinghouse further described how it will implement the methodology. In the October 9, 2002, letter, Westinghouse gave examples to demonstrate how the abbreviated methodology would be implemented. From these examples, it is apparent to the staff that the analyst will be able to make decisions that would allow the methodology to perform LBLOCA analyses using the methodology consistent with the standards set for the source methodologies, while maintaining control of uncertainties within the corrective capabilities of the methodologies. The analyst will also be able to determine when the original approach (WCAP-12945-P-A or WCAP-14449-P-A) is required. The staff's review indicates that the intent of the abbreviated approach is to implement the approved methodology previously used to perform a given plant's best estimate LBLOCA analyses utilizing elements of the previous calculation that continue to directly apply to the current reanalysis. This is done by adjusting elements as needed to suit the reanalyses while not significantly changing their qualitative contribution to the overall calculation, and by exercising the corrective capabilities of the previous approach to assure that the impact on the uncertainty analysis is not significant. Therefore, the staff finds that the proposed abbreviated methodology satisfies the requirements of 10 CFR 50.46(a)(1) regarding the acceptability of the calculational methodology.

The staff requested that Westinghouse provide information regarding controls that would ensure that the methodology would be properly implemented, since the decisions by the analyst require sound technical judgement. In the December 16, 2003, letter, Westinghouse described the process that Westinghouse would implement and the general reanalysis guidelines to provide more objective criteria for decisions to help assure the methodology is not misapplied.

As part of the process, the Westinghouse "Evaluation Model Lead Engineer" would review and concur with the analyses. As a last step, Westinghouse would maintain documentation of the reanalyses, the basis for concluding that the specific application is within the limits of applicability, and the record of concurrence in the Westinghouse plant files for the unit being reanalyzed. This record could be audited and, if necessary, emended.

The controls provided by Westinghouse, along with other programs and other information necessary for application of the calculational framework to a specific LOCA analysis, shared with and/or implemented by the plant licensee (see Section 4.0, "Limitations"), assure that the programmatic requirements for a vendor of 10 CFR 50.46(c) will be satisfied.

The staff also finds that the TR, though associated with previously approved LBLOCA analysis methodologies, is a unique LBLOCA analysis methodology in and of itself. Therefore, in its

initial licensing applications for the various plants to which it may be applied, licensees must submit plant-specific license amendment requests to adopt this methodology, including technical specifications changes, core operating limit report changes, and initial LBLOCA reanalysis results.

4.0 LIMITATIONS

Licensees must include in individual plant requests a statement that the licensee and its fuel vendor (Westinghouse) have ongoing processes which assure that the ranges and values of input parameters for the plant (LOCA) analysis bound the ranges and values of the as-operated plant values for those parameters

"Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" is a unique LBLOCA analysis methodology in and of itself. Therefore, in its initial licensing applications for the various plants to which it may be applied, licensees must submit plant-specific license amendment requests to adopt this methodology, including technical specifications changes, core operating limit report changes, and initial LBLOCA reanalysis results.

As proposed by Westinghouse, licensees may only apply "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" to plants whose approved LBLOCA analyses were performed using methodologies described in either WCAP-12945-P-A or WCAP-14449-P-A.

The staff also finds that the TR, though associated with previously approved LBLOCA analysis methodologies, is a unique LBLOCA analysis methodology in and of itself. . Therefore, in its initial licensing applications for the various plants to which it may be applied, licensees must submit plant-specific license amendment requests to adopt this methodology, including technical specifications changes, core operating limit report changes, and initial LBLOCA reanalysis results.

5.0 CONCLUSION

Based on its review as discussed above, the staff concludes that "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" meets applicable requirements of 10 CFR 50.46(a)(1) and (c). Therefore, the staff finds this proposed LBLOCA methodology acceptable within the limitations specified in Section 4.0.

As proposed by Westinghouse, licensees may only apply "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" to plants whose approved LBLOCA analyses were performed using methodologies described in either WCAP-12945-P-A or WCAP-14449-P-A.

Principle Contributor: F. Orr

Date: March 11, 2004

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ABSTRACT

The Westinghouse best-estimate LOCA analysis methodology for 3- and 4-loop plants with cold leg ECCS injection was previously published in WCAP-12945-P-A (proprietary) and WCAP-14747-NP-A (non-proprietary). The methodology was extended to 2-loop plants with upper plenum injection in WCAP-14449-P-A (proprietary) and WCAP-14450-NP-A (non-proprietary). This addendum to those reports describes and justifies a method for satisfying the reanalysis requirements of 10 CFR 50.46, for plants previously analyzed with one of these approved methodologies. The reanalysis methodology involves a recalculation of the reference transient and the superposition correction factor, and re-sampling of the superposition correction uncertainty. Application of this reanalysis methodology is limited to situations where the fundamental plant-specific large break LOCA transient characteristics are unchanged by the error corrections, evaluation model changes, or small changes in expected operating conditions.

SECTION 1
INTRODUCTION

10 CFR 50.46 includes the following requirements relative to ECCS evaluation model changes and errors:

"For each change to or error discovered in an acceptable evaluation model or in the application of such a model that affects the temperature calculation, the applicant or licensee shall report the nature of the change or error and its estimated effect on the limiting ECCS analysis to the Commission at least annually as specified in § 50.4. If the change or error is significant, the applicant or licensee shall provide this report within 30 days and include with the report a proposed schedule for providing a reanalysis or taking other action as may be needed to show compliance with § 50.46 requirements."

The purpose of this report is to provide a technical and regulatory basis for using the superposition correction step of the Westinghouse best-estimate large break LOCA methodology to satisfy the reanalysis requirements stated in 10 CFR 50.46. This justification is applicable to the following evaluation models:

1996 Westinghouse Best Estimate Large Break LOCA Evaluation Model (Bajorek et al., 1998)
1999 Westinghouse Best Estimate Large Break LOCA Evaluation Model, Application to PWRs with Upper Plenum Injection (Dederer et al., 1999)

SECTION 2
OVERVIEW OF WESTINGHOUSE BEST-ESTIMATE LARGE BREAK LOCA METHODOLOGY

A detailed description of the Westinghouse best-estimate large break LOCA methodology for 3-/4-loop PWRs with cold leg ECCS injection is given in Section 26 of WCAP-12945-P-A (Bajorek et al., 1998). The methodology uses a combination of response surfaces and Monte Carlo techniques to develop an uncertainty distribution for the peak cladding temperature (PCT). This can be qualitatively illustrated using the following simplified equation for iteration i:

$$PCT_i = PCT_{REF} + \Delta PCT_{PD,i} + \Delta PCT_{IC,i} + \Delta PCT_{MOD,i} + \Delta PCT_{SUP,i}$$

where,

PCT_{REF} = peak cladding temperature for a fixed set of reference conditions defined by the approved methodology

$\Delta PCT_{PD,i}$ = change in PCT due to the power distribution parameters sampled for iteration i

$\Delta PCT_{IC,i}$ = change in PCT due to sampling of the initial and boundary condition uncertainty distribution for iteration i

$\Delta PCT_{MOD,i}$ = change in PCT due to the thermal-hydraulic models sampled for iteration i

$\Delta PCT_{SUP,i}$ = change in PCT due to application of the superposition correction factor, and sampling of the superposition correction uncertainty for iteration i

The methodology for treating each of the uncertainty components in this equation is summarized below.

Power Distribution Parameters – Variations in total peaking factor (FQ), enthalpy rise peaking factor (FdH), and axial power distribution (characterized by normalized 1/3 power integrals PBOT and PMID) are considered. Additionally, uncertainties in core power, decay heat, gamma energy redistribution, and peaking factor calculational uncertainties are considered [

]a,c

A typical power distribution run matrix is shown in Table 1.

Initial and Boundary Conditions – Other plant parameters that are considered in the uncertainty methodology include RCS fluid temperature and pressure; accumulator water volume, temperature, pressure and line resistance; and safety injection (refueling water storage tank) temperature. [

]a,c

The plant parameters considered in this category are shown in Table 2 for a typical plant-specific application.

Thermal-Hydraulic Models – The thermal-hydraulic models are separated into two groups. "Global" models are those that affect the system response to the transient. "Local" models are those that affect only the hot spot response. The global models considered in the uncertainty analysis are break flow rate (CD), broken cold leg nozzle resistance (KN), broken loop pump resistance (KP), downcomer condensation (XC), and break type (guillotine or split). [

]a,c

The global model run matrix for 3- and 4-loop plants is shown in Table 3 for guillotine breaks, and in Table 4 for split breaks. The local models considered in the HOTSPOT code are:

Local Hot Spot Peaking Factor

Fuel Conductivity Before Burst

Fuel Conductivity After Burst

Fuel Relocation

Gap Conductance

Rod Internal Pressure

Burst Temperature

Burst Strain

Zirc-Water Reaction

Heat Transfer Coefficient

Minimum Film Boiling Temperature

The above discussion is applicable to 3- and 4-loop plants with ECCS injection into the cold legs. For 2-loop plants with low head safety injection into the upper plenum, variations in parameters that control the upper plenum drain distribution are important, while downcomer condensation is not. Therefore, the methodology for 2-loop plants with upper plenum injection replaces variations in downcomer condensation with simultaneous variations in interfacial drag (XD) and condensation (XCU) in the regions of the vessel that control the drain distribution. The revised global model run matrix for 2-loop plants is shown in Table 5 for guillotine breaks, and in Table 6 for split breaks. A detailed description of the Westinghouse best-estimate large break LOCA methodology for 2-loop PWRs with upper plenum injection is given in Sections 5 and 6 of WCAP-14449-P-A (Dederer et al., 1999).

