WCAP 11524-A
Addendum 1
Revision 2-A

WESTINGHOUSE CLASS 3

THE 1981 VERSION OF THE WESTINGHOUSE ECCS EVALUATION MODEL USING THE BASH CODE ADDENDUM 1: POWER SHAPE SENSITIVITY STUDIES

J. J. Besspiata
J. N. Kabadi
M. Y. Young

December 15, 1987

Work Performed Under Shop Order DGKP 70103

Westinghouse Electric Corporation
Nuclear Energy Systems
P.O. Box 355
Pittsburgh, Pennsylvania 15230

1.0 INTRODUCTION

This report contains a study of the effect of different power shapes on the calculated peak cladding temperature. The evaluation model used is the 1981 version of the Westinghouse ECCS evaluation model, using the BASH code.

This report presents the power shape study as Appendix J, which is a continuation of the Appendices contained in the main report describing the BASH code[1]. The study was performed for typical 3 and 4 loop plants. Because use of BASH for two loop plants is not anticipated, a study for two loop plants was not performed.

The results contained in this report are considered typical of all three and four loop plants with cold leg emergency core cooling systems and are therefore generically applicable.

---

1 "The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code," WCAP 10266, Revision 2 (Proprietary).

SEP 21 1987

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

September 15, 1987

RECEIVED SEP 21 1987 Nuclear Safety Department

Mr. W. J. Johnson, Manager
Nuclear Safety Department
Westinghouse Electric Corporation
P. O. Box 355
Pittsburgh, Pennsylvania 15230-0355

Dear Mr. Johnson:

SUBJECT: ACCEPTANCE FOR REFERENCING OF ADDENDUM 1 TO WCAP-10266, BASH POWER SHAPE SENSITIVITY STUDIES

We have completed our review of WCAP-10266, Revision 2, Addendum 1, Power Shape Sensitivity Studies submitted by your letter of January 26, 1987, as amended June 22, 1987. We find this report to be acceptable for referencing in licensing applications to the extent specified and under the restrictions delineated in the report and the associated NRC safety evaluation, which is enclosed. The evaluation defines the basis for acceptance of this report.

We do not intend to repeat our review of the matters described in the report and found acceptable when the report appears as a reference in license applications except to assure that the material presented is applicable to the specific plant involved. Our acceptance applies only to the matters described in the report.

In accordance with procedures established in NUREG-0390, it is requested that Westinghouse publish accepted versions of this report, proprietary and non-proprietary, within three months of receipt of this letter. The accepted versions should incorporate this letter and the enclosed evaluation as Appendix J to the accepted version of WCAP-10266, Revision 2.

Should our criteria or regulations change such that our conclusions as to the acceptability of the report are invalidated, Westinghouse and/or the applicants referencing the topical report will be expected to revise and resubmit their respective documentation, or submit justification for the continued effective applicability of the topical report without revision of their respective documentation.

Sincerely,

A C Thadani

Ashok C. Thadani, Assistant Director
for Systems
Division of Engineering & Systems Technology
Office of Nuclear Reactor Regulation

Enclosure:
As stated

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

ENCLOSURE 1

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION RELATING TO BASH POWER SHAPE SENSITIVITY STUDIES WCAP-10266, REVISION 2, ADDENDUM 1

1.0 INTRODUCTION

For a loss of coolant accident (LOCA) analysis, Appendix K to 10 CFR 50 requires, among other things, that a sensitivity study for a range of possible power distribution shapes be performed to determine the worst shape which results in the most severe calculated consequence during a LOCA. A 1974 Westinghouse axial power shape study in WCAP-8340 (Ref. 1) concluded that the chopped cosine power shape yielded the highest peak cladding temperature (PCT) and was therefore the limiting shape to be used for LOCA analyses.

During the review of the topical report WCAP-10266 (Ref. 2) which describes a Westinghouse ECCS evaluation model using the BASH code for reflood heat transfer calculation, the staff questioned the validity of referencing the results of WCAP-8340 since they were done with different codes. The staff safety evaluation report (Ref. 3) for WCAP-10266 indicated acceptance for Westinghouse to reference the power shape study results of WCAP-8340. This acceptance was based on a commitment from Westinghouse to perform a confirmatory analysis with the first BASH plant calculation of each type (two-, three-, or four-loop plant) to demonstrate that the cosine power shape is limiting and is the appropriate power shape to use for licensing calculations.

