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SUBJECT: Provides further info re incidence of spurious CHG lockout

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Compiler Problem and Spurious CHF Lockout

On November 18, 1996 Allen Levin, Joe Staudenmeier, George Thomas, and Jack Donohew of the USNRC and Rich Gottula, Gene Jensen, Kent Richert, Mike Hibbard, and Don Curet of SPC had discussions by phone regarding compiler problems and a spurious CHF lockout reported to the USNRC by CP&L and SPC. Of particular interest to the NRC staff was the spurious CHF lockout noted in a 50.46 notification by CP&L to the NRC. There was some discussion and explanation about the cause of this lockout by Kent Richert. However, the staff requested SPC to provide additional written information regarding the CHF lockout. This letter is intended to provide further explanation regarding the incidence of spurious CHF lockout experienced and reported to the NRC.

Initially, a consultant assisting SPC to convert the RELAP4 code for execution on a DEC Alpha workstation noted differences between the original code results from the Cray platform and the code results for the same input from the DEC Alpha workstation. The RELAP4 code requires user input including variables ISBAJ and ISWTAB in the core section data cards (16XXX5). These data are then read in and if necessary converted for code use by the code input processing routines. The processed input data are then printed and used by the code. The consultant noted for runs made on the Cray the values printed and used by the code for the ISLBAJ and the ISWTAB parameters differed from the user input values. This use of different values for these parameters creates potential errors in the analyses performed using the code.

The same source code and user input when compiled and run on a Cyber platform (platform used prior to the Cray) or a DEC Alpha workstation executed properly and yielded the same results. However, the same source code compiled on the Cray and executed with the same input resulted in different results. Compiler optimization was suspected to be the problem and RELAP4 was recompiled on the Cray computer with optimization turned off when compiling the input processing routine (Subroutine INCORE). Running the same input with the recompiled code gave correct values for the affected parameters, and yielded results essentially overlaying those obtained with the DEC Alpha workstation.

<u>Compiler Problem Evaluations</u>

Since no one had ever directly compared all processed input data to user data for the RELAP4 analyses performed on the Cray, extensive evaluations of previous PWR LBLOCA analyses were undertaken. PWR LBLOCA analyses for both U.S. and European reactors with the RELAP4 code were reanalyzed. The results of the analyses for these PWRs follow.

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A001

Millstone Unit 2

The LBLOCA peak cladding temperature (PCT) for Millstone Unit 2 calculated on the Cray, before the compiler problem was identified, was 1798°F. The PCT based on correction of the compiler optimization is 1790°F.

St. Lucie Unit 1

The LBLOCA PCT for St. Lucie Unit 1 calculated on the Cray, before the compiler problem was identified, was 1901°F. The PCT based on correction of the compiler optimization is 1902°F

Robinson

The LBLOCA PCT for Robinson calculated on the Cray, before the compiler problem was identified, was 2006°F. The PCT based on correction of the compiler optimization is 2001°F.

Palisades

The LBLOCA PCT for Palisades calculated on the Cray, before the compiler problem was identified, was 1991°F. The PCT based on correction of the compiler optimization is 1992°F.

Harris

At the time of the evaluations the reported LBLOCA PCT for Harris was 2025°F for a 0.8 DECLG, MOC axial shape. This PCT was determined, during the evaluation of the compiler problem, to be excessively conservative because an early, unrealistic CHF lockout was predicted to have occurred in the bottom average core volume in the RELAP4 model. Calculations performed for the 0.6, 0.8, and 1.0 Double-Ended-Cold-Leg-Guillotine break cases with a BOC axial shape to evaluate the effect of the Cray compiler optimization showed the effect of the Cray compiler optimization to range from +4°F to -6°F. The PCT for the limiting case based on correction of the Cray compiler optimization was 2019°F. Also a large reduction in PCT of -115°F, attributed to the mitigation of the consequences of the unrealistic, early CHF lockout during the calculation on the DEC Alpha workstation, resulted in a PCT of 1904°F. These changes in PCTs were reported by CP&L to the NRC (see attached CP&L letter).

Tihange

The Tihange LBLOCA analysis evaluation of the compiler optimization problem showed a 7°F increase in PCT for ANF fuel and an 11°F increase for Framatome fuel.