Superposition Correction and Calculation of Total Uncertainty – A preliminary estimate of the PCT uncertainty distributions for the guillotine and limiting split break transients is first performed. A simplified (illustrative) description of the methodology as applied to guillotine breaks follows:

1) Sample from the probability distributions for FQN, FdH, PBOT, PMID, core power, decay heat, gamma energy redistribution, and peaking factor calculational uncertainties. [ ]^{a,c} Insert the resulting values into the response surface equation to obtain the change in PCT due to power related parameters for iteration i, $\Delta PCT_{PD,i}$.

2) Sample from the [

]a,c to obtain the change in PCT due to initial/boundary conditions for iteration i, $\Delta PCT_{IC,i}$.

3) Sample from the probability distributions for CD, KN' and XC. Insert the resulting values into the response surface equations to obtain $HPCT_{ave}$ and σ_{HPCT}. Sample from the normal distribution defined by σ_{HPCT}, and add the result to $HPCT_{ave}$ to obtain the change in PCT due to thermal hydraulic models for iteration i, $\Delta PCT_{MOD,i}$. (For split breaks, sample from the probability distributions for KN' and XC. For UPI plants, sampling of XD+XCU replaces sampling of XC.)

4) Add the results of steps 1 through 3 to obtain the overall PCT for iteration i:

$$PCT_i = PCT_{REF} + \Delta PCT_{PD,i} + \Delta PCT_{IC,i} + \Delta PCT_{MOD,i}$$

5) Repeat steps 1 through 4 10,000 times to develop the overall PCT uncertainty distribution.

The above is performed for guillotine and split breaks, and the most limiting break type is selected. An additional set of analyses is then performed for the limiting break type, to account for the uncertainty in the assumption that the uncertainty components are additive. This is referred to as the "superposition correction" step. A series of WCOBRA/TRAC runs are made, with global models, power distributions, and initial/boundary conditions all varied simultaneously. The run matrix is designed to [

]a,c

The final PCT uncertainty distribution is then calculated for the limiting break type. Steps 1 through 4 are performed for each iteration. [

]a,c Again, 10,000 iterations are used to get the final PCT uncertainty distribution.

SECTION 3
USE OF SUPERPOSITION CORRECTION STEP TO PERFORM REANALYSES

As noted previously, 10 CFR 50.46 includes the following requirements relative to ECCS evaluation model changes and errors:

"For each change to or error discovered in an acceptable evaluation model or in the application of such a model that affects the temperature calculation, the applicant or licensee shall report the nature of the change or error and its estimated effect on the limiting ECCS analysis to the Commission at least annually as specified in § 50.4. If the change or error is significant, the applicant or licensee shall provide this report within 30 days and include with the report a proposed schedule for providing a reanalysis or taking other action as may be needed to show compliance with § 50.46 requirements."

For licensees with an existing best-estimate analysis, it is proposed that the 10 CFR 50.46 reanalysis requirement for significant changes or errors can be satisfied by reanalyzing the reference transient and the superposition correction cases from the original analysis. A more detailed description of this process is given below.

1) [

]a,c

4) The local and core-wide oxidation results from the prior analysis will be reviewed, and updated if necessary using the methodology described in Section 26-5-3 of WCAP-12945-P-A (Bajorek et al., 1999).

It is noted that the NRC has previously approved the use of a similar reanalysis philosophy in the case of a steam generator replacement program (Padovan, 1999).

Several illustrative examples of the use of this reanalysis approach to establish a new 95th percentile PCT follow.

Example 1: A significant error is found in the application of the evaluation model. No changes in the expected operating range of the plant are contemplated.

[

]a,c

Example 2: A significant error is found in the application of the evaluation model. [

]a,c

In each of these examples, a partial reanalysis of the affected portions of the original analysis would be used to quantify the effect of the change(s) on PCT. The final 95th percentile PCT would be considered to be the result of a new analysis, meeting the requirements for 10 CFR 50.46 reanalysis. As such, it would be reported as the new licensing basis PCT.

SECTION 4
APPLICATION TO ANALYSES THAT BOUND MULTIPLE UNITS

Several licensees have used a single best-estimate large break LOCA analysis to bound multiple units. In each of these cases, any plant-to-plant variation in design and/or operating conditions was carefully considered, and comparative calculations were used to aid selection of the bounding plant configuration.

Any applications of the reanalysis strategy presented in this report to analyses that bound multiple units will include comparative calculations of the reanalysis scenario to ensure that the previously selected bounding plant configuration remains applicable. In the event that this cannot be clearly established, additional discussions will be held with the NRC on the proposed plan for completing the reanalysis.

It is noted that the above approach is considered to be consistent with the NRC recommendations in the aforementioned steam generator replacement program (Padovan, 1999).

Example 3: A significant error is found in the application of the evaluation model for a licensee that uses one analysis to bound two units with the same power rating and fuel type, but different vessel designs. As in example 2, [

]a,c

SECTION 5
CONCLUSIONS

This report provides a technical and regulatory basis for using the superposition correction step of the Westinghouse best-estimate large break LOCA methodology to satisfy the reanalysis requirements stated in 10 CFR 50.46. For significant changes to, or errors in, the approved codes and methods, the reanalysis involves [

]a,c The resulting 95th percentile peak cladding temperature is considered to be the new licensing basis PCT.

As part of the reanalysis process, the licensee may wish to make small changes in allowable operating conditions that would not be expected to affect the previously determined sensitivity to variations in power distributions, initial conditions, or thermal-hydraulic models. Examples have been presented to illustrate how these types of changes would be incorporated in the reanalysis.

SECTION 6
REFERENCES

Bajorek, S. M., et al., 1998, "Code Qualification Document for Best Estimate LOCA Analysis," WCAP-12945-P-A, Volume 1, Revision 2, and Volumes 2 through 5, Revision 1, and WCAP-14747 (Non-Proprietary).

Dederer, S. I., et al., 1999, "Application of Best Estimate Large Break LOCA Methodology to Westinghouse PWRs with Upper Plenum Injection," WCAP-14449-P-A, Revision 1, and WCAP-14450-NP-A (Non-Proprietary).

Letter, L. M. Padovan to D. N. Morey, "Joseph M. Farley Nuclear Plant, Units 1 and 2 – Issuance of Amendments Re: Steam Generator Replacements," December 29, 1999.

Table 1: Power Distribution Run Matrix

[				
				]a,c

Table 2: Initial and Boundary Condition Run Matrix

Parameter	Variation	Range of Variation
RCS Temperature	+, -	[
Pressurizer Pressure	+, -	
SI Temperature	+, -	
Accumulator Pressure	+, -	
Accumulator Water Volume	+, -	
Accumulator Temperature	+, -	
Accumulator Line Resistance	+, -	]a,c

Table 3: Global Model Run Matrix for Guillotine Breaks (3-/4-loop plants)

[			
			]a,c

Table 4: Global Model Run Matrix for Split Breaks (3-/4-loop plants)

[		
		]a,c

Table 5: Global Model Run Matrix for Guillotine Breaks (2-loop plants)

[			
			]a,c

Table 6: Global Model Run Matrix for Split Breaks (2-loop plants)

[		
		]a,c

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APPENDIX A

Westinghouse

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Our ref: LTR-NRC-03-73

December 16, 2003

Subject: Proposed Limits of Applicability for Best-Estimate LOCA Reanalysis Methodology

Reference: LTR-NRC-02-51, "Request for Review and Approval of Proposed Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," October 9, 2002.

The Reference submitted a proposed methodology for satisfying 10 CFR 50.46 reanalysis requirements for the approved Westinghouse best-estimate large break LOCA methodologies (WCAP-12945-P-A and WCAP-14449-P-A). The staff's review has resulted in a request for Westinghouse to clarify the limits of applicability of the methodology. The attachment contains our response to this request.

When applying the reanalysis methodology to a given plant, Westinghouse will document the basis for concluding that the specific application is within the limits of applicability, and will retain that documentation in our plant records. Concurrence with that conclusion by the engineer currently designated as the Evaluation Model Lead Engineer will be documented as part of those records.

It is our intent to publish the approved version of the reanalysis methodology as Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A, "Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models."

Please contact Mitch Nissley at (412) 374-4303 if you have any questions concerning this transmittal.

Very truly yours,

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

Enclosures

cc: B. J. Benney, NRC (w/3 copies)

A BNFL Group company

Clarification on Limits of Applicability for Proposed Reanalysis Methodology

The proposed reanalysis methodology will only be applied in circumstances where the fundamental LOCA transient characteristics are unchanged by the error corrections, evaluation model changes, or small changes in expected operating conditions. The fundamental LOCA transient characteristics for a given plant may be described based on its behavior during blowdown and reflood as follows:

Blowdown – Turnaround of the initial hot rod cladding heatup for the reference transient is by one of the following mechanisms:

a) Primarily upward core flow
b) Primarily downward core flow
c) Combination of upward and downward core flow

Reflood – Final turnaround of the hot rod cladding heatup for the reference transient during reflood occurs during one of the following time periods:

a) The initial surge of water into the hot assembly during the first 30 seconds of reflood, prior to boiling in the downcomer
b) Dispersed flow film boiling heat transfer following a period of degraded heat transfer due to boiling in the downcomer

If the fundamental LOCA transient characteristics are unchanged for the reference transient, it is reasonable to assume that changes in transient response due to ranging of the dominant physical phenomena will not be significantly affected, and the proposed reanalysis methodology will be appropriate.

