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Dr. Thomas E. Murley, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Document Control Desk

ttention: Mr. Marvin W. Hodges, Reactor Systems Branch Chief, Division of Engineering and System Technology

Subject: Correction of Errors and Modifications to the NOTRUMP Code in the Westinghouse Small Break LOCA ECCS Evaluation Model Which Are Potentially Significant

Dear Dr. Murley:

In preparation to support the annual reporting of errors or changes in the emergency core cooling system (ECCS) Evaluation Models, as required by the October 17, 1988 revision to 10CFR Section 50.46, it was determined that the modifications to correct errors in the NOTRUMP and small break LOCTA-IV computer codes in the Westinghouse small break LOCA ECCS Evaluation Model could be considered significant. 10CFR50.46(a)(3)(i) defines a significant change or error in an ECCS Evaluation Model as follows;

> "For this purpose, a significant change or error is one which results in a calculated peak fuel cladding temperature different by more than 50°F from the temperature calculated for the limiting transient using the last acceptable model, or is a cumulation of changes and errors such that the sum of the absolute magnitudes of the respective temperature changes is greater than 50°F.

The attachment to this letter provides information concerning potentially significant modifications made to the NOTRUMP and small break LOCTA-IV computer codes. The attachment also provides an assessment of the effect of the modifications on the calculated peak cladding temperature (PCT) resulting from analyses of small break loss-of-coolant accident (LOCA). The cumulation of the absolute magnitudes of the respective temperature changes resulting from the various modifications to the NOTRUMP and small break LOCTA-IV computer codes could potentially exceed 50°F.

For the corrections which could affect the calculational results, code modifications have been made to the versions of the NOTRUMP and small break LOCTA-IV computer codes which are currently used to perform small break LOCA safety analyses in support of plant licensing. For some of the corrections which would not affect the calculational results, the code modifications will be implemented during the next general update of the computer code.

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For plants which support licensing activities utilizing the Westinghouse large break and small break LOCA ECCS Evaluation Models, the small break LOCA analyses do not result in the limiting transient. In all cases, the effect of incorporating the modifications in those analyses which have been performed with versions of the NOTRUMP computer code which did not contain the modifications would not result in exceeding the limits of 10CFR50.46. Consequently, no immediate actions are needed to show compliance with 10CFR50.46 requirements.

Furthermore, the effect of incorporating the modifications in those analyses which have been performed with versions of the NOTRUMP computer code which did not contain the modifications would not result in the small break LOCA analyses becoming the limiting transient for plants licensed with Westinghouse large break and small break LOCA ECCS Evaluation Models. The effect of the modifications, as indicated to date would result in a net reduction in the peak cladding temperature for those plants analyses which would be affected by the modifications to the NOTRUMP and small break LOCTA-IV computer codes. Therefore, a schedule for reanalysis or other actions is unnecessary.

The modifications to the NOTRUMP computer code in the Westinghouse small break LOCA ECCS Evaluation Model were not considered to be significant individually or cumulatively. However, analysis calculations performed to quantify the effect of the modifications indicated a larger than expected sensitivity for the peak cladding temperature results in some cases. Similarly, larger than expected peak cladding temperature sensitivities, in some instances, have been observed when analyses were performed to support safety evaluations of the effect of plant design changes under 10CFR50.59 using the NOTRUMP computer code. The unexpected sensitivity results are under investigation at Westinghouse and may be due to the artificial restrictions on loop seal steam venting placed on the model for conservatism. Should the results of the investigation indicate that additional modifications to the Westinghouse ECCS Evaluation Models are necessary, the NRC will be informed in accordance with the requirements of 10CFR50.46.

A copy of this letter will be provided to applicants and holders of operating licenses or construction permits which utilize the results of Westinghouse small break LOCA ECCS Evaluation Model analyses performed with the NOTRUMP computer code to support plant licensing. Should the modifications be deemed significant by the NRC upon review, please contact Mr. M. Y. Young (412-374-4720) or Mr. W. D. Tauche (412-374-5506) of my staff. Also please contact these individuals should you require any additional details or if you have any questions on this subject.

Very truly yours,

W.J. Johnson, Manager
Nuclear Safety Department

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Attachment

ATTACHMENT

POTENTIALLY SIGNIFICANT MODIFICATIONS TO THE NOTRUMP AND SMALL BREAK LOCTA-IV COMPUTER CODES IN THE WESTINGHOUSE SMALL BREAK LOCA ECCS EVALUATION MODEL

In preparation to support the annual reporting of errors or changes in the emergency core cooling system (ECCS) Evaluation Models, as required by the October 17, 1988 revision to 10CFR50.46, it was determined that the correction of errors in the NOTRUMP computer code in the Westinghouse small break LOCA ECCS Evaluation Model could be potentially significant. 10CFR Section 50.46(a)(3)(ii) requires the reporting of significant changes or errors in an approved ECCS Evaluation Model. 10CFR50.46(a)(3)(i) defines a significant change or error in an ECCS Evaluation Model as follows;

> "For this purpose, a significant change or error is one which results in a calculated peak fuel cladding temperature different by more than 50°F from the temperature calculated for the limiting transient using the last acceptable model, or is a cumulation of changes and errors such that the sum of the absolute magnitudes of the respective temperature changes is greater than 50°F."

