CENPD-279
SUPPLEMENT 5

ANNUAL REPORT ON
C-E ECCS CODES AND METHODS
FOR 10CFR50.46

COMBUSTION ENGINEERING NUCLEAR FUEL
FUEL ENGINEERING

ABB

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Combustion Engineering, Inc.

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ANNUAL REPORT ON C-E ECCS CODES AND METHODS FOR 10CFR50.46

PREPARED FOR THE

C-E NSSS OWNERS

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ABB COMBUSTION ENGINEERING
NUCLEAR POWER
COMBUSTION ENGINEERING, INC.

Abstract

This report describes changes and errors in the ABB Combustion Engineering codes and analysis methodology for ECCS analysis in 1993 per the requirements of 10CFR50.46. For this reporting period, one error in the COMPERC-II refill/reflood code for large break LOCA analysis was found and corrected. No models or methods were changed for the large break, small break or post-LOCA long term cooling calculations. Correction of the error in COMPERC-II had no effect on the cladding temperature (PCT) for large break LOCA. The sum of the absolute magnitudes of the temperature changes for large break LOCA from all reports to date continues to be less than 1 °F. No changes occured in the peak cladding temperature due to small break LOCA or post-LOCA long term cooling. Per the criteria of 10CFR50.46, no action beyond this annual report is required.

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1.0 Introduction

This report addresses the NRC requirement to report changes or errors in licensed codes for ECCS analysis. The revision to the ECCS Acceptance Criteria, Reference 1, spells out reporting requirements and actions required when errors are corrected or changes are made in an evaluation model or in the application of a model for an operating licensee or construction permittee of a nuclear power plant.

The action requirements in 10CFR50.46(a)(3) are:

1. Each applicant for or holder of an operating license or construction permit shall estimate the effect of any change to or error in an acceptable evaluation model or in the application of such a model to determine if the change or error is significant. For this purpose, a significant change or error is one which results in a calculated peak fuel cladding temperature (PCT) 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.

2. 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 10CFR50.46.

3. 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 10CFR50.46 requirements. This schedule may be developed using an integrated scheduling system previously approved for the facility by the NRC. For those facilities not using an NRC approved integrated scheduling system, a schedule will be established by the NRC staff within 60 days of receipt of the proposed schedule.

4. Any change or error correction that results in a calculated ECCS performance that does not conform to the criteria set forth in paragraph (b) of 10CFR50.46 is a reportable event as described in 10CFR50.55(e), 50.72 and 50.73. The affected applicant or licensee shall propose immediate steps to demonstrate compliance or bring plant design or operation into compliance with 10CFR50.46 requirements.

This report documents all the errors corrected in and/or changes to the presently licensed ABB C-E LOCA analysis models and methodology, made in the year covered by this report, which have not been reviewed by the NRC staff. This document is provided to satisfy the reporting requirements of the second item above. C-E reports for earlier years are given in References 2-6.

2.0 C-E Codes Used for ECCS Evaluation

ABB C-E uses several digital computer codes for ECCS analysis that are described in topical reports, are licensed by the NRC, and are covered by the provisions of 10CFR50.46. Those for large break LOCA calculations are CEFLASH-4A, COMPERC-II, HCROSS, PARCH, STRIKIN-II, and CUMZIRC. CEFLASH-4AS is used in conjunction with COMPERC-II, STRIKIN-II, and PARCH for small break LOCA calculations. The codes for post-LOCA long term cooling analysis are BORON, CEPAC, NATFLOW, and CELDA.

3.0 Error Corrections and Model or Methods Changes

This section discusses all error corrections and model or other changes to the licensed codes which may affect the calculated PCT. In 1993 an error in one computer code used in the large break LOCA evaluation model was corrected. The nature of this error and the steps taken to resolve it are described below.

3.1 COMPERC-II for Large Break LOCA

3.1.1 Code Description

COMPERC-II calculates the rate at which mass is added to the reactor vessel during the refill/reflood portion of a large break LOCA transient. Models are provided in the code for the hydraulic behavior of the NSSS, addition and removal of fluid, core heat transfer, containment pressure, related systems, and properties. It also calculates the reflood heat transfer coefficient for the cladding using the FLECHT correlations.

3.1.2 Error in COMPERC-II

The error identified and corrected is in the model used to calculate the containment pressure. The containment pressure model includes a provision for heat addition or removal from thermal masses in the containment (components) as well as the containment building itself. The method used to initialize the temperature distribution in a thermal mass with a temperature gradient, such as the containment building, is the source of the error.