The staff has asked Westinghouse to further delineate those circumstances where the proposed reanalysis methodology may <u>not</u> be applicable. In response to this request, Westinghouse has identified the following examples:

1) The proposed reanalysis methodology is not considered applicable for changes that substantially affect the blowdown cooling behavior. For example, consider a plant in which the blowdown cooling for the reference transient is primarily due to upflow. If the changes result in blowdown cooling for the reference transient that is primarily due to downflow, it would be expected that the propagation of global model uncertainties would be substantially affected by the changes. More specifically, variations in break flow rate or broken cold leg nozzle resistance would be expected to affect blowdown cooling differently than in the previous analysis.

2) The proposed reanalysis methodology is not considered applicable for changes that introduce significant downcomer boiling effects into an analysis that did not previously have them. In this case, the changes would require that the PCT uncertainty be estimated for the late reflood period, which would not have been done in the previous analysis.

3) The proposed reanalysis methodology is not considered applicable for error corrections that obviously invalidate part of the previous uncertainty analysis. An illustrative example would be correction of an error that had over-written the steady state axial power distribution with a uniform distribution at the beginning of the transient. In this example the propagation of power distribution uncertainties established in the previous analysis would obviously not be valid.

Reference:

LTR-NRC-02-51, "Request for Review and Approval of Proposed Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," October 9, 2002.

Westinghouse Non-Proprietary Class 3

WCAP-14747 & WCAP-14450-NP-A
Addendum 1-A, Revision 0

December 2004

Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best Estimate LOCA Evaluation Models

Westinghouse

WCAP-14747 & WCAP-14450-NP-A

Addendum 1-A, Revision 0

Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models

Mitchell E. Nissley
LOCA Integrated Services

December 2004

Westinghouse Electric Company LLC
P.O. Box 355
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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 11, 2004

Mr. John Gresham, Manager
Regulatory and Licensing Engineering
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: FINAL SAFETY EVALUATION FOR WESTINGHOUSE TOPICAL REPORT, "ADDENDUM 1 TO WCAP-12945-P-A AND WCAP-14449-P-A, METHOD FOR SATISFYING 10 CFR 50.46 REANALYSIS REQUIREMENTS FOR BEST-ESTIMATE LOCA EVALUATION MODELS" (TAC NO. MB6803)

Dear Mr. Gresham:

By letter dated October 9, 2002, the Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A, Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," to the staff for review. Westinghouse supplemented the information in the above TR in a letter dated December 16, 2003, which provided clarifying details regarding process controls that would be implemented in performing reanalyses using the proposed addendum methodology. On January 23, 2004, an NRC draft safety evaluation (SE) regarding our approval of the TR was provided for your review and comments. By e-mail dated February 11, 2004, Westinghouse agreed with the content of the SE.

The staff has found that the TR is acceptable for referencing as an approved methodology in plant licensing applications. The enclosed SE documents the staff's evaluation of Westinghouse's justification for the improved methodology.

Our acceptance applies only to the 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's TR website, we request that Westinghouse publish an accepted version of this TR within three months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed SE between the title page and the abstract. It must be well indexed such that information is readily located. Also, it must contain in appendices historical review information, such as questions and accepted responses, draft SE comments, and original report pages that were replaced. The accepted version shall include a "-A" (designating "accepted") following the report identification symbol.

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If the NRC's criteria or regulations change so that its conclusions in this letter, that the TR is acceptable, is invalidated, Westinghouse and/or the licensees referencing the TR will be expected to revise and resubmit its respective documentation, or submit justification for the continued applicability of the TR without revision of the respective documentation.

Sincerely,

Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 700

Enclosure: Safety Evaluation

cc w/encl:
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

"ADDENDUM 1 TO WCAP-12945-P-A AND WCAP-14449-P-A, METHOD FOR SATISFYING 10 CFR 50.46 REANALYSIS REQUIREMENTS FOR BEST-ESTIMATE LOCA EVALUATION MODELS"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 INTRODUCTION

By letter dated October 9, 2002, the Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A, Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," to the NRC for review and approval. The TR describes a proposed methodology to perform best-estimate large break (LB) loss-of-coolant accident (LOCA) reanalyses for plants already licensed with LBLOCA analyses performed using the methodology described in either of the Westinghouse LBLOCA TRs identified in the Addendum title. The proposed reanalysis methodology would implement an abbreviated calculational approach which would preserve the characteristic plant-specific LBLOCA transient while implementing changes or correcting errors in accordance with 10 CFR 50.46(a)(3). Westinghouse proposed this abbreviated methodology to reduce unnecessary regulatory burden. The staff reviewed the proposal and found it acceptable, as discussed below.

Westinghouse supplemented the information in the above TR in a letter dated December 16, 2003, which provided clarifying details regarding process controls that would be implemented in performing reanalyses using the proposed addendum methodology.

2.0 BACKGROUND AND REGULATORY EVALUATION

The regulations specified in 10 CFR 50.46(a)(1) identify calculational methodology requirements for nuclear power plant LOCA methodologies. Section 10 CFR 50.46(c) identifies the types of processes which are required to assure that LOCA analyses performed for a given plant actually represent that plant. Section 50.46(a)(3)(i and ii) specifies criteria to be applied and actions to be taken when significant changes or errors in parts of the plant-specific LOCA methodology, defined in accordance with 10 CFR 50.46(a)(1) and (c), are found to have accumulated. When the licensee makes changes to its plant input model, or finds errors in parts of the plant-specific LOCA methodology covered by 10 CFR 50.46(a)(1) and (c) that are significant, the licensee must reanalyze the plant's LOCA response. This is usually done by repeating the plant's LOCA analyses (reanalyzing) using a LOCA methodology approved for the plant, with changes and errors updated if the base LOCA methodology remains the same. With

LOCA methodologies covered by 10 CFR Part 50, Appendix K, this reanalysis entails performing one LOCA calculation for each case analyzed. Using the best-estimate LOCA methodologies described in WCAP-12945-P-A and WCAP-14449-P-A, several LOCA calculations are required. The proposed methodology would significantly reduce the number of LOCA calculations needed to perform the reanalysis, and therefore significantly reduce unnecessary regulatory burden, while assuring plant safety.

WCAP-12945-P-A describes the approved Westinghouse best-estimate LBLOCA analysis methodology that applies to Westinghouse three- and four-loop reactor designs with conventional cold leg emergency core cooling system (ECCS) injection. WCAP-14449-P-A describes the approved Westinghouse best-estimate LBLOCA analysis methodology that applies to Westinghouse two-loop reactor designs with upper plenum ECCS injection. The proposed abbreviated best-estimate LBLOCA analysis methodology uses the same computer code, WCOBRA/TRAC, as the staff approved for use in the methodologies described in the TRs.

The Westinghouse best-estimate LBLOCA analysis methodology uses a combination of response surfaces and Monte Carlo techniques to develop a peak cladding temperature (PCT) uncertainty distribution for a plant. Westinghouse demonstrates this using the following equation:

$$PCT_i = PCT_{REF} + \Delta PCT_{PD,i} + \Delta PCT_{IC,i} + \Delta PCT_{MOD,i} + \Delta PCT_{SUP,i}$$

where:

PCT_{REF} = PCT for a fixed set of reference conditions by the approved methodology,

$\Delta PCT_{PD,i}$ = change in PCT due to the power distribution parameters sampled for iteration i,

$\Delta PCT_{IC,i}$ = change in PCT due to sampling of the initial and boundary condition uncertainty distribution for iteration i,

$\Delta PCT_{MOD,i}$ = change in PCT due to the thermal-hydraulic models sampled for iteration i,

$\Delta PCT_{SUP,i}$ = change in PCT due to application of the superposition correction factor, and sampling of the superposition correction uncertainty for iteration i,

In the proposed abbreviated reanalysis methodology, only the PCT_{REF} and $\Delta PCT_{SUP,i}$ are completely recalculated, unless the analyst determines that input changes for the reanalysis will significantly alter the characteristic profile of any of the other factors (i.e., $\Delta PCT_{PD,i}$, $\Delta PCT_{IC,i}$, and $\Delta PCT_{MOD,i}$). If the analyst does determine that one or more of the other factors, or the characteristic plant-specific LBLOCA transient profile is so altered, a decision must be made whether a full reanalysis must be performed in lieu of implementing the abbreviated reanalysis methodology.

The staff reviewed the proposed methodology using as criteria: (1) preservation of the characteristic plant-specific LBLOCA transient profile, and (2) substantial retention of the statistical process profile for the plant. Fulfilling these two objectives provides assurance that the proposed abbreviated reanalysis methodology for the Westinghouse best-estimate LBLOCA analysis methodology will be able to satisfy 10 CFR 50.46(a)(1) and applicable parts of 10 CFR 50.46(c).

3.0 TECHNICAL EVALUATION

The Westinghouse October 9, 2002, letter describes the proposed abbreviated reanalysis methodology and its implementation, as discussed in Section 2.0 above. In a letter dated December 16, 2003, Westinghouse further described how it will implement the methodology. In the October 9, 2002, letter, Westinghouse gave examples to demonstrate how the abbreviated methodology would be implemented. From these examples, it is apparent to the staff that the analyst will be able to make decisions that would allow the methodology to perform LBLOCA analyses using the methodology consistent with the standards set for the source methodologies, while maintaining control of uncertainties within the corrective capabilities of the methodologies. The analyst will also be able to determine when the original approach (WCAP-12945-P-A or WCAP-14449-P-A) is required. The staff's review indicates that the intent of the abbreviated approach is to implement the approved methodology previously used to perform a given plant's best estimate LBLOCA analyses utilizing elements of the previous calculation that continue to directly apply to the current reanalysis. This is done by adjusting elements as needed to suit the reanalyses while not significantly changing their qualitative contribution to the overall calculation, and by exercising the corrective capabilities of the previous approach to assure that the impact on the uncertainty analysis is not significant. Therefore, the staff finds that the proposed abbreviated methodology satisfies the requirements of 10 CFR 50.46(a)(1) regarding the acceptability of the calculational methodology.

