CEOG COMBUSTION ENGINEERING OWNERS GROUP

CENPD-279
SUPPLEMENT 6

ANNUAL REPORT ON ABB CE ECCS PERFORMANCE EVALUATION MODELS

FINAL REPORT

CEOG TASK 865

prepared for the

C-E OWNERS GROUP

February 1995

ABB Combustion Engineering Nuclear Operations

ABB

LEGAL NOTICE

ABSTRACT

This report describes changes and errors in the ABB Combustion Engineering evaluation models for ECCS analysis in 1994 per the requirements of 10CFR50.46. For this reporting period, one error in the PARCH peak cladding temperature code for small break LOCA and two errors in the PARCH steam cooling heat transfer coefficient code for large break LOCA analysis were found and corrected. No other changes were made to the ABB CE evaluation models for the large break, small break or post-LOCA long term cooling calculations.

Correction of the errors in PARCH had no effect on the peak 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 change occured in the PCT due to correction of the error in PARCH for small break LOCA nor was there any change due to post-LOCA long term cooling. Per the requirements of 10CFR50.46, no action beyond this annual report is required.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

This report addresses the NRC requirement to report changes or errors in ECCS performance evaluation models. 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 10CFR50.4.

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 CE ECCS performance evaluation models, 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. ABB CE reports for earlier years are given in References 2-7.

2.0 ABB CE CODES USED FOR ECCS EVALUATION

ABB CE uses several digital computer codes for ECCS evaluation 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 COMZIRC. 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 EVALUATION MODEL CHANGES AND ERROR CORRECTIONS

This section discusses all error corrections and model changes to the ABB CE ECCS performance evaluation models which may affect the calculated PCT. In 1994 one error in the PARCH computer code used in the small break LOCA evaluation model (EM) was corrected. Two errors in the PARCH computer code used in the large break LOCA evaluation model were corrected. The nature of these errors and the steps taken to resolve them are described below. No other changes were made to the ABB CE evaluation model for ECCS analysis.

3.1 PARCH for Small Break LOCA

3.1.1 Code Description

PARCH calculates the fuel rod heatup and the resulting cladding surface temperature and zirconium oxidation for a small break LOCA transient. Models are provided in the code for pool boiling heat transfer, fuel rod temperature, fuel-cladding gap conductivity, coolant heatup and steam release, cladding swelling and rupture, and zirconium-water reaction.

3.1.2 Error in Code

The error identified and corrected is in the model used to calculate Young's modulus for the zirconium cladding. The original model implemented in the code, Reference 8, finds Young's modulus, E, from a linear fit as

$$E = X(186) - X(187)*T_c$$

where T_c is the cladding temperature in °F. This is correct for temperatures up to about 1760°F. At higher cladding temperatures, this expression predicts too small a value for Young's modulus. As temperature increases, it falls to zero and becomes negative. The resulting temperature dependence of Young's modulus is shown by the solid line in Figure 1. This is incorrect for higher temperatures.

The error in Young's modulus can affect the temperature history of the cladding by its effect on the cladding thermal expansion, consequently, on the fuel-cladding gap conductivity. The inside diameter of the cladding increases as the pressure difference between the gas gap and the coolant increases and as the cladding temperature increases. Young's modulus determines the elastic deformation component of the cladding dimension change. An increase in the fuel-cladding gap decreases the gap conductivity which reduces heat transfer across the gap. During the approach to maximum cladding temperature, more energy is stored in the fuel when the gap is large and less is stored when the gap is small. Consequently, the maximum cladding temperature and zirconium oxidation can be affected.

Two conditions must be satisfied for the error in Young's modulus to affect cladding temperature. First, cladding temperature must exceed about 1760°F where the error in Young's modulus becomes significant, Figure 1. Second, the cladding must not rupture until temperatures above this threshold are exceeded.

3.1.3 Correction of Code Error

The error is corrected by revising the correlation for Young's modulus of zirconium in PARCH to follow the representation used in STRIKIN-II, Reference 10. The STRIKIN-II model uses the same linear fit for Young's modulus as PARCH does until it deviates from a straight line fit. Linear interpolation from a table is used above this temperature with a minimum value of Young's modulus at higher temperatures. The corrected representation Young's modulus is shown by the broken line in Figure 1.