In a January 26, 1987 letter (Ref. 4) as amended June 22, 1987 (Ref. 5), Westinghouse fulfilled its commitment by submitting Addendum 1 to WCAP-10266 describing its analyses for three and four loop plants. The letters also indicated that Westinghouse did not anticipate to use BASH for the two-loop plants and therefore the analysis with the two-loop plants was omitted. The staff has reviewed this submittal and our evaluation follows.

2.0 STAFF EVALUATION

Addendum 1 to WCAP-10266 provides a sensitivity study of the effect of various axial power shapes on the calculated PCTs for a large break LOCA. The analysis was done with the 1981 version of the Westinghouse ECCS evaluation model using the BASH code as described in WCAP-10266.

Previous sensitivity study of WCAP-8340 was performed with consideration of only the chopped cosine and top skewed power shapes. Westinghouse had concluded that any power shape with its peak near the bottom of the core would always receive better cooling during reflood and would never be limiting. Therefore, in a reactor core of 12 feet active fuel length, analyses were done for the axial power shapes having their peaks at the six- (chopped cosine), eight-, and ten-foot locations. In the current analysis using the BASH code, a bottom skewed shape with its peak at the four-foot location is also included in addition to the six-, eight-, and ten-foot peak power shapes. These power shapes represent possible core power configuration during extreme load follow strategies. The total peaking factor, $Fq(z)$, at an axial location is restricted by the $k(z)$ curve specified in the plant technical specification at the allowable maximum total peaking factor Fq.

The results of the studies are shown in Figures J-5 and J-6 of the report where axial cladding temperature profiles for the 4, 6, 8, and 10 foot peaked power shapes are shown for the beginning of core recovery (BOCREC), and Figures J-11 through J-14 where the PCT history during reflood periods are shown for the various power shapes studied. The PCT comparisons for these power shapes are summarized in Table J-1 for both three and four loop plants.

The results clearly show that the 6-foot peaked (chopped cosine) power shape results in the highest PCT with the 4-foot peaked shape having the lowest PCT among the four shapes studied. These studies were performed with the maximum total peaking factor, Fq, of 2.32. An additional confirmatory study (Ref. 5) was also done with Fq of 2.5 to confirm the same trend for other total peaking factors. Only two peak locations (6-foot and 7.5-foot peak) were studied for Fq=2.5. The results again show that the 6-foot peak cosine shape yield the highest PCT. We therefore conclude that Westinghouse has adequately confirmed the conclusion of WCAP-8340 that the 6-foot peak chopped cosine shape is the most limiting power shape which can be used for plant licensing calculations.

3.0 SUMMARY

The staff has reviewed the power shape sensitivity study of WCAP-10266, Revision 2, Addendum 1. We concur with the conclusion that the chopped cosine axial power shape is the limiting power shape for LOCA analysis using the BASH code. Therefore, the power shape study conclusion of WCAP-10266, Addendum 1 is acceptable. This acceptance is only applicable to the Westinghouse three-and-four-loop plants, since no analysis was performed for the two-loop plant.

4.0 REFERENCES

1. WCAP-8340, "Westinghouse Emergency Core Cooling System - Plant Sensitivity Studies," July 1974.

2. WCAP-10266, Revision 2, "The 1981 Version of the Westinghouse ECCS Evaluation Model using the BASH Code," August 1986.

3. Letter from C. E. Rossi (NRC) to E. P. Rahe, Jr. (Westinghouse), "Acceptance for Referencing of Licensing Topical Report WCAP-10266, 'The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code'", November 13, 1986.

4. Letter from W. J. Johnson (Westinghouse) to James Lyons (NRC), "Submittal of WCAP-10266, Addendum 1 BASH Power Shape Sensitivity Studies," NS-NRC-87-3199, SED-THA-87-007, January 26, 1987.

5. Letter from W. J. Johnson (Westinghouse) to James Lyons (NRC), "Submittal of WCAP-10266, Addendum 1 (Rev. 1), BASH Power Shape Sensitivity Studies," NS-NRC-87-3237, June 22, 1987.