The staff requested that Westinghouse provide information regarding controls that would ensure that the methodology would be properly implemented, since the decisions by the analyst require sound technical judgement. In the December 16, 2003, letter, Westinghouse described the process that Westinghouse would implement and the general reanalysis guidelines to provide more objective criteria for decisions to help assure the methodology is not misapplied.

As part of the process, the Westinghouse "Evaluation Model Lead Engineer" would review and concur with the analyses. As a last step, Westinghouse would maintain documentation of the reanalyses, the basis for concluding that the specific application is within the limits of applicability, and the record of concurrence in the Westinghouse plant files for the unit being reanalyzed. This record could be audited and, if necessary, emended.

The controls provided by Westinghouse, along with other programs and other information necessary for application of the calculational framework to a specific LOCA analysis, shared with and/or implemented by the plant licensee (see Section 4.0, "Limitations"), assure that the programmatic requirements for a vendor of 10 CFR 50.46(c) will be satisfied.

The staff also finds that the TR, though associated with previously approved LBLOCA analysis methodologies, is a unique LBLOCA analysis methodology in and of itself. Therefore, in its

initial licensing applications for the various plants to which it may be applied, licensees must submit plant-specific license amendment requests to adopt this methodology, including technical specifications changes, core operating limit report changes, and initial LBLOCA reanalysis results.

4.0 LIMITATIONS

Licensees must include in individual plant requests a statement that the licensee and its fuel vendor (Westinghouse) have ongoing processes which assure that the ranges and values of input parameters for the plant (LOCA) analysis bound the ranges and values of the as-operated plant values for those parameters

"Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" is a unique LBLOCA analysis methodology in and of itself. Therefore, in its initial licensing applications for the various plants to which it may be applied, licensees must submit plant-specific license amendment requests to adopt this methodology, including technical specifications changes, core operating limit report changes, and initial LBLOCA reanalysis results.

As proposed by Westinghouse, licensees may only apply "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" to plants whose approved LBLOCA analyses were performed using methodologies described in either WCAP-12945-P-A or WCAP-14449-P-A.

The staff also finds that the TR, though associated with previously approved LBLOCA analysis methodologies, is a unique LBLOCA analysis methodology in and of itself. Therefore, in its initial licensing applications for the various plants to which it may be applied, licensees must submit plant-specific license amendment requests to adopt this methodology, including technical specifications changes, core operating limit report changes, and initial LBLOCA reanalysis results.

5.0 CONCLUSION

Based on its review as discussed above, the staff concludes that "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" meets applicable requirements of 10 CFR 50.46(a)(1) and (c). Therefore, the staff finds this proposed LBLOCA methodology acceptable within the limitations specified in Section 4.0.

As proposed by Westinghouse, licensees may only apply "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" to plants whose approved LBLOCA analyses were performed using methodologies described in either WCAP-12945-P-A or WCAP-14449-P-A.

Principle Contributor: F. Orr

Date: March 11, 2004

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ABSTRACT

The Westinghouse best-estimate LOCA analysis methodology for 3- and 4-loop plants with cold leg ECCS injection was previously published in WCAP-12945-P-A (proprietary) and WCAP-14747-NP-A (non-proprietary). The methodology was extended to 2-loop plants with upper plenum injection in WCAP-14449-P-A (proprietary) and WCAP-14450-NP-A (non-proprietary). This addendum to those reports describes and justifies a method for satisfying the reanalysis requirements of 10 CFR 50.46, for plants previously analyzed with one of these approved methodologies. The reanalysis methodology involves a recalculation of the reference transient and the superposition correction factor, and re-sampling of the superposition correction uncertainty. Application of this reanalysis methodology is limited to situations where the fundamental plant-specific large break LOCA transient characteristics are unchanged by the error corrections, evaluation model changes, or small changes in expected operating conditions.

SECTION 1
INTRODUCTION

10 CFR 50.46 includes the following requirements relative to ECCS evaluation model changes and errors:

"For each change to or error discovered in an acceptable evaluation model or in the application of such a model that affects the temperature calculation, the applicant or licensee shall report the nature of the change or error and its estimated effect on the limiting ECCS analysis to the Commission at least annually as specified in § 50.4. If the change or error is significant, the applicant or licensee shall provide this report within 30 days and include with the report a proposed schedule for providing a reanalysis or taking other action as may be needed to show compliance with § 50.46 requirements."

The purpose of this report is to provide a technical and regulatory basis for using the superposition correction step of the Westinghouse best-estimate large break LOCA methodology to satisfy the reanalysis requirements stated in 10 CFR 50.46. This justification is applicable to the following evaluation models:

1996 Westinghouse Best Estimate Large Break LOCA Evaluation Model (Bajorek et al., 1998)
1999 Westinghouse Best Estimate Large Break LOCA Evaluation Model, Application to PWRs with Upper Plenum Injection (Dederer et al., 1999)

SECTION 2
OVERVIEW OF WESTINGHOUSE BEST-ESTIMATE LARGE BREAK LOCA METHODOLOGY

A detailed description of the Westinghouse best-estimate large break LOCA methodology for 3-/4-loop PWRs with cold leg ECCS injection is given in Section 26 of WCAP-12945-P-A (Bajorek et al., 1998). The methodology uses a combination of response surfaces and Monte Carlo techniques to develop an uncertainty distribution for the peak cladding temperature (PCT). This can be qualitatively illustrated using the following simplified equation for iteration i:

$$PCT_i = PCT_{REF} + \Delta PCT_{PD,i} + \Delta PCT_{IC,i} + \Delta PCT_{MOD,i} + \Delta PCT_{SUP,i}$$

where,

PCT_{REF} = peak cladding temperature for a fixed set of reference conditions defined by the approved methodology

$\Delta PCT_{PD,i}$ = change in PCT due to the power distribution parameters sampled for iteration i

$\Delta PCT_{IC,i}$ = change in PCT due to sampling of the initial and boundary condition uncertainty distribution for iteration i

$\Delta PCT_{MOD,i}$ = change in PCT due to the thermal-hydraulic models sampled for iteration i

$\Delta PCT_{SUP,i}$ = change in PCT due to application of the superposition correction factor, and sampling of the superposition correction uncertainty for iteration i

The methodology for treating each of the uncertainty components in this equation is summarized below.

Power Distribution Parameters – Variations in total peaking factor (FQ), enthalpy rise peaking factor (FdH), and axial power distribution (characterized by normalized 1/3 power integrals PBOT and PMID) are considered. Additionally, uncertainties in core power, decay heat, gamma energy redistribution, and peaking factor calculational uncertainties are considered [

]a,c

A typical power distribution run matrix is shown in Table 1.

Initial and Boundary Conditions – Other plant parameters that are considered in the uncertainty methodology include RCS fluid temperature and pressure; accumulator water volume, temperature, pressure and line resistance; and safety injection (refueling water storage tank) temperature. [

]a,c

The plant parameters considered in this category are shown in Table 2 for a typical plant-specific application.

Thermal-Hydraulic Models – The thermal-hydraulic models are separated into two groups. "Global" models are those that affect the system response to the transient. "Local" models are those that affect only the hot spot response. The global models considered in the uncertainty analysis are break flow rate (CD), broken cold leg nozzle resistance (KN), broken loop pump resistance (KP), downcomer condensation (XC), and break type (guillotine or split). [

]a,c

The global model run matrix for 3- and 4-loop plants is shown in Table 3 for guillotine breaks, and in Table 4 for split breaks. The local models considered in the HOTSPOT code are:

Local Hot Spot Peaking Factor

Fuel Conductivity Before Burst

Fuel Conductivity After Burst

Fuel Relocation

Gap Conductance

Rod Internal Pressure

Burst Temperature

Burst Strain

Zirc-Water Reaction

Heat Transfer Coefficient

Minimum Film Boiling Temperature

The above discussion is applicable to 3- and 4-loop plants with ECCS injection into the cold legs. For 2-loop plants with low head safety injection into the upper plenum, variations in parameters that control the upper plenum drain distribution are important, while downcomer condensation is not. Therefore, the methodology for 2-loop plants with upper plenum injection replaces variations in downcomer condensation with simultaneous variations in interfacial drag (XD) and condensation (XCU) in the regions of the vessel that control the drain distribution. The revised global model run matrix for 2-loop plants is shown in Table 5 for guillotine breaks, and in Table 6 for split breaks. A detailed description of the Westinghouse best-estimate large break LOCA methodology for 2-loop PWRs with upper plenum injection is given in Sections 5 and 6 of WCAP-14449-P-A (Dederer et al., 1999).

<u>Superposition Correction and Calculation of Total Uncertainty</u> – A preliminary estimate of the PCT uncertainty distributions for the guillotine and limiting split break transients is first performed. A simplified (illustrative) description of the methodology as applied to guillotine breaks follows:

1) Sample from the probability distributions for FQN, FdH, PBOT, PMID, core power, decay heat, gamma energy redistribution, and peaking factor calculational uncertainties. [ ]^{a,c} Insert the resulting values into the response surface equation to obtain the change in PCT due to power related parameters for iteration i, $\Delta PCT_{PD,i}$.

2) Sample from the [

]^{a,c} to obtain the change in PCT due to initial/boundary conditions for iteration i, $\Delta PCT_{IC,i}$.