Pursuant to the requirements of 10CFR50.46, the following information is provided to describe the potentially significant modifications to the Westinghouse small break LOCA ECCS Evaluation Model which have been made and the effect of the modifications on the calculated peak cladding temperature.

The NOTRUMP small break LOCA ECCS Evaluation Model (reference 1) was developed by Westinghouse in cooperation with the Westinghouse Owners Group to address technical issues expressed in NUREG-0611, "Small Break LOCA and Feedwater Transients in W PWRs," in compliance with the requirements of NUREG-0737, "Implementation of the TMI Action Plan," Section II.K.3.30. In the NOTRUMP small break LOCA ECCS Evaluation Model, the NOTRUMP code is used to calculate the thermal-hydraulic response of the reactor coolant system during a small break LOCA and the small break LOCTA-IV computer program is used to calculate the performance of fuel rods in the hot assembly

MODIFICATIONS TO THE NOTRUMP COMPUTER CODE

Several modifications have been made to the NOTRUMP computer (Reference 2) to correct erroneous coding or improve the coding logic to preclude erroneous calculations. The modifications indicated in A through I below have been incorporated into the production version of the code. Remaining corrections and modifications are not significant and will be incorporated during the next code update in accordance with the Westinghouse quality assurance procedures for computer code maintenance.

The following modifications to the NOTRUMP small break LOCA ECCS Evaluation Model have been made:

A Modification: A modification was made to preclude changing the region designation (upper, lower) for a node in a stack which does not contain the mixture-vapor interface. The purpose of the modification was to enhance tracking of the mixture-vapor interface in a stacked series of fluid nodes and to preclude a node in a stack, which does not contain the mixture-vapor interface, from changing the region designation.

The update does not affect the fluid conditions in the node, only the designation of the region of the node. The region designation does not typically affect the calculations, except for the nodes representing the core fluid volume (core nodes). In core nodes which are designated as containing vapor regions, the use of the steam cooling heat transfer correlation is forced on the calculation in compliance with the requirements of Appendix K to 10CFR50, even if the node conditions would indicate otherwise. The use of the steam cooling heat transfer regime above the mixture level is documented on page 3-1 of reference 2.

Effect of Modification On PCT: In rare instances, an incorrect heat transfer correlation could be selected if the region designation was improperly reflected. An analysis calculation was performed for a three-loop plant which resulted in a decrease in the PCT of 6.5°F when the corrections were made for a calculation which would be affected by the change.

B Modification: Typographical errors in the equations which calculate the heat transfer rate derivatives for subcooled, saturated, and superheated natural convection conditions for the the upper region of interior fluid nodes were corrected. The heat transfer rate derivatives for subcooled, saturated, and superheated natural convection conditions for the the upper region of interior fluid nodes are given by equations 6-55, 6-56, and 6-57 of reference 2. A typographical error led to the use of the lower region heat transfer area instead of the upper region heat transfer area in the calculation of derivatives. The error affected only the upper region heat transfer derivatives which are used by the code to characterize the implicit coupling of the heat rates to changes in the independent nodal variables.

Effect of Modification On Peak Cladding Temperature: In rare instances, the amount of heat that could be transferred to the fluid could be improperly calculated. The effect of the errors was expected to be small since the error would only affect the derivatives of the heat rates for vapor regions that are in natural convection. An analysis calculation was performed for a three-loop plant which resulted in a larger than expected increase in the PCT of 36.7°F when the correction was made on a calculation which would be affected by the change.

C Modification: Typographical errors in equations which calculate the derivatives of the natural convection mode of heat transfer in the subroutine HEAT were corrected. A conductivity term used in the equations which calculate the derivatives of the natural convection mode of heat transfer was incorrectly typed as CK (to be used for the Thom or McBeth correlations, instead of CKNC (to be used for the desired McAdams correlation.

Effect of Modification On PCT: A review of the code logic was performed to assess the effect of the error. In all equations that contain the typographical error, the incorrect variable is multiplied by zero. Therefore the typographical errors have no effect on the PCT results of the calculations.