APPENDIX J - POWER SHAPE STUDY

A study is performed in this section to determine the clad temperature response during a LOCA with a variety of core axial power shapes. These power shapes are representative of those which could occur during normal operation.

Previous studies[1] investigated the effect of power shapes which had 6, 8 and 10 foot peaks. These power shapes were chosen from a wide variety of possible power shapes, and were chosen because they yielded the highest local power at the given elevation. The 6 foot power shape was used primarily to confirm that the chopped cosine shape was a reasonable approximation to actual six foot power shapes.

a,c

It was also concluded that any power shapes with peaks near the bottom of the core would always receive better cooling during reflood, and would therefore never be limiting.

To confirm that the conclusions of reference [1] still apply to the BASH methodology, LOCA analyses were repeated using 10 foot, 8 foot, and 4 foot power shapes. These shapes were obtained from a large data base of calculated power shapes. These power shapes represent possible core configurations during extreme load follow strategies, and flux imbalances, and a range of cycle burnups.

The hot rod power shapes which exhibited the highest local power at the given elevation were chosen. Because these power shapes are based on realistic load follow calculations, they exhibit peak powers lower than the limits on which the LOCA analysis is based. Generally, the total peaking factor for top skewed shapes is substantially lower than symmetric or bottom skewed shapes, due to higher moderator temperature at the top of the core, and the use of control rods. The core average power shape consistent with these hot rod power shapes was also determined.

The technical specifications in a plant provide for limits on the peak local power at any location in the core, in the form of a K(Z) curve (see Figure J-1). This curve, normalized to the maximum peaking factor, is made up of three line segments and defines the maximum allowable total peaking factor at any location in the core. Usually, the third line segment is set by peak clad temperatures during small break (i.e., if the total peaking factor at locations above 10.8 feet does not exceed K(Z) * maximum allowable Fq, cladding temperatures at these locations will not exceed 2200°F during a LOCA).

a,c

In order to confirm that the K(Z) curve assures calculated peak clad temperatures below 2200°F at all elevations, the realistic power shapes are scaled upward such that their peaks touch the K(Z) curve at the appropriate elevation, and these power shapes are then used in the LOCA analysis to determine the peak cladding temperature. These scaled power shapes are shown in Figures J-2, J-3, and J-4 for the 4 foot, 8 foot, and 10 foot shapes, respectively. The six foot cosine shape is also shown for comparison.

Several cases were analyzed, using the power shapes shown in Figures J-2 to J-4 and the same plant models described in Section 9 of reference [2]. The initial cladding temperatures at the beginning of reflood (BOCREC) are compared for each power shape in Figures J-5 and J-6. It can be seen that the skewed power shapes have lower initial temperature, due to better cooling near the ends of the core during blowdown.

The resulting BASH reflood integrals and smoothed flooding rates are shown in Figures J-7 to J-10. It can be seen that the reflood transients are similar.

a,c

The peak cladding temperatures for the shapes studied, including the chopped cosine results presented in Section 9, are compared in Figures J-11 to J-14, and summarized in Table J-1. It can be seen that the peak cladding temperature for all shapes is below 2200°F. In addition, the cosine power shape yields the highest peak cladding temperature. Because of the higher peak cladding temperature, the six foot cosine shape is considered more limiting than skewed power shapes for LOCA analyses.

The analyses presented above assumed that the total peaking factor was 2.32, which is typical of most plants. For some plants, BASH will provide sufficient margin to allow raising the peaking factor. To determine whether the results of the previous power shape analysis was still valid, additional calculations were performed. A power shape with peak power at the 7.5 foot elevation (Figure J-15) was analyzed at a total peaking factor of 2.45 (due to the K(Z) curve, the 7.5 foot peak power is slightly lower than the 6 foot peak power) and compared with the cosine power shape analyzed at a total peaking factor of 2.5. The plant analyzed was the four loop plant which, as can be seen from Table J-1, has calculated peak cladding temperatures sufficiently low to allow raising the peaking factor. The 7.5 foot shape was chosen because the previous sensitivity studies indicated that power shapes with peaks above but close to the six foot peak would have higher peak cladding temperatures.