3) Sample from the probability distributions for CD, KN' and XC. Insert the resulting values into the response surface equations to obtain $HPCT_{ave}$ and σ_{HPCT}. Sample from the normal distribution defined by σ_{HPCT}, and add the result to $HPCT_{ave}$ to obtain the change in PCT due to thermal hydraulic models for iteration i, $\Delta PCT_{MOD,i}$. (For split breaks, sample from the probability distributions for KN' and XC. For UPI plants, sampling of XD+XCU replaces sampling of XC.)

4) Add the results of steps 1 through 3 to obtain the overall PCT for iteration i:

$$PCT_i = PCT_{REF} + \Delta PCT_{PD,i} + \Delta PCT_{IC,i} + \Delta PCT_{MOD,i}$$

5) Repeat steps 1 through 4 10,000 times to develop the overall PCT uncertainty distribution.

The above is performed for guillotine and split breaks, and the most limiting break type is selected. An additional set of analyses is then performed for the limiting break type, to account for the uncertainty in the assumption that the uncertainty components are additive. This is referred to as the "superposition correction" step. A series of WCOBRA/TRAC runs are made, with global models, power distributions, and initial/boundary conditions all varied simultaneously. The run matrix is designed to [

]^{a,c}

The final PCT uncertainty distribution is then calculated for the limiting break type. Steps 1 through 4 are performed for each iteration. [

]^{a,c} Again, 10,000 iterations are used to get the final PCT uncertainty distribution.

SECTION 3
USE OF SUPERPOSITION CORRECTION STEP TO PERFORM REANALYSES

As noted previously, 10 CFR 50.46 includes the following requirements relative to ECCS evaluation model changes and errors:

"For each change to or error discovered in an acceptable evaluation model or in the application of such a model that affects the temperature calculation, the applicant or licensee shall report the nature of the change or error and its estimated effect on the limiting ECCS analysis to the Commission at least annually as specified in § 50.4. If the change or error is significant, the applicant or licensee shall provide this report within 30 days and include with the report a proposed schedule for providing a reanalysis or taking other action as may be needed to show compliance with § 50.46 requirements."

For licensees with an existing best-estimate analysis, it is proposed that the 10 CFR 50.46 reanalysis requirement for significant changes or errors can be satisfied by reanalyzing the reference transient and the superposition correction cases from the original analysis. A more detailed description of this process is given below.

1) [

]a,c

4) The local and core-wide oxidation results from the prior analysis will be reviewed, and updated if necessary using the methodology described in Section 26-5-3 of WCAP-12945-P-A (Bajorek et al., 1999).

It is noted that the NRC has previously approved the use of a similar reanalysis philosophy in the case of a steam generator replacement program (Padovan, 1999).

Several illustrative examples of the use of this reanalysis approach to establish a new 95th percentile PCT follow.

Example 1: A significant error is found in the application of the evaluation model. No changes in the expected operating range of the plant are contemplated.

[

]a,c

Example 2: A significant error is found in the application of the evaluation model. [

]a,c

In each of these examples, a partial reanalysis of the affected portions of the original analysis would be used to quantify the effect of the change(s) on PCT. The final 95th percentile PCT would be considered to be the result of a new analysis, meeting the requirements for 10 CFR 50.46 reanalysis. As such, it would be reported as the new licensing basis PCT.

SECTION 4
APPLICATION TO ANALYSES THAT BOUND MULTIPLE UNITS

Several licensees have used a single best-estimate large break LOCA analysis to bound multiple units. In each of these cases, any plant-to-plant variation in design and/or operating conditions was carefully considered, and comparative calculations were used to aid selection of the bounding plant configuration.

Any applications of the reanalysis strategy presented in this report to analyses that bound multiple units will include comparative calculations of the reanalysis scenario to ensure that the previously selected bounding plant configuration remains applicable. In the event that this cannot be clearly established, additional discussions will be held with the NRC on the proposed plan for completing the reanalysis.

It is noted that the above approach is considered to be consistent with the NRC recommendations in the aforementioned steam generator replacement program (Padovan, 1999).

Example 3: A significant error is found in the application of the evaluation model for a licensee that uses one analysis to bound two units with the same power rating and fuel type, but different vessel designs. As in example 2, [

]a,c

SECTION 5
CONCLUSIONS

This report provides a technical and regulatory basis for using the superposition correction step of the Westinghouse best-estimate large break LOCA methodology to satisfy the reanalysis requirements stated in 10 CFR 50.46. For significant changes to, or errors in, the approved codes and methods, the reanalysis involves [

]a,c The resulting 95th percentile peak cladding temperature is considered to be the new licensing basis PCT.

As part of the reanalysis process, the licensee may wish to make small changes in allowable operating conditions that would not be expected to affect the previously determined sensitivity to variations in power distributions, initial conditions, or thermal-hydraulic models. Examples have been presented to illustrate how these types of changes would be incorporated in the reanalysis.

SECTION 6
REFERENCES

Bajorek, S. M., et al., 1998, "Code Qualification Document for Best Estimate LOCA Analysis," WCAP-12945-P-A, Volume 1, Revision 2, and Volumes 2 through 5, Revision 1, and WCAP-14747 (Non-Proprietary).

Dederer, S. I., et al., 1999, "Application of Best Estimate Large Break LOCA Methodology to Westinghouse PWRs with Upper Plenum Injection," WCAP-14449-P-A, Revision 1, and WCAP-14450-NP-A (Non-Proprietary).

Letter, L. M. Padovan to D. N. Morey, "Joseph M. Farley Nuclear Plant, Units 1 and 2 – Issuance of Amendments Re: Steam Generator Replacements," December 29, 1999.

Table 1: Power Distribution Run Matrix

[				
				]a,c

Table 2: Initial and Boundary Condition Run Matrix

Parameter	Variation	Range of Variation
RCS Temperature	+, -	[
Pressurizer Pressure	+, -	
SI Temperature	+, -	
Accumulator Pressure	+, -	
Accumulator Water Volume	+, -	
Accumulator Temperature	+, -	
Accumulator Line Resistance	+, -	]a,c

Table 3: Global Model Run Matrix for Guillotine Breaks (3-/4-loop plants)

[			
			]a,c

Table 4: Global Model Run Matrix for Split Breaks (3-/4-loop plants)

[		
		]a,c

Table 5: Global Model Run Matrix for Guillotine Breaks (2-loop plants)

[			
			]a,c

Table 6: Global Model Run Matrix for Split Breaks (2-loop plants)

[		
		]a,c

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APPENDIX A

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Our ref: LTR-NRC-03-73

December 16, 2003

Subject: Proposed Limits of Applicability for Best-Estimate LOCA Reanalysis Methodology

Reference: LTR-NRC-02-51, "Request for Review and Approval of Proposed Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," October 9, 2002.

The Reference submitted a proposed methodology for satisfying 10 CFR 50.46 reanalysis requirements for the approved Westinghouse best-estimate large break LOCA methodologies (WCAP-12945-P-A and WCAP-14449-P-A). The staff's review has resulted in a request for Westinghouse to clarify the limits of applicability of the methodology. The attachment contains our response to this request.

When applying the reanalysis methodology to a given plant, Westinghouse will document the basis for concluding that the specific application is within the limits of applicability, and will retain that documentation in our plant records. Concurrence with that conclusion by the engineer currently designated as the Evaluation Model Lead Engineer will be documented as part of those records.

It is our intent to publish the approved version of the reanalysis methodology as Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A, "Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models."

Please contact Mitch Nissley at (412) 374-4303 if you have any questions concerning this transmittal.

Very truly yours,

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

Enclosure

cc: B. J. Benney, NRC (w/3 copies)

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Clarification on Limits of Applicability for Proposed Reanalysis Methodology

The proposed reanalysis methodology will only be applied in circumstances where the fundamental LOCA transient characteristics are unchanged by the error corrections, evaluation model changes, or small changes in expected operating conditions. The fundamental LOCA transient characteristics for a given plant may be described based on its behavior during blowdown and reflood as follows:

Blowdown – Turnaround of the initial hot rod cladding heatup for the reference transient is by one of the following mechanisms:

a) Primarily upward core flow
b) Primarily downward core flow
c) Combination of upward and downward core flow

Reflood – Final turnaround of the hot rod cladding heatup for the reference transient during reflood occurs during one of the following time periods:

a) The initial surge of water into the hot assembly during the first 30 seconds of reflood, prior to boiling in the downcomer
b) Dispersed flow film boiling heat transfer following a period of degraded heat transfer due to boiling in the downcomer

If the fundamental LOCA transient characteristics are unchanged for the reference transient, it is reasonable to assume that changes in transient response due to ranging of the dominant physical phenomena will not be significantly affected, and the proposed reanalysis methodology will be appropriate.

The staff has asked Westinghouse to further delineate those circumstances where the proposed reanalysis methodology may not be applicable. In response to this request, Westinghouse has identified the following examples:

1) The proposed reanalysis methodology is not considered applicable for changes that substantially affect the blowdown cooling behavior. For example, consider a plant in which the blowdown cooling for the reference transient is primarily due to upflow. If the changes result in blowdown cooling for the reference transient that is primarily due to downflow, it would be expected that the propagation of global model uncertainties would be substantially affected by the changes. More specifically, variations in break flow rate or broken cold leg nozzle resistance would be expected to affect blowdown cooling differently than in the previous analysis.

2) The proposed reanalysis methodology is not considered applicable for changes that introduce significant downcomer boiling effects into an analysis that did not previously have them. In this case, the changes would require that the PCT uncertainty be estimated for the late reflood period, which would not have been done in the previous analysis.