D Modification: A typographical error was corrected in an equation which calculates the internal energy for nodes associated with the reactor coolant pump model when the associated reactor coolant pump flow links are found to be in critical flow. An incorrect value for the mixture region internal energy in the fluid node downstream of a pump flow link would be calculated if the pump flow link were in critical flow.

Effect of Modification On PCT: This section of coding is not expected to be executed for small break LOCA Evaluation Model calculations since critical flow in the reactor coolant pump flow links does not occur. Therefore this modification has no effect on the calculations. This was confirmed in an analysis calculation for a three-loop plant which demonstrated no change to the PCT.

E Modification: A modification was made to properly call some doubly dimensioned variables in subroutines INIT and TRANSNT. Some variables are doubly dimensioned (X,Y) but were being used as if they were singly dimensioned.

Effect of Modification On PCT: A detailed review of the code logic indicated that all of the doubly dimensioned variables had 1 as the second dimension in any of the erroneous calls. The computer inferred a 1 for the second dimension in the improper subroutine calls. Therefore, there is no effect of this modification on the PCT.

F Modification: A modification was made to prevent code aborts resulting from implementation of a new FORTRAN compiler. Due to the different treatments of the precision of numbers between the FORTRAN compilers, the subtraction of two large, but close numbers resulted in exactly zero. The zero value was used in the denominator of a derivative equation, which resulted in code aborts. This situation only occurred when the mass of a region in a node approached, but was not equal to zero.

Effect of Modification On PCT: An analysis calculation was performed for a four-loop plant which resulted in a larger than expected increase in the PCT of $4.8^{o}F$ when the modification was implemented.

G Modification: An error in the implementation of equation 5-33 of reference 2 was corrected. Equations 5-33 describes the calculation of the flow link friction parameter c_k for single phase flow in a non-critical flow link k. In the erroneous implementation, equation 5-33 was replaced by equation 5-34 which is used for all flow conditions. For the case where the flow quality is zero, equation 5-34 is similar in form to equation 5-33 since the two-phase friction multipliers are exactly unity when the flow quality is zero and the donor cell and flow link fluids are saturated, equations 5-33 and 5-34 are equivalent. However, for subcooled flow the flow link specific volume v_k in equation 5-33 is not equivalent to the saturated fluid donor cell specific volume (v_k,donor(k)) in equation 5-34.

Effect of Modification On PCT: This modification was expected to have only a small beneficial effect on the analysis. However, an analysis calculation was performed for a three-loop plant to quantify the effect and a larger than expected decrease in the peak cladding temperature of 217°F resulted. Larger than expected peak cladding temperature sensitivities, in some instances, have been observed when analyses to support safety evaluations of the effect of plant design changes under 10CFR50.59 were performed using the NOTRUMP computer code. The unexpected sensitivity results are under investigation at Westinghouse and may be due to the artificial restrictions on loop seal steam venting placed on the model for conservatism. Evaluations of the effect of this change will be examined as part of the investigation of the larger than expected sensitivity results.

H Modification: A test was added in the rod-to-steam radiation heat transfer coefficient calculation to preclude the use of the correlation when the wall-to-steam temperature differential dropped below the useful range of the correlation. This limit was derived based upon the physical limitations of the radiation phenomena.

Effect of Modification On PCT: There is no effect of the modification on reported PCTs since the erroneous use of the correlation forced the calculations into aborted conditions.

I Modification: A modification was made to correct an error in implementing equations L-28, L-52 and L-29, L-53 of reference 2. The two pairs of equations respectively describe the partial derivatives of F^k with respect to pressure and specific enthalpy. F^k is an interpolation parameter that is defined by equations L-27, L-51 of reference 2. In each pair the lower equation number is for the subcooled condition, and the higher equation number is for the superheated condition. The denominator of each equation contains the differences between h^k and h^{k-1} where h^k is defined by equations L-21, L-45 and h^{k-1} is defined by equations L-22, L-46 of reference 2. Although the expression defining h^k and h^{k-1} were correctly calculated in NOTRUMP, they were not used in equations L-28, L-52 and L-29, L-53 as they should have been.

Effect of Modification On PCT: An analysis calculation was performed for a four-loop plant which resulted in a decrease in the PCT of 12.8°F when the modification was made for a calculation which would be affected.

Several modifications will be made to the NOTRUMP computer (Reference 2) to correct erroneous coding or printed information. The modifications indicated in J through L below will be incorporated into the production version of the code during the next maintenance upgrade to the computer code in accordance with Westinghouse quality assurance procedures. The corrections and modifications do not affect the results of small break LOCA ECCS Evaluation Model analyses.

J Modification: An error in the printed value for the break flow link specific volume in the Moody break flow model has been identified. Only the printed output value of the specific volume is incorrect.

Effect of Modification On PCT: The small break LOCA ECCS Evaluation Model calculations do not use the printed value of the break flow link specific volume for any purpose, therefore this error does not affect the calculational result for the PCT.