Doel 2

The Doel 2 LBLOCA analysis evaluation of the compiler optimization problem showed a 40°F decrease in PCT for ANF fuel and a 22°F decrease in PCT for Framatome fuel.

The following table summarizes the differences in PCT results for the Cray compiler problem evaluations on PWR LBLOCA calculations.

PLANT	PCT Differences
Millstone Unit 2	-8°F
St. Lucie Unit 1	+1°F
Robinson	-5°F
Palisades	+1°F
Harris	-6°F
Tihange	+7°F for ANF fuel +11°F for Framatome fuel
Doel 2	-40°F for ANF fuel -22°F for Framatome fuel

Harris Spurious CHF Lockout

A significant reduction in PCT (-115°F) was calculated during the compiler problem evaluations. It is clear from the consistency of all the cases run, that the compiler problem is a small effect, and that the PCT reduction observed for this one Harris case is due to some larger effect which is triggered by the compiler change. Further examination showed that this is indeed the case. As stated earlier and in the CP&L letter to the NRC, this reduction in PCT is attributed to an unrealistic, early CHF lockout that occurred unobserved in the previous analyses. Appendix K requires that after CHF is first predicted at an axial location during blowdown or if the temperature difference between the cladding temperature and saturated fluid temperature exceeds 300° F, the calculation shall not use nucleate boiling heat transfer correlations at that location subsequently during the blowdown. This requirement is implemented in the RELAP4 program by locking out pre-CHF regimes once the calculated surface heat flux has exceeded the calculated critical heat flux on any fuel rod node or if the temperature difference between the cladding temperature and saturated fluid temperature exceeds 300° F. However, the calculation of the occurrence of CHF lockout with RELAP4 may not always be phenomenological. RELAP4, as all other LOCA analysis codes, uses numerical methods and discrete nodalization to represent a reactor primary system for LOCA analysis. A result of such analysis with numerical methods and nodalization is that while the basic LOCA phenomena are calculated, sudden oscillations, which are not physically real, are occasionally observed. These oscillations can be observed in the prediction of CHF due to modeling and numerical effects.

The Harris calculation is an example of this effect being observed. An early CHF lockout occurred in the bottom average core volume in the RELAP4 model of Harris. This volume represents about one-third the volume of the core. Thus, after the volume experienced CHF lockout it then significantly perturbed subsequent thermal-hydraulic LOCA behavior. As described by Mr. Richert, such an early CHF lockout may occur during a rapid core flow reversal. The heat transfer and CHF correlations require a volume averaged flow. RELAP4 currently uses the same volume average flow definition for the momentum flux model and the heat transfer and CHF models. While the momentum flux model requires a vector quantity for flow, the heat transfer and CHF models are only concerned with the absolute value of flow. If the inlet and the outlet flows for a given volume happen to have opposite signs but similar magnitude, the vector average flow would be very small; while a more physical, integrated absolute value average would be more representative of the volume flow. If both the inlet and outlet flows are small, then both definitions would result in a small value and hence a real,

physical CHF lockout. In Figure 1 the very oscillatory behavior of the calculated CHF values can be seen. The average of the peak to peak CHF values is considered to be most representative of the CHF behavior. Figure 2, which is an expanded view of the data shown in Figure 1, shows that the early CHF lockout experienced in the Harris analysis occurred at about 1.0 second into the blowdown when the CHF value was less than the calculated surface heat flux. Again, this lockout is considered to be extraordinary as it occurred in the bottom average core volume where the heat fluxes are low and the lockout would be expected to occur when the temperature difference between the cladding temperature and saturated fluid temperature exceeds 300° F. Also upon close examination of the spurious lockout event for Harris it was noticed that a time step selection at a time when the inlet and outlet flows of the lower core volume were algebraically equal resulted in a CHF lockout at an unrealistically low CHF value. Figure 3 is the same Harris LOCA case run on the Cray with the recompiled code and as can be seen the early CHF lockout did not occur. The lockout for this reanalysis occurs as expected just beyond two seconds into the blowdown when the temperature difference between the cladding temperature and saturated fluid temperature first exceeds 300° F.