3) The proposed reanalysis methodology is not considered applicable for error corrections that obviously invalidate part of the previous uncertainty analysis. An illustrative example would be correction of an error that had over-written the steady state axial power distribution with a uniform distribution at the beginning of the transient. In this example the propagation of power distribution uncertainties established in the previous analysis would obviously not be valid.

Reference:

LTR-NRC-02-51, "Request for Review and Approval of Proposed Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," October 9, 2002.

Westinghouse Non-Proprietary Class 3

WCAP-14747 & WCAP-14450-NP-A
Addendum 1-A, Revision 0

December 2004

Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best Estimate LOCA Evaluation Models

Westinghouse

WCAP-14747 & WCAP-14450-NP-A

Addendum 1-A, Revision 0

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Mitchell E. Nissley
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December 2004

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WASHINGTON, D.C. 20555-0001

March 11, 2004

Mr. John Gresham, Manager
Regulatory and Licensing Engineering
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: FINAL SAFETY EVALUATION FOR WESTINGHOUSE TOPICAL REPORT, "ADDENDUM 1 TO WCAP-12945-P-A AND WCAP-14449-P-A, METHOD FOR SATISFYING 10 CFR 50.46 REANALYSIS REQUIREMENTS FOR BEST-ESTIMATE LOCA EVALUATION MODELS" (TAC NO. MB6803)

Dear Mr. Gresham:

By letter dated October 9, 2002, the Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A, Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," to the staff for review. Westinghouse supplemented the information in the above TR in a letter dated December 16, 2003, which provided clarifying details regarding process controls that would be implemented in performing reanalyses using the proposed addendum methodology. On January 23, 2004, an NRC draft safety evaluation (SE) regarding our approval of the TR was provided for your review and comments. By e-mail dated February 11, 2004, Westinghouse agreed with the content of the SE.

The staff has found that the TR is acceptable for referencing as an approved methodology in plant licensing applications. The enclosed SE documents the staff's evaluation of Westinghouse's justification for the improved methodology.

Our acceptance applies only to the 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's TR website, we request that Westinghouse publish an accepted version of this TR within three months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed SE between the title page and the abstract. It must be well indexed such that information is readily located. Also, it must contain in appendices historical review information, such as questions and accepted responses, draft SE comments, and original report pages that were replaced. The accepted version shall include a "-A" (designating "accepted") following the report identification symbol.

If the NRC's criteria or regulations change so that its conclusions in this letter, that the TR is acceptable, is invalidated, Westinghouse and/or the licensees referencing the TR will be expected to revise and resubmit its respective documentation, or submit justification for the continued applicability of the TR without revision of the respective documentation.

Sincerely,

Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 700

Enclosure: Safety Evaluation

cc w/encl:
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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

"ADDENDUM 1 TO WCAP-12945-P-A AND WCAP-14449-P-A, METHOD FOR SATISFYING 10 CFR 50.46 REANALYSIS REQUIREMENTS FOR BEST-ESTIMATE LOCA EVALUATION MODELS"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 INTRODUCTION

By letter dated October 9, 2002, the Westinghouse Electric Company (Westinghouse) submitted Topical Report (TR) "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A, Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," to the NRC for review and approval. The TR describes a proposed methodology to perform best-estimate large break (LB) loss-of-coolant accident (LOCA) reanalyses for plants already licensed with LBLOCA analyses performed using the methodology described in either of the Westinghouse LBLOCA TRs identified in the Addendum title. The proposed reanalysis methodology would implement an abbreviated calculational approach which would preserve the characteristic plant-specific LBLOCA transient while implementing changes or correcting errors in accordance with 10 CFR 50.46(a)(3). Westinghouse proposed this abbreviated methodology to reduce unnecessary regulatory burden. The staff reviewed the proposal and found it acceptable, as discussed below.

Westinghouse supplemented the information in the above TR in a letter dated December 16, 2003, which provided clarifying details regarding process controls that would be implemented in performing reanalyses using the proposed addendum methodology.

2.0 BACKGROUND AND REGULATORY EVALUATION

The regulations specified in 10 CFR 50.46(a)(1) identify calculational methodology requirements for nuclear power plant LOCA methodologies. Section 10 CFR 50.46(c) identifies the types of processes which are required to assure that LOCA analyses performed for a given plant actually represent that plant. Section 50.46(a)(3)(i and ii) specifies criteria to be applied and actions to be taken when significant changes or errors in parts of the plant-specific LOCA methodology, defined in accordance with 10 CFR 50.46(a)(1) and (c), are found to have accumulated. When the licensee makes changes to its plant input model, or finds errors in parts of the plant-specific LOCA methodology covered by 10 CFR 50.46(a)(1) and (c) that are significant, the licensee must reanalyze the plant's LOCA response. This is usually done by repeating the plant's LOCA analyses (reanalyzing) using a LOCA methodology approved for the plant, with changes and errors updated if the base LOCA methodology remains the same. With

LOCA methodologies covered by 10 CFR Part 50, Appendix K, this reanalysis entails performing one LOCA calculation for each case analyzed. Using the best-estimate LOCA methodologies described in WCAP-12945-P-A and WCAP-14449-P-A, several LOCA calculations are required. The proposed methodology would significantly reduce the number of LOCA calculations needed to perform the reanalysis, and therefore significantly reduce unnecessary regulatory burden, while assuring plant safety.

WCAP-12945-P-A describes the approved Westinghouse best-estimate LBLOCA analysis methodology that applies to Westinghouse three- and four-loop reactor designs with conventional cold leg emergency core cooling system (ECCS) injection. WCAP-14449-P-A describes the approved Westinghouse best-estimate LBLOCA analysis methodology that applies to Westinghouse two-loop reactor designs with upper plenum ECCS injection. The proposed abbreviated best-estimate LBLOCA analysis methodology uses the same computer code, WCOBRA/TRAC, as the staff approved for use in the methodologies described in the TRs.

The Westinghouse best-estimate LBLOCA analysis methodology uses a combination of response surfaces and Monte Carlo techniques to develop a peak cladding temperature (PCT) uncertainty distribution for a plant. Westinghouse demonstrates this using the following equation:

$$PCT_i = PCT_{REF} + \Delta PCT_{PD,i} + \Delta PCT_{IC,i} + \Delta PCT_{MOD,i} + \Delta PCT_{SUP,i}$$

where:

PCT_{REF} = PCT for a fixed set of reference conditions by the approved methodology,

$\Delta PCT_{PD,i}$ = change in PCT due to the power distribution parameters sampled for iteration i,

$\Delta PCT_{IC,i}$ = change in PCT due to sampling of the initial and boundary condition uncertainty distribution for iteration i,

$\Delta PCT_{MOD,i}$ = change in PCT due to the thermal-hydraulic models sampled for iteration i,

$\Delta PCT_{SUP,i}$ = change in PCT due to application of the superposition correction factor, and sampling of the superposition correction uncertainty for iteration i,

In the proposed abbreviated reanalysis methodology, only the PCT_{REF} and $\Delta PCT_{SUP,i}$ are completely recalculated, unless the analyst determines that input changes for the reanalysis will significantly alter the characteristic profile of any of the other factors (i.e., $\Delta PCT_{PD,i}$, $\Delta PCT_{IC,i}$, and $\Delta PCT_{MOD,i}$). If the analyst does determine that one or more of the other factors, or the characteristic plant-specific LBLOCA transient profile is so altered, a decision must be made whether a full reanalysis must be performed in lieu of implementing the abbreviated reanalysis methodology.

The staff reviewed the proposed methodology using as criteria: (1) preservation of the characteristic plant-specific LBLOCA transient profile, and (2) substantial retention of the statistical process profile for the plant. Fulfilling these two objectives provides assurance that the proposed abbreviated reanalysis methodology for the Westinghouse best-estimate LBLOCA analysis methodology will be able to satisfy 10 CFR 50.46(a)(1) and applicable parts of 10 CFR 50.46(c).

3.0 TECHNICAL EVALUATION

The Westinghouse October 9, 2002, letter describes the proposed abbreviated reanalysis methodology and its implementation, as discussed in Section 2.0 above. In a letter dated December 16, 2003, Westinghouse further described how it will implement the methodology. In the October 9, 2002, letter, Westinghouse gave examples to demonstrate how the abbreviated methodology would be implemented. From these examples, it is apparent to the staff that the analyst will be able to make decisions that would allow the methodology to perform LBLOCA analyses using the methodology consistent with the standards set for the source methodologies, while maintaining control of uncertainties within the corrective capabilities of the methodologies. The analyst will also be able to determine when the original approach (WCAP-12945-P-A or WCAP-14449-P-A) is required. The staff's review indicates that the intent of the abbreviated approach is to implement the approved methodology previously used to perform a given plant's best estimate LBLOCA analyses utilizing elements of the previous calculation that continue to directly apply to the current reanalysis. This is done by adjusting elements as needed to suit the reanalyses while not significantly changing their qualitative contribution to the overall calculation, and by exercising the corrective capabilities of the previous approach to assure that the impact on the uncertainty analysis is not significant. Therefore, the staff finds that the proposed abbreviated methodology satisfies the requirements of 10 CFR 50.46(a)(1) regarding the acceptability of the calculational methodology.

The staff requested that Westinghouse provide information regarding controls that would ensure that the methodology would be properly implemented, since the decisions by the analyst require sound technical judgement. In the December 16, 2003, letter, Westinghouse described the process that Westinghouse would implement and the general reanalysis guidelines to provide more objective criteria for decisions to help assure the methodology is not misapplied.