K Modification: An error in the fuel pellet to cladding contact pressure (used in the fuel rod gap conductance model) has been identified. The erroneous coding is called only when no gap between the fuel pellet and the cladding exists.

Effect of Modification On PCT: For small break LOCA ECCS Evaluation Model calculations, fuel data pertaining to the time of highest fuel temperatures is used. At this time in life, a gap exists between the pellet and the cladding. Therefore this error does not affect the calculational result for the PCT.

L Modification: An error in the calculation of the saturated or subcooled boiling critical heat fluxes using the McBeth correlation has been identified. In the correlation, the effective equivalent diameter is expected to be specified in the units of inches. However, for the NOTRUMP code this diameter is input by the user in the units of feet and is not converted prior to being used in the critical heat flux equation.

Effect of Modification On PCT: A review of the coding and the output from analyses using NOTRUMP indicates that this error will not affect any small break LOCA Evaluation Model analysis results. For heat link calculations, the heat flux is computed for subcooled or saturated nucleate boiling is always less than both the erroneous and correct values for the critical heat flux. In the core nodes where the critical heat flux could be exceeded, the core heat links correctly convert the equivalent diameter to the proper dimension. Therefore this error does not affect the calculational results for the PCT.

MODIFICATIONS TO THE SMALL BREAK LOCTA-IV COMPUTER CODE

The following modifications to the LOCTA-IV computer code in the small break LOCA ECCS Evaluation Model have been made;

M Modification: A test was added in the rod-to-steam radiation heat transfer coefficient calculation to preclude the use of the correlation when the wall-to-steam temperature differential dropped below the useful range of the correlation. This limit was derived based upon the physical limitations of the radiation phenomena.

Effect of Modification On PCT: There is no effect of the modification on reported PCTs since the erroneous use of the correlation forced the calculations into aborted conditions.

N Modification: An update was performed to allow the use of fuel rod performance data from the revised Westinghouse (PAD 3.3) model.

Effect of Modification On PCT: An evaluation indicated that there is an insignificant effect of the modification on reported PCTs.

O Modification: Modifications supporting a general upgrade of the computer program were implemented as follows;

1) the removal of unused or redundant coding,
2) better coding organization to increase the efficiency of calculations, and
3) improvements in user friendliness
   a) through defaulting of some input variables,
   b) simplification of input,
   c) input diagnostic checks, and
   d) clarification of the output.

Effect of Modification On PCT: Verification analyses calculations demonstrated that there was no effect on the calculated output resulting from these changes.

P Modification: Two modifications improving the consistency between the Westinghouse fuel rod performance data (PAD) and the small break LOCTA-IV fuel rod models were implemented;

1) The form of the equation for the density of Uranium-dioxide in the specific heat correlation, which modelled three dimensional expansion was corrected to account for only two-dimensional thermal expansion due to the way the fuel rod is modeled.
2) An error in the equation for the pellet/clad contact pressure was corrected. The contact resistance is never used in licensing calculations.

Effect of Modification On PCT: The Uranium-dioxide density correction is estimated to have a maximum PCT benefit of less than $2^{0}F$, while the contact resistance modification has no PCT effect since it is not used.

CONCLUSIONS

The effect of changes and errors in the Westinghouse small break LOCA ECCS Evaluation Model have been assessed in accordance with the requirements of 10CFR50.46(a)(3)(i). Appropriate modifications to the NOTRUMP and small break LOCTA-IV computer codes in the Westinghouse small break LOCA ECCS Evaluation Model could be significant, but would not result in the small break LOCA analyses becoming the limiting transient for any plants which support plant licensing with the Westinghouse large break and small break LOCA ECCS Evaluation Models.

In all cases, the effect of incorporating the modifications in those analyses which have been performed with versions of the NOTRUMP and small break LOCTA-IV computer codes which did not incorporate the modifications would not result in violation of the limits of 10CFR50.46. Consequently, no immediate actions are needed to show compliance with 10CFR50.46 requirements.

Furthermore, the effect of the modifications, as indicated to date would result in a net reduction in the peak cladding temperature for those plants analyses which would be affected by the modifications to the NOTRUMP and small break LOCTA-IV computer codes. Therefore, a schedule for reanalysis or other actions is unnecessary.

REFERENCES

1. WCAP-10054-P-A (Proprietary), WCAP-10081-A (Non-Proprietary), "Westinghouse Small Break ECCS Evaluation Model Using the NOTRUMP Code." Lee, N., et. al., August 1985.

2. WCAP-10079-P-A (Proprietary), WCAP-10080-A (Non-Proprietary), "NOTRUMP A Nodal Transient Small Break And General Network Code," Meyer,P.E., August 1985.