<u>Summary</u>

Many LBLOCA calculations, in addition to the limiting PCT cases, were performed with consistent inputs between the Cray and DEC Alpha platforms to fully assess the compiler optimization problem. Harris calculation results are considered to be unique due to the one case where the early CHF lockout occurred in previous calculations on the Cray platform. Therefore, elimination of the early CHF lockout in the LOCA analysis executed on the on the Cray with the recompiled code and on a DEC Alpha workstation is considered to be more representative of anticipated LOCA results.

If you have any questions, please call me at (509) 375-8563.

Very truly yours,

H D Curet

H. D. Curet, Manager
Product Licensing

Attachments

cc: T. E. Collins (USNRC)
A. E. Levin (USNRC)
G. Thomas (USNRC)
E. Y. Wang (USNRC)
R. E. Collingham
R. A. Copeland
L. J. Federico
R. C. Gottula
S. E. Jensen
R. S. Reynolds

RLP4EM/0 usep93a RUN ON 01/26/96 PLOTTED ON 26JUN96

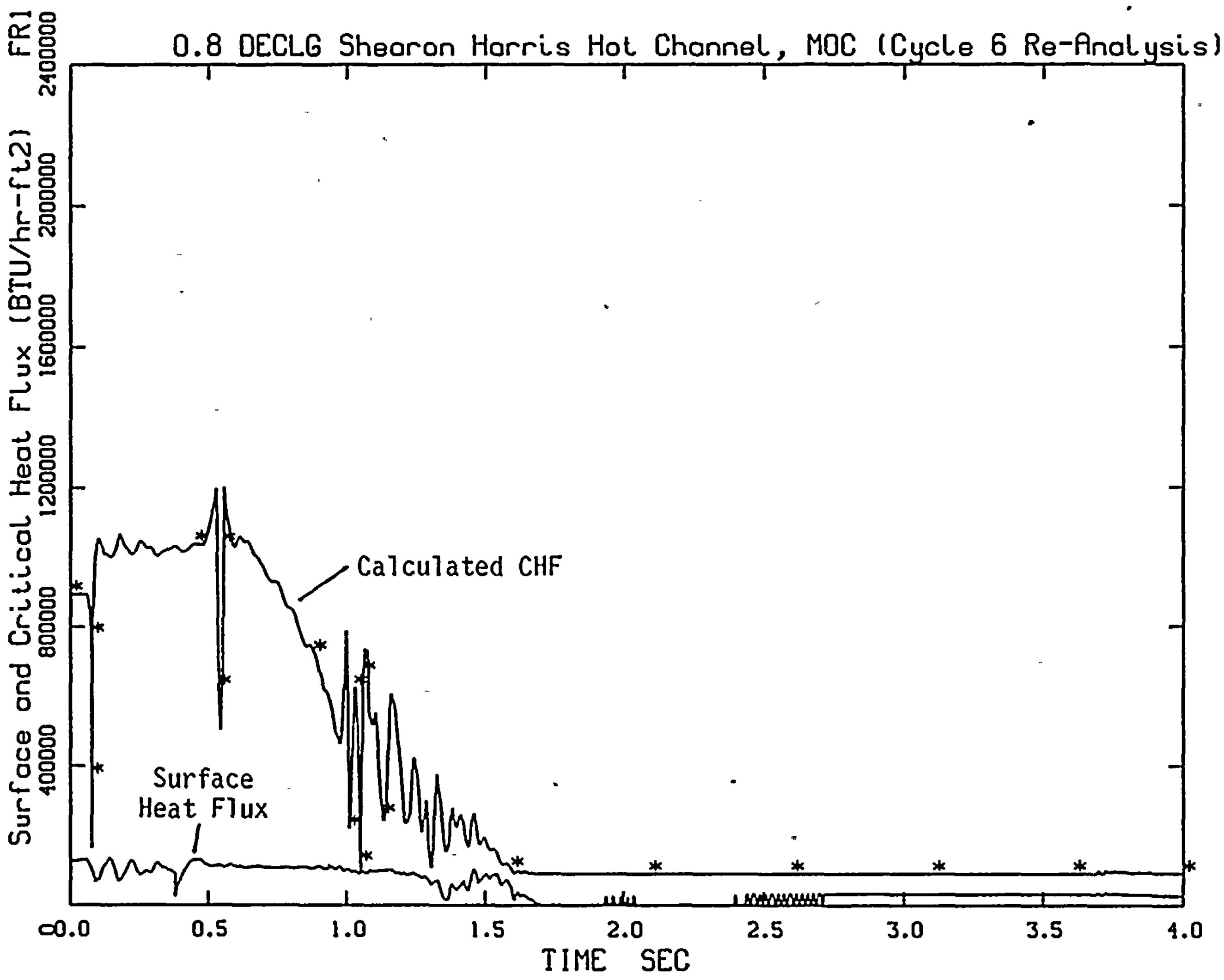

Figure 1

RLP4EM/0 usep93a RUN ON 11/11/94 PLOTTED ON 26JUN96

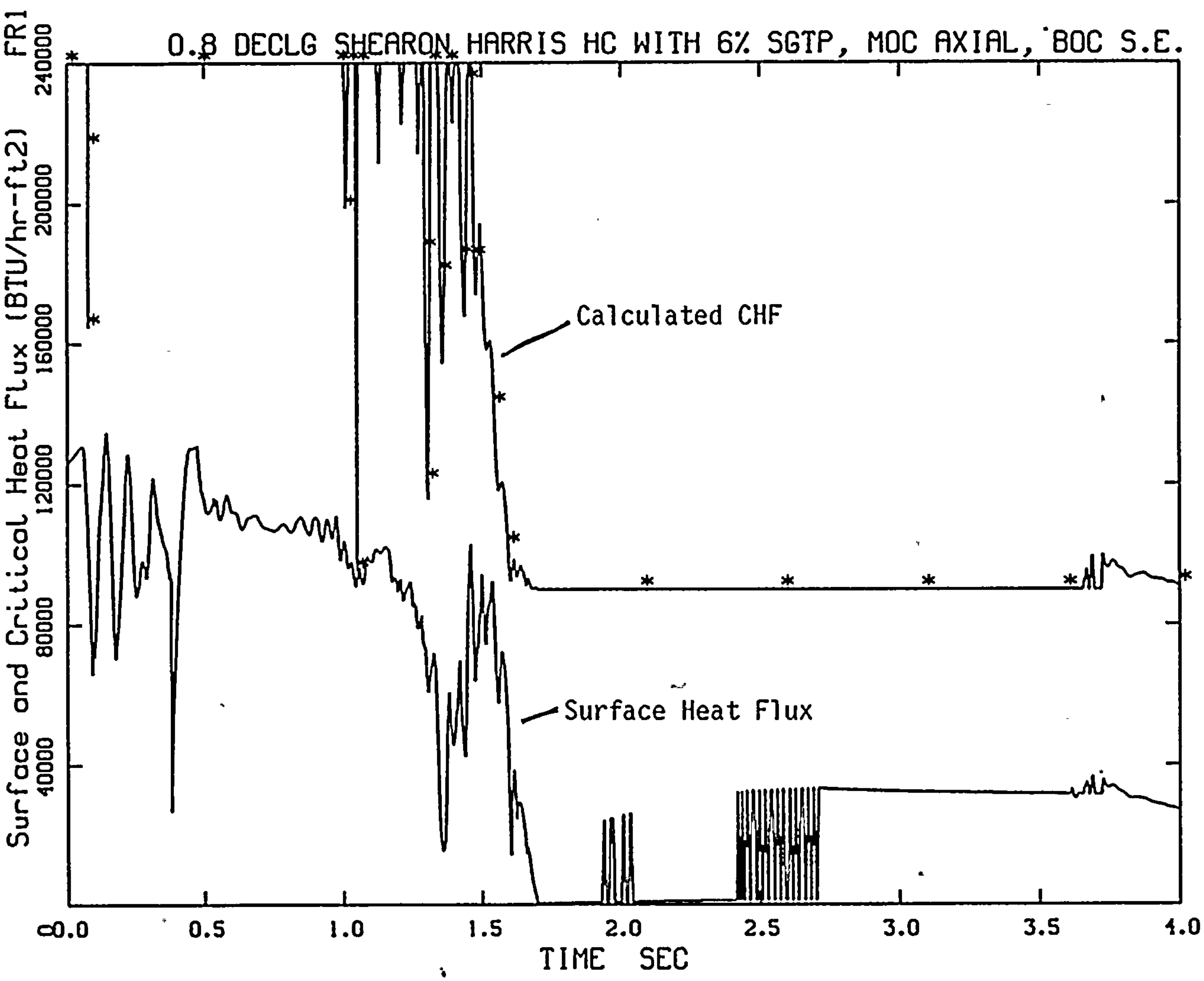

Figure 2