As part of the process, the Westinghouse "Evaluation Model Lead Engineer" would review and concur with the analyses. As a last step, Westinghouse would maintain documentation of the reanalyses, the basis for concluding that the specific application is within the limits of applicability, and the record of concurrence in the Westinghouse plant files for the unit being reanalyzed. This record could be audited and, if necessary, emended.

The controls provided by Westinghouse, along with other programs and other information necessary for application of the calculational framework to a specific LOCA analysis, shared with and/or implemented by the plant licensee (see Section 4.0, "Limitations"), assure that the programmatic requirements for a vendor of 10 CFR 50.46(c) will be satisfied.

The staff also finds that the TR, though associated with previously approved LBLOCA analysis methodologies, is a unique LBLOCA analysis methodology in and of itself. Therefore, in its

initial licensing applications for the various plants to which it may be applied, licensees must submit plant-specific license amendment requests to adopt this methodology, including technical specifications changes, core operating limit report changes, and initial LBLOCA reanalysis results.

4.0 LIMITATIONS

Licensees must include in individual plant requests a statement that the licensee and its fuel vendor (Westinghouse) have ongoing processes which assure that the ranges and values of input parameters for the plant (LOCA) analysis bound the ranges and values of the as-operated plant values for those parameters

"Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" is a unique LBLOCA analysis methodology in and of itself. Therefore, in its initial licensing applications for the various plants to which it may be applied, licensees must submit plant-specific license amendment requests to adopt this methodology, including technical specifications changes, core operating limit report changes, and initial LBLOCA reanalysis results.

As proposed by Westinghouse, licensees may only apply "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" to plants whose approved LBLOCA analyses were performed using methodologies described in either WCAP-12945-P-A or WCAP-14449-P-A.

The staff also finds that the TR, though associated with previously approved LBLOCA analysis methodologies, is a unique LBLOCA analysis methodology in and of itself. Therefore, in its initial licensing applications for the various plants to which it may be applied, licensees must submit plant-specific license amendment requests to adopt this methodology, including technical specifications changes, core operating limit report changes, and initial LBLOCA reanalysis results.

5.0 CONCLUSION

Based on its review as discussed above, the staff concludes that "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" meets applicable requirements of 10 CFR 50.46(a)(1) and (c). Therefore, the staff finds this proposed LBLOCA methodology acceptable within the limitations specified in Section 4.0.

As proposed by Westinghouse, licensees may only apply "Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A" to plants whose approved LBLOCA analyses were performed using methodologies described in either WCAP-12945-P-A or WCAP-14449-P-A.

Principle Contributor: F. Orr

Date: March 11, 2004

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ABSTRACT

The Westinghouse best-estimate LOCA analysis methodology for 3- and 4-loop plants with cold leg ECCS injection was previously published in WCAP-12945-P-A (proprietary) and WCAP-14747-NP-A (non-proprietary). The methodology was extended to 2-loop plants with upper plenum injection in WCAP-14449-P-A (proprietary) and WCAP-14450-NP-A (non-proprietary). This addendum to those reports describes and justifies a method for satisfying the reanalysis requirements of 10 CFR 50.46, for plants previously analyzed with one of these approved methodologies. The reanalysis methodology involves a recalculation of the reference transient and the superposition correction factor, and re-sampling of the superposition correction uncertainty. Application of this reanalysis methodology is limited to situations where the fundamental plant-specific large break LOCA transient characteristics are unchanged by the error corrections, evaluation model changes, or small changes in expected operating conditions.

SECTION 1
INTRODUCTION

10 CFR 50.46 includes the following requirements relative to ECCS evaluation model changes and errors:

"For each change to or error discovered in an acceptable evaluation model or in the application of such a model that affects the temperature calculation, the applicant or licensee shall report the nature of the change or error and its estimated effect on the limiting ECCS analysis to the Commission at least annually as specified in § 50.4. If the change or error is significant, the applicant or licensee shall provide this report within 30 days and include with the report a proposed schedule for providing a reanalysis or taking other action as may be needed to show compliance with § 50.46 requirements."

The purpose of this report is to provide a technical and regulatory basis for using the superposition correction step of the Westinghouse best-estimate large break LOCA methodology to satisfy the reanalysis requirements stated in 10 CFR 50.46. This justification is applicable to the following evaluation models:

1996 Westinghouse Best Estimate Large Break LOCA Evaluation Model (Bajorek et al., 1998)
1999 Westinghouse Best Estimate Large Break LOCA Evaluation Model, Application to PWRs with Upper Plenum Injection (Dederer et al., 1999)

SECTION 2
OVERVIEW OF WESTINGHOUSE BEST-ESTIMATE LARGE BREAK LOCA METHODOLOGY

A detailed description of the Westinghouse best-estimate large break LOCA methodology for 3-/4-loop PWRs with cold leg ECCS injection is given in Section 26 of WCAP-12945-P-A (Bajorek et al., 1998). The methodology uses a combination of response surfaces and Monte Carlo techniques to develop an uncertainty distribution for the peak cladding temperature (PCT). This can be qualitatively illustrated using the following simplified equation for iteration i:

$$PCT_i = PCT_{REF} + \Delta PCT_{PD,i} + \Delta PCT_{IC,i} + \Delta PCT_{MOD,i} + \Delta PCT_{SUP,i}$$

where,

PCT_{REF} = peak cladding temperature for a fixed set of reference conditions defined by the approved methodology

$\Delta PCT_{PD,i}$ = change in PCT due to the power distribution parameters sampled for iteration i

$\Delta PCT_{IC,i}$ = change in PCT due to sampling of the initial and boundary condition uncertainty distribution for iteration i

$\Delta PCT_{MOD,i}$ = change in PCT due to the thermal-hydraulic models sampled for iteration i

$\Delta PCT_{SUP,i}$ = change in PCT due to application of the superposition correction factor, and sampling of the superposition correction uncertainty for iteration i

The methodology for treating each of the uncertainty components in this equation is summarized below.

Power Distribution Parameters – Variations in total peaking factor (FQ), enthalpy rise peaking factor (FdH), and axial power distribution (characterized by normalized 1/3 power integrals PBOT and PMID) are considered. Additionally, uncertainties in core power, decay heat, gamma energy redistribution, and peaking factor calculational uncertainties are considered [

]^{a,c}

A typical power distribution run matrix is shown in Table 1.

<u>Initial and Boundary Conditions</u> – Other plant parameters that are considered in the uncertainty methodology include RCS fluid temperature and pressure; accumulator water volume, temperature, pressure and line resistance; and safety injection (refueling water storage tank) temperature. [

]a,c

The plant parameters considered in this category are shown in Table 2 for a typical plant-specific application.

<u>Thermal-Hydraulic Models</u> – The thermal-hydraulic models are separated into two groups. "Global" models are those that affect the system response to the transient. "Local" models are those that affect only the hot spot response. The global models considered in the uncertainty analysis are break flow rate (CD), broken cold leg nozzle resistance (KN), broken loop pump resistance (KP), downcomer condensation (XC), and break type (guillotine or split). [

]a,c

The global model run matrix for 3- and 4-loop plants is shown in Table 3 for guillotine breaks, and in Table 4 for split breaks. The local models considered in the HOTSPOT code are:

Local Hot Spot Peaking Factor

Fuel Conductivity Before Burst

Fuel Conductivity After Burst

Fuel Relocation

Gap Conductance

Rod Internal Pressure

Burst Temperature

Burst Strain

Zirc-Water Reaction

Heat Transfer Coefficient

Minimum Film Boiling Temperature

The above discussion is applicable to 3- and 4-loop plants with ECCS injection into the cold legs. For 2-loop plants with low head safety injection into the upper plenum, variations in parameters that control the upper plenum drain distribution are important, while downcomer condensation is not. Therefore, the methodology for 2-loop plants with upper plenum injection replaces variations in downcomer condensation with simultaneous variations in interfacial drag (XD) and condensation (XCU) in the regions of the vessel that control the drain distribution. The revised global model run matrix for 2-loop plants is shown in Table 5 for guillotine breaks, and in Table 6 for split breaks. A detailed description of the Westinghouse best-estimate large break LOCA methodology for 2-loop PWRs with upper plenum injection is given in Sections 5 and 6 of WCAP-14449-P-A (Dederer et al., 1999).

Superposition Correction and Calculation of Total Uncertainty – A preliminary estimate of the PCT uncertainty distributions for the guillotine and limiting split break transients is first performed. A simplified (illustrative) description of the methodology as applied to guillotine breaks follows:

1) Sample from the probability distributions for FQN, FdH, PBOT, PMID, core power, decay heat, gamma energy redistribution, and peaking factor calculational uncertainties. [ ]^{a,c} Insert the resulting values into the response surface equation to obtain the change in PCT due to power related parameters for iteration i, $\Delta PCT_{PD,i}$.

2) Sample from the [

]^{a,c} to obtain the change in PCT due to initial/boundary conditions for iteration i, $\Delta PCT_{IC,i}$.

3) Sample from the probability distributions for CD, KN' and XC. Insert the resulting values into the response surface equations to obtain $HPCT_{ave}$ and σ_{HPCT}. Sample from the normal distribution defined by σ_{HPCT}, and add the result to $HPCT_{ave}$ to obtain the change in PCT due to thermal hydraulic models for iteration i, $\Delta PCT_{MOD,i}$. (For split breaks, sample from the probability distributions for KN' and XC. For UPI plants, sampling of XD+XCU replaces sampling of XC.)