Table J-2 compares the calculated results for the 6 foot and 7.5 foot power shapes at a total peaking factor of 2.5 and shows that the six foot power shape is still limiting. Transient cladding temperatures are shown in Figure J-16.

REFERENCES

1. "Westinghouse Emergency Core Cooling System - Plant Sensitivity Studies," WCAP-8340, July 1974. [PROPRIETARY]

2. "The 1981 Version of the Westinghouse ECCS Evaluation Model using the BASH Code," WCAP-10266, Revision 2, August 1986. [PROPRIETARY]

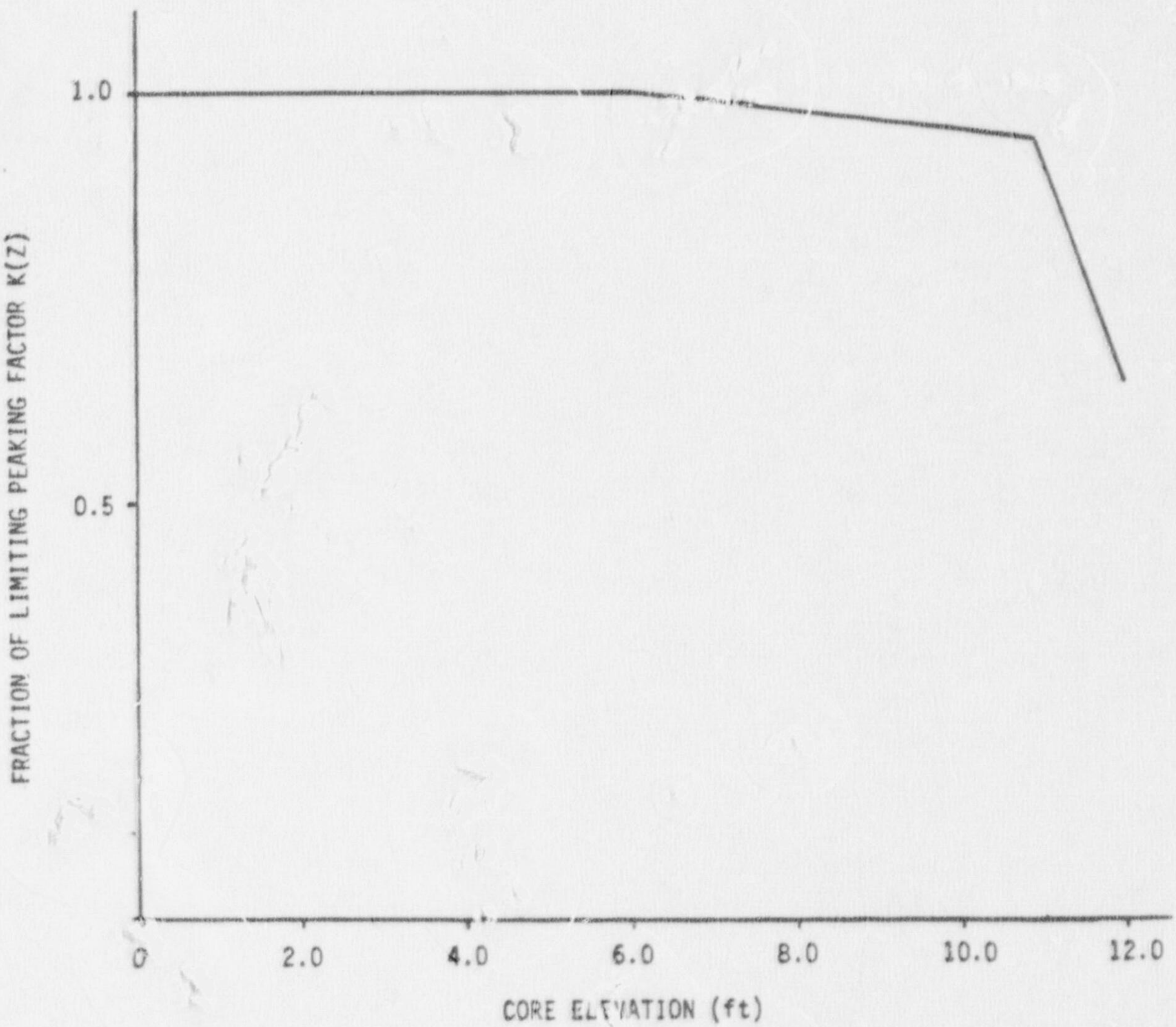


Figure J-1. Typical K(Z) Limit Curve

a,c

Figure J-2. Power Shape Peaked at 4 Feet

a,c

Figure J-3. Power Shape Peaked at 8 Feet

a,c

Figure J-4. Power Shape Peaked at 10 Feet

a,c

Figure J-5. Hot Rod Temperature Profiles at Beginning of Reflood (BOCREC) - Four Loop Plant

a,c

Figure J-6. Hot Rod Temperature Profiles at Beginning of Reflood (BOCREC) - Three Loop Plant