3.1.4 Impact of Error on Cladding Temperature

The effect of the erroneous model for Young's modulus is shown in Figure 2. In order to observe the potential impact of the error, the cladding rupture model was turned off. This allows the cladding temperature to exceed that at which the error in Young's modulus is significant without cladding rupture. The solid line in Figure 2 shows that the monotonic cladding temperature

heatup is interupted before the maximum temperature is reached. The interuption occurs at the temperature where Young's modulus approaches zero and the width of the fuel-cladding gap increases. This is followed by an abrupt rise in cladding temperature after Young's modulus becomes negative and the fuel-cladding gap closes. The corrected model for Young's modulus, broken line in Figure 2, produces a monotonic rise in cladding temperature like that produced by the erroneous Young's modulus model except that there is no interuption in the temperature rise before the maximum value is reached.

The PARCH code error for Young's modulus has little effect on the maximum cladding temperature for small break LOCA. For several plants, the maximum cladding temperature for small break LOCA is below the temperature at which the error in Young's modulus has any effect on the transient. For most other plants, cladding rupture occurs for a cladding temperature below that at which a significant error is made in the value of Young's modulus. In such cases, the error in Young's modulus has no effect on the maximum cladding temperature. Finally, one plant has been reanalyzed with the corrected version of PARCH.

3.2 PARCH for Large Break LOCA

3.2.1 Code Description

PARCH calculates the steam cooling heat transfer coeffients for large break LOCA at and above the rupture node when the reflood rate is less than one inch per second. The code contains the models described in Section 3.1.1 for small break LOCA analysis with the additional models described in Reference 9.

3.2.2 Errors in Code

The two errors found and corrected are in Young's modulus for zirconium and in default values for several input parameters to the code.

The error in Young's modulus described in Section 3.1.2 also existed in PARCH for large break LOCA analysis. It does not affect large break LOCA results as discussed in Section 3.2.4.

The second error affects default values of nine input parameters for the code. The code used a value of zero instead of the intended default values if no data was entered for these input parameters. This would prevent the code from running if all nine values were omitted from the input. It might affect the steam cooling heat transfer coefficients calculated by the code if some of the variables were omitted from the input.

3.2.3 Correction of Code Errors

The error in Young's modulus is corrected as described in Section 3.1.3.

The second error is corrected by removal of coding that produces duplicate declarations of default values for the nine input parameters. The corrected coding ensures that the desired default values are used if no input values are entered for these parameters.

3.2.4 Impact of Errors on PCT

Correction of the errors in Young's modulus and the default input parameters has no effect on PCT for large break LOCA. The error in Young's modulus does not affect the cladding dimension or the fuel-cladding gap since PARCH is initialized with the cladding ruptured. Hence, it has no effect on the steam cooling heat transfer coefficients. The erroneous default values for input parameters had no effect on any large break LOCA transient results since values have been input for all of these parameters in all plant analyses.

4.0 CONCLUSIONS

One error was found and corrected in the PARCH computer code used for small break LOCA analysis during 1994. Two errors were found and corrected in the PARCH computer code used for large break LOCA analysis. There was no change in the PCT as a result of correcting these errors. No other changes to the ABB CE ECCS performance evaluation models or corrections of errors were made in 1994. The sum of the absolute magnitudes of the changes in PCT calculated using the ABB CE ECCS performance evaluation models, including those from previous annual reports, References 2-7, remains less than 1°F.

Based on the results reported here, the errors found and corrected during this reporting period were determined to not be significant as defined in Section 10CFR50.46 (a)(3)(i) of Reference 1. Therefore, in accordance with Section 10CFR50.46 (a)(3)(ii) of Reference 1, 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. "Annual Report on C-E ECCS Codes and Methods for 10CFR50.46," CENPD-279, Supplement 5, February, 1994.

8. "PARCH, A FORTRAN-IV Digital Computer Program to Evaluate Pool Boiling, Axial Rod and Coolant Heatup," CENPD-138 P, August 1974.

   "PARCH, A FORTRAN-IV Digital Computer Program to Evaluate Pool Boiling, Axial Rod and Coolant Heatup (Modifications)," CENPD-138 P, Supplement 1, February 1975.

   "PARCH, A FORTRAN-IV Digital Computer Program to Evaluate Pool Boiling, Axial Rod and Coolant Heatup," CENPD-138, Supplement 2-P, January 1977.