The model for the containment heat conducting surfaces is described in Appendix Q of Reference 7. Additional information about these models is given in Reference 8. The equation being solved is

$$\frac{1}{\alpha}\ \frac{\partial T}{\partial t} = \frac{\partial^2 T}{\partial x^2}$$

where α is the thermal diffusivity, T is temperature, t is time, and x is distance. The wall conduction equations are solved by backward time difference. The resulting matrix form of the equation is

$$A{\cdot}X = B$$

where A is a tri-diagonal coefficient matrix, X is the vector of the wall node temperatures at time t, and B is the vector of the wall node temperatures at time $t\text{-}\Delta t$. The matrix is solved at each time step by Gaussian elimination.

If the temperatures of the two surfaces of a thermal mass such as the containment building are different, COMPERC-II finds the initial (steady state) temperature distribution by iteration using the transient solution coding. The timestep length is increased to 10,000 seconds to accelerate convergence to the steady state solution and 20 iterations are made to determine the temperature distribution. This does not produce a converged temperature distribution. Within a segment of the wall that has a constant thermal conductivity, the steady state temperature distribution should vary linearly between the temperature of the two surfaces of the wall segment. The code predicts a convex curve for the temperature distribution that overpredicts the average temperature of the wall by about 1 °F and slightly overpredicts the stored energy in the wall.

3.1.3 Correction of COMPERC-II Code Error

The error is corrected by revising the steady state solution procedure in COMPERC-II as follows:

1. The time step length for the iteration is increased to 10^6 seconds to accelerate convergence of the transient algorithm.
2. The iteration procedure for the steady state temperature solution is changed to iterate until a temperature convergence criterion is satisfied instead of using a fixed number of iterations. The method used to do the iteration and test for convergence is the same as that used for the transient solution.
3. The number of iterations required to converge the steady state temperature distribution is printed to show the user that the steady-state temperature is converged.

3.1.4 Impact of COMPERC-II Error on PCT

The revised iteration and convergence procedure in COMPERC-II produces a uniform heat flux through each layer in a wall and a straight-line temperature profile in each layer of the wall with constant thermal conductivity. This confirms proper steady state behavior of the code.

The effect of the initial containment wall temperature profile error on transient results is examined by comparing results calculated by COMPERC-II before and after correction of the error. A full reflood-refill transient typical of those which occur in a large break LOCA is used for this comparison. The criterion of merit is the water mass added to the core during the refill/reflood transient since this is the data which is used to drive the PCT calculation during the refill/reflood portion of a LOCA.

The reflood-refill liquid mass added to the reactor is essentially unchanged after the error in the initial temperature distribution is corrected. This is expected since the inside containment wall temperature is changed by less than 0.1 °F 30 seconds or later into the transient which has a negligible effect on the heat transfered between the containment atmosphere and the containment wall. Hence, the small error in the initial temperature distribution of the containment wall has a negligible effect on the transient PCT for a large break LOCA.

4.0 Conclusions

One error was found and corrected in the COMPERC-II computer code used for large break LOCA analysis during 1993. There was no change in the PCT as a result of correcting this error. No other changes to the models and methods or corrections of errors were made in 1993. The sum of the absolute magnitudes of the changes in PCT calculated using the C-E ECCS evaluation models, including those from previous annual reports, References 2-6, remains less than 1 °F.

Based on the results reported here, there was no significant change in the sense of 10CFR50.46 in 1993 and no action beyond the submission of this report is needed.

5.0 References

1. "Emergency Core Cooling System; Revisions to Acceptance Criteria, "10CFR50, Federal Register, Vol. 53, No. 180, September 16, 1988.

2. "Annual Report on C-E ECCS Codes and Methods for 10CFR50.46," CENPD-279, April, 1989.

3. "Annual Report on C-E ECCS Codes and Methods for 10CFR50.46," CENPD-279, Supplement 1, February, 1990.

4. "Annual Report on C-E ECCS Codes and Methods for 10CFR50.46," CENPD-279, Supplement 2, April, 1991.

5. "Annual Report on C-E ECCS Codes and Methods for 10CFR50.46," CENPD-279, Supplement 3, April, 1992.

6. "Annual Report on C-E ECCS Codes and Methods for 10CFR50.46," CENPD-279, Supplement 4, April, 1993.

7. "COMPERC-II, A Program for Emergency-Refill-Reflood of the the Core," CENPD-134 P, August, 1974.

   COMPERC-II, A Program for Emergency Refill-Reflood of the Core (Modifications)," CENPD-134 P, Supplement 1, February, 1985.

8. R. C. Mitchell, "Containment Thermodynamic Analysis," CENPD-140-A, June, 1976.