a,c

Figure J-7. BASH Flooding Rate Integrals (Smoothed) - Four Loop Plant

a,c

Figure J-8. BASH Flooding Rate Integrals (Smoothed) - Three Loop Plant

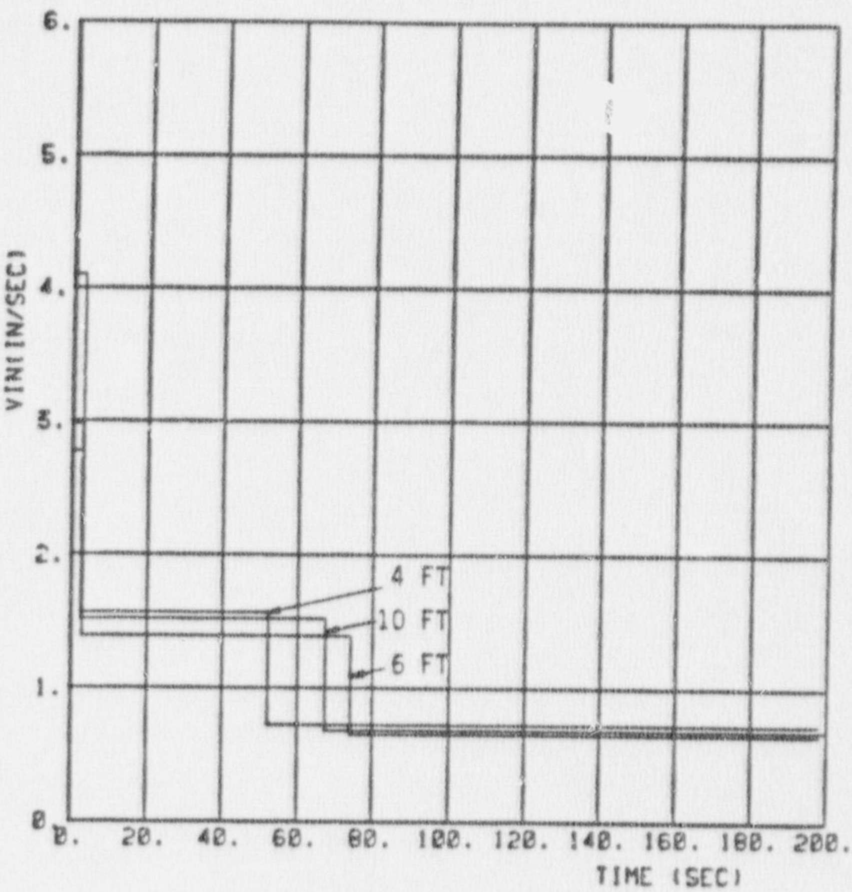