4) Add the results of steps 1 through 3 to obtain the overall PCT for iteration i:

$$PCT_i = PCT_{REF} + \Delta PCT_{PD,i} + \Delta PCT_{IC,i} + \Delta PCT_{MOD,i}$$

5) Repeat steps 1 through 4 10,000 times to develop the overall PCT uncertainty distribution.

The above is performed for guillotine and split breaks, and the most limiting break type is selected. An additional set of analyses is then performed for the limiting break type, to account for the uncertainty in the assumption that the uncertainty components are additive. This is referred to as the "superposition correction" step. A series of WCOBRA/TRAC runs are made, with global models, power distributions, and initial/boundary conditions all varied simultaneously. The run matrix is designed to [

]^{a,c}

The final PCT uncertainty distribution is then calculated for the limiting break type. Steps 1 through 4 are performed for each iteration. [

]^{a,c} Again, 10,000 iterations are used to get the final PCT uncertainty distribution.

SECTION 3
USE OF SUPERPOSITION CORRECTION STEP TO PERFORM REANALYSES

As noted previously, 10 CFR 50.46 includes the following requirements relative to ECCS evaluation model changes and errors:

"For each change to or error discovered in an acceptable evaluation model or in the application of such a model that affects the temperature calculation, the applicant or licensee shall report the nature of the change or error and its estimated effect on the limiting ECCS analysis to the Commission at least annually as specified in § 50.4. If the change or error is significant, the applicant or licensee shall provide this report within 30 days and include with the report a proposed schedule for providing a reanalysis or taking other action as may be needed to show compliance with § 50.46 requirements."

For licensees with an existing best-estimate analysis, it is proposed that the 10 CFR 50.46 reanalysis requirement for significant changes or errors can be satisfied by reanalyzing the reference transient and the superposition correction cases from the original analysis. A more detailed description of this process is given below.

1) [

]a,c

4) The local and core-wide oxidation results from the prior analysis will be reviewed, and updated if necessary using the methodology described in Section 26-5-3 of WCAP-12945-P-A (Bajorek et al., 1999).

It is noted that the NRC has previously approved the use of a similar reanalysis philosophy in the case of a steam generator replacement program (Padovan, 1999).

Several illustrative examples of the use of this reanalysis approach to establish a new 95th percentile PCT follow.

Example 1: A significant error is found in the application of the evaluation model. No changes in the expected operating range of the plant are contemplated.

[

]a,c

Example 2: A significant error is found in the application of the evaluation model. [

]a,c

In each of these examples, a partial reanalysis of the affected portions of the original analysis would be used to quantify the effect of the change(s) on PCT. The final 95th percentile PCT would be considered to be the result of a new analysis, meeting the requirements for 10 CFR 50.46 reanalysis. As such, it would be reported as the new licensing basis PCT.

SECTION 4
APPLICATION TO ANALYSES THAT BOUND MULTIPLE UNITS

Several licensees have used a single best-estimate large break LOCA analysis to bound multiple units. In each of these cases, any plant-to-plant variation in design and/or operating conditions was carefully considered, and comparative calculations were used to aid selection of the bounding plant configuration.

Any applications of the reanalysis strategy presented in this report to analyses that bound multiple units will include comparative calculations of the reanalysis scenario to ensure that the previously selected bounding plant configuration remains applicable. In the event that this cannot be clearly established, additional discussions will be held with the NRC on the proposed plan for completing the reanalysis.

It is noted that the above approach is considered to be consistent with the NRC recommendations in the aforementioned steam generator replacement program (Padovan, 1999).

Example 3: A significant error is found in the application of the evaluation model for a licensee that uses one analysis to bound two units with the same power rating and fuel type, but different vessel designs. As in example 2, [

]a,c

SECTION 5
CONCLUSIONS

This report provides a technical and regulatory basis for using the superposition correction step of the Westinghouse best-estimate large break LOCA methodology to satisfy the reanalysis requirements stated in 10 CFR 50.46. For significant changes to, or errors in, the approved codes and methods, the reanalysis involves [

]a,c The resulting 95th percentile peak cladding temperature is considered to be the new licensing basis PCT.

As part of the reanalysis process, the licensee may wish to makesmall changes in allowable operating conditions that would not be expected to affect the previously determined sensitivity to variations in power distributions, initial conditions, or thermal-hydraulic models. Examples have been presented to illustrate how these types of changes would be incorporated in the reanalysis.

SECTION 6
REFERENCES

Bajorek, S. M., et al., 1998, "Code Qualification Document for Best Estimate LOCA Analysis," WCAP-12945-P-A, Volume 1, Revision 2, and Volumes 2 through 5, Revision 1, and WCAP-14747 (Non-Proprietary).

Dederer, S. I., et al., 1999, "Application of Best Estimate Large Break LOCA Methodology to Westinghouse PWRs with Upper Plenum Injection," WCAP-14449-P-A, Revision 1, and WCAP-14450-NP-A (Non-Proprietary).

Letter, L. M. Padovan to D. N. Morey, "Joseph M. Farley Nuclear Plant, Units 1 and 2 – Issuance of Amendments Re: Steam Generator Replacements," December 29, 1999.

Table 1: Power Distribution Run Matrix

[				
				]a,c

Table 2: Initial and Boundary Condition Run Matrix

Parameter	Variation	Range of Variation
RCS Temperature	+, -	[
Pressurizer Pressure	+, -	
SI Temperature	+, -	
Accumulator Pressure	+, -	
Accumulator Water Volume	+, -	
Accumulator Temperature	+, -	
Accumulator Line Resistance	+, -	]a,c

Table 3: Global Model Run Matrix for Guillotine Breaks (3-/4-loop plants)

[			
			][a,c]

Table 4: Global Model Run Matrix for Split Breaks (3-/4-loop plants)

[		
		][a,c]

Table 5: Global Model Run Matrix for Guillotine Breaks (2-loop plants)

[			
			]a,c

Table 6: Global Model Run Matrix for Split Breaks (2-loop plants)

[		
		]a,c

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APPENDIX A

Westinghouse

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Our ref: LTR-NRC-03-73

December 16, 2003

Subject: Proposed Limits of Applicability for Best-Estimate LOCA Reanalysis Methodology

Reference: LTR-NRC-02-51, "Request for Review and Approval of Proposed Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," October 9, 2002.

The Reference submitted a proposed methodology for satisfying 10 CFR 50.46 reanalysis requirements for the approved Westinghouse best-estimate large break LOCA methodologies (WCAP-12945-P-A and WCAP-14449-P-A). The staff's review has resulted in a request for Westinghouse to clarify the limits of applicability of the methodology. The attachment contains our response to this request.

When applying the reanalysis methodology to a given plant, Westinghouse will document the basis for concluding that the specific application is within the limits of applicability, and will retain that documentation in our plant records. Concurrence with that conclusion by the engineer currently designated as the Evaluation Model Lead Engineer will be documented as part of those records.

It is our intent to publish the approved version of the reanalysis methodology as Addendum 1 to WCAP-12945-P-A and WCAP-14449-P-A, "Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models."

Please contact Mitch Nissley at (412) 374-4303 if you have any questions concerning this transmittal.

Very truly yours,

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

Enclosures

cc: B. J. Benney, NRC (w/3 copies)

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Clarification on Limits of Applicability for Proposed Reanalysis Methodology

The proposed reanalysis methodology will only be applied in circumstances where the fundamental LOCA transient characteristics are unchanged by the error corrections, evaluation model changes, or small changes in expected operating conditions. The fundamental LOCA transient characteristics for a given plant may be described based on its behavior during blowdown and reflood as follows:

Blowdown – Turnaround of the initial hot rod cladding heatup for the reference transient is by one of the following mechanisms:

a) Primarily upward core flow
b) Primarily downward core flow
c) Combination of upward and downward core flow

Reflood – Final turnaround of the hot rod cladding heatup for the reference transient during reflood occurs during one of the following time periods:

a) The initial surge of water into the hot assembly during the first 30 seconds of reflood, prior to boiling in the downcomer
b) Dispersed flow film boiling heat transfer following a period of degraded heat transfer due to boiling in the downcomer

If the fundamental LOCA transient characteristics are unchanged for the reference transient, it is reasonable to assume that changes in transient response due to ranging of the dominant physical phenomena will not be significantly affected, and the proposed reanalysis methodology will be appropriate.

The staff has asked Westinghouse to further delineate those circumstances where the proposed reanalysis methodology may <u>not</u> be applicable. In response to this request, Westinghouse has identified the following examples:

1) The proposed reanalysis methodology is not considered applicable for changes that substantially affect the blowdown cooling behavior. For example, consider a plant in which the blowdown cooling for the reference transient is primarily due to upflow. If the changes result in blowdown cooling for the reference transient that is primarily due to downflow, it would be expected that the propagation of global model uncertainties would be substantially affected by the changes. More specifically, variations in break flow rate or broken cold leg nozzle resistance would be expected to affect blowdown cooling differently than in the previous analysis.

2) The proposed reanalysis methodology is not considered applicable for changes that introduce significant downcomer boiling effects into an analysis that did not previously have them. In this case, the changes would require that the PCT uncertainty be estimated for the late reflood period, which would not have been done in the previous analysis.

3) The proposed reanalysis methodology is not considered applicable for error corrections that obviously invalidate part of the previous uncertainty analysis. An illustrative example would be correction of an error that had over-written the steady state axial power distribution with a uniform distribution at the beginning of the transient. In this example the propagation of power distribution uncertainties established in the previous analysis would obviously not be valid.

Reference:

LTR-NRC-02-51, "Request for Review and Approval of Proposed Method for Satisfying 10 CFR 50.46 Reanalysis Requirements for Best-Estimate LOCA Evaluation Models," October 9, 2002.