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}

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] 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.

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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.

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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, [

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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

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				][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)

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

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		]a,c

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

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			][a,c]

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

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