Figure J-9. BASH Smoothed Flooding Rates - Four Loop Plant

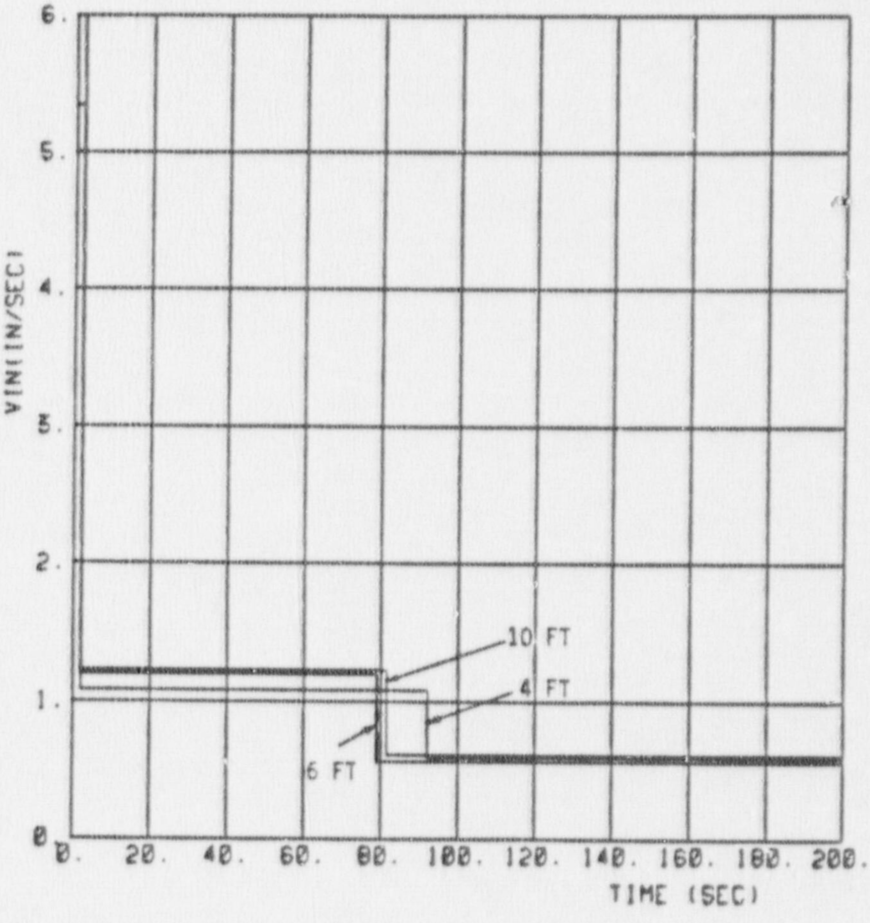
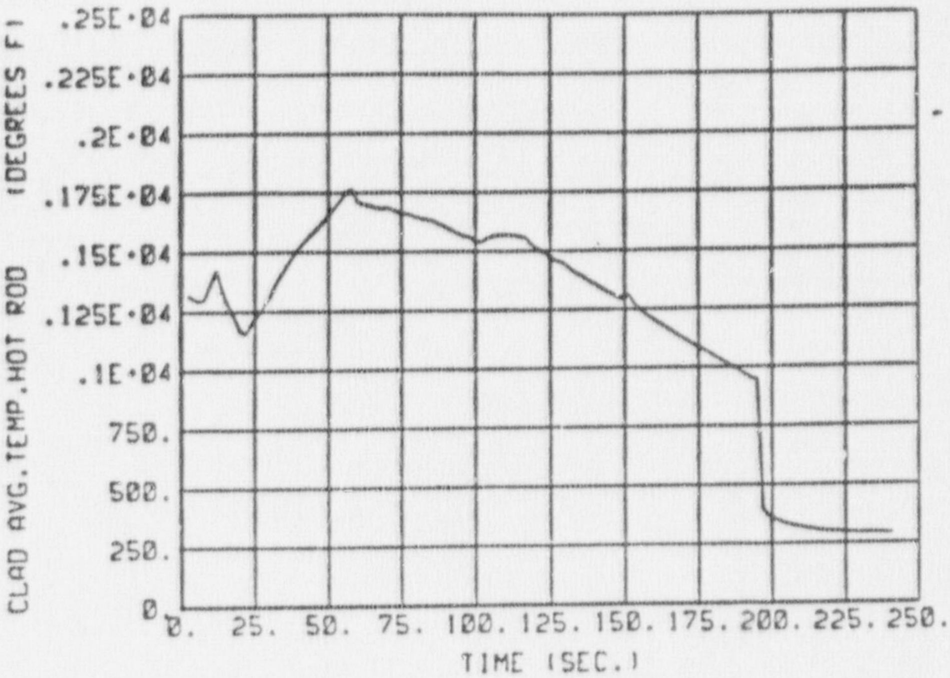
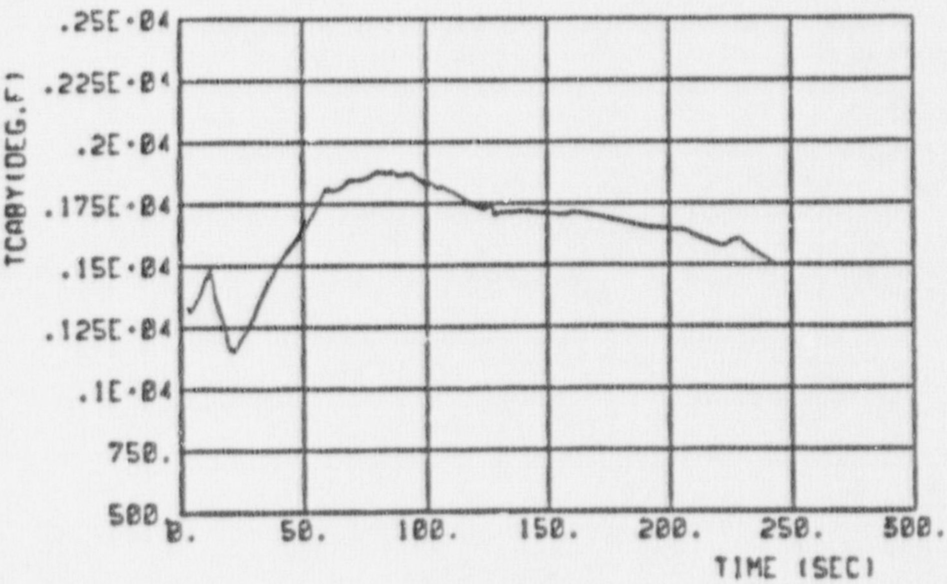