RLP4EM/O usep93c RUN ON 03/09/96 PLOTTED ON 25JUN96

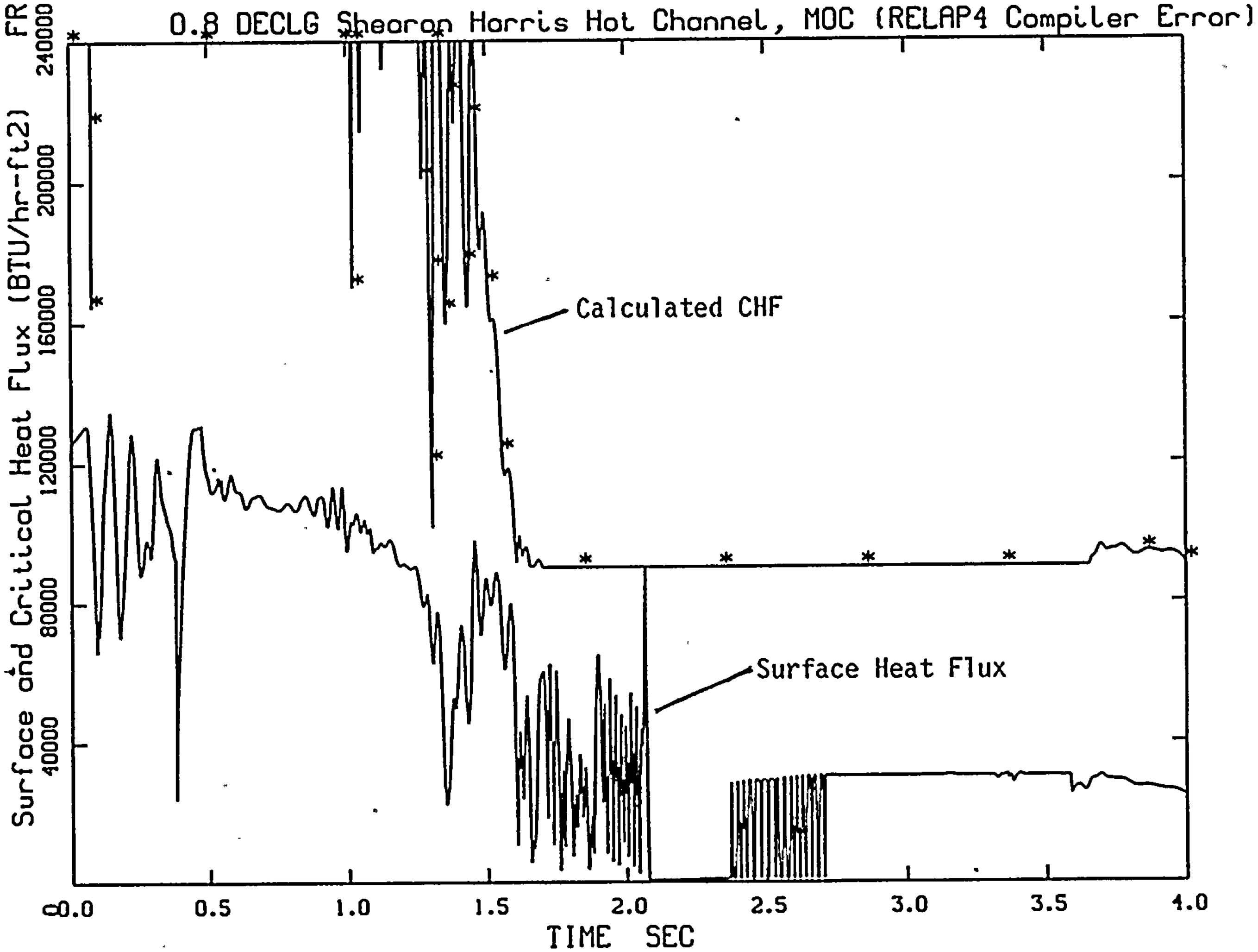

Figure 3

HI/A-20
9/20/96
Report Validation Package

CP&L

Carolina Power & Light Company
PO Box 165
New Hill NC 27562

William R. Robinson
Vice President
Harris Nuclear Plant

SERIAL: HNP-96-160
10CFR50.46

United States Nuclear Regulatory Commission
ATTENTION: Document Control Desk
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SHEARON HARRIS NUCLEAR POWER PLANT
DOCKET NO. 50-400/LICENSE NO. NPF-63
EMERGENCY CORE COOLING SYSTEM EVALUATION CHANGES