9. "C-E ECCS Evaluation Model, Flow Blockage Analysis," Enclosure 1-P to LD-81-095, December 1981.

10. "STRIKIN-II, A Cylindrical Geometry Fuel Rod Heat Transfer Program," CENPD-135 P, August 1974.

Figure 1

PARCH Model of Young's Modulus for Zircaloy

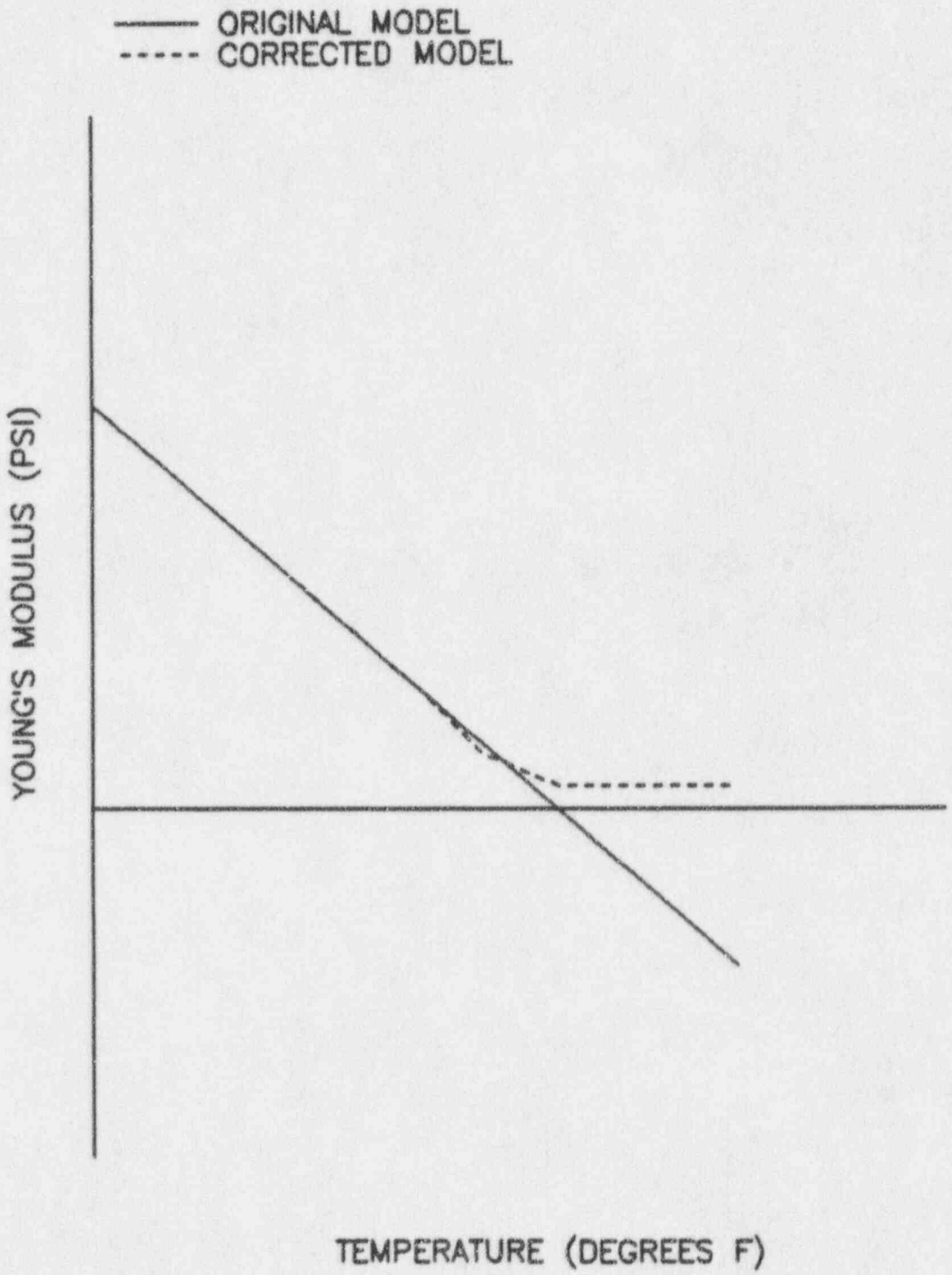

Figure 2

Effect of PARCH Error on Small Break LOCA Cladding Surface Temperature