Figure J-10. BASH Smoothed Flooding Rates - Three Loop Plant



(a)



(b)

Figure J-11. Peak Cladding Temperature (Four Loop Plant)
(a) Four foot peak
(b) Six foot peak

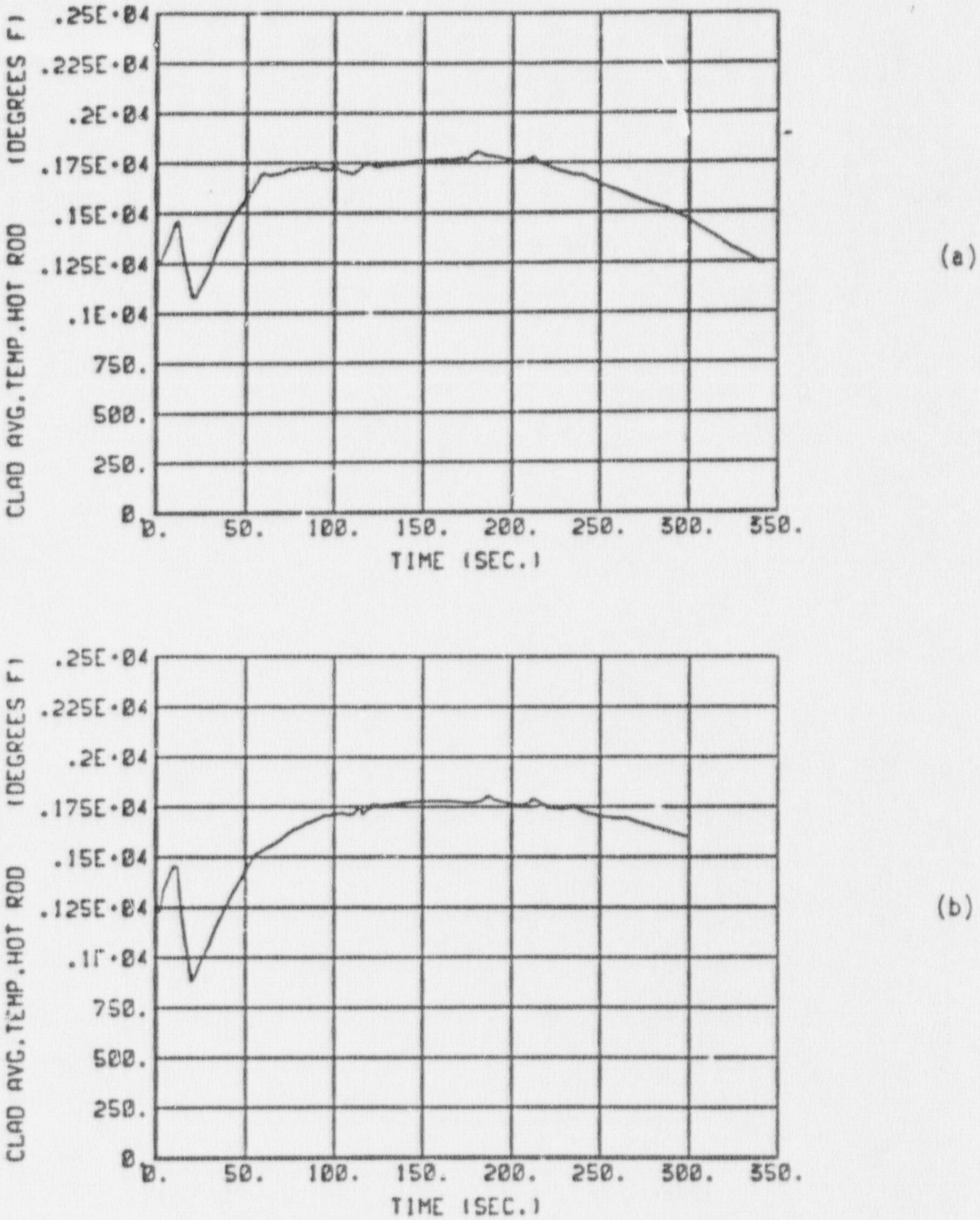
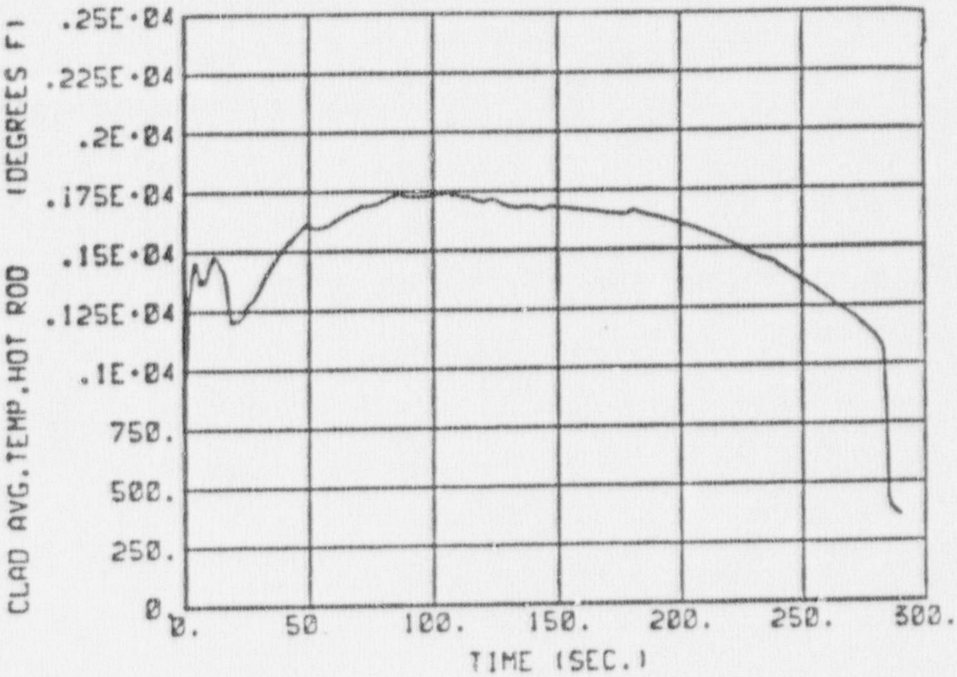