Dear Sir or Madam:

Carolina Power and Light (CP&L) was notified by Siemen's Power Corporation (SPC) on August 19, 1996 of significant changes in the peak fuel cladding temperatures (PCT) resulting from a revision to the large break loss of coolant accident (LBLOCA) analysis for the Harris Plant. The changes to the LBLOCA analysis of record (AOR) and the effects of those changes are being reported in accordance with 10 CFR 50.46(a)(3)(ii). The revised analysis removes the SPC 1991 changes to the TOODEE2 LBLOCA analysis code currently under review by the NRC, and includes the correction of a complier problem. The revised analysis uses the 1986 approved reflood methodology and thereby avoids the concern relative to changes that SPC implemented to the LOCA model which were not specifically reviewed and approved by the NRC.

The new LBLOCA analysis results in a PCT of 1982°F for a 0.8 Double-Ended-Guillotine-Cold-Leg break and middle-of-cycle axial power shape. The previous LOCA analysis which used the 1991 TOODEE2 model reported a PCT of 2025°F for the same break and power shape combination.

This PCT reduction from 2025°F to 1982°F results from three factors. First, Siemens recognized an error associated with the compiler used in the LBLOCA calculations. Correction of that compiler error produced a reduction in the Harris PCT of about 6°F. Based on that assessment, Siemens determined that the Harris analysis of record (AOR) was conservative and it was not formally revised at that time. The compiler error correction is incorporated in this revised analysis.

Secondly, correction of the complier error coincidentally eliminated a conservative, non-physical spurious critical heat flux (CHF) lockout condition occasionally observed in some LOCA computer analysis runs. The CHF lockout was triggered when junction flows at each end of a RELAP4 volume were in opposite directions.

These flows were averaged by the RELAP4 code, resulting in a momentary, unrealistically low flow rate being used in the calculation of CHF. This produced an unrealistic spiked decrease in the CHF, resulting in momentary entry into CHF which trips an early CHF lockout in one of the RELAP4 volumes. The early CHF lockout results in a overly-conservative calculation of PCT. The previous AOR for Harris contained this spurious lockout which contributed 115°F to the 2025°F PCT. The correction of the compiler error caused the RELAP4 code to experience a slightly different calculational path. This calculational path coincidentally did not produce the spurious CHF lockout and its 115°F overly-conservative contribution to the PCT. Therefore, the elimination of the spurious CHF lockout reduced PCT for LBLOCA analysis by 115°F.

Removing the 1991 SPC changes to the TOODEE2 model actually produced a + 78°F increase in the PCT. The NRC is currently reviewing the 1991changes to determine if the changes should have been classified by SPC as a model change to the NRC approved evaluation model.

The LBLOCA analysis changes and resulting PCT contributions discussed above are summarized in the following table.

Base Calculation and Subsequent Individual Changed Conditions	Calculated PCTs	Individual Changed Condition ΔPCTs
Post-1991 TOODEE2 Model Used	2025 °F	----
Compiler Error Corrected	2019 °F	- 6 °F
Spurious CHF Lockout Eliminated	1904 °F	- 115 °F
Pre-1991 TOODEE2 Model Used	1982 °F	+ 78 °F

Collectively, the changes result in a net decrease in PCT of 43°F. These changes are considered to be significant per 10CFR50.46 (a)(3)(i) and are therefore being reported to the NRC in accordance with 10CFR50.46 (a)(3)(ii). Harris remains in compliance with the requirements specified in 10CFR50.46(b).

Questions regarding this matter may be referred to Mr. T. D. Walt at (919) 362-2711.

Sincerely,

WRR

DBA/dba

c: Mr. J. B. Brady, HNP Senior Resident Inspector, NRC
Mr. S. D. Ebneter, Region II Regional Administrator, NRC
Mr. N. B. Le, NRR Project Manager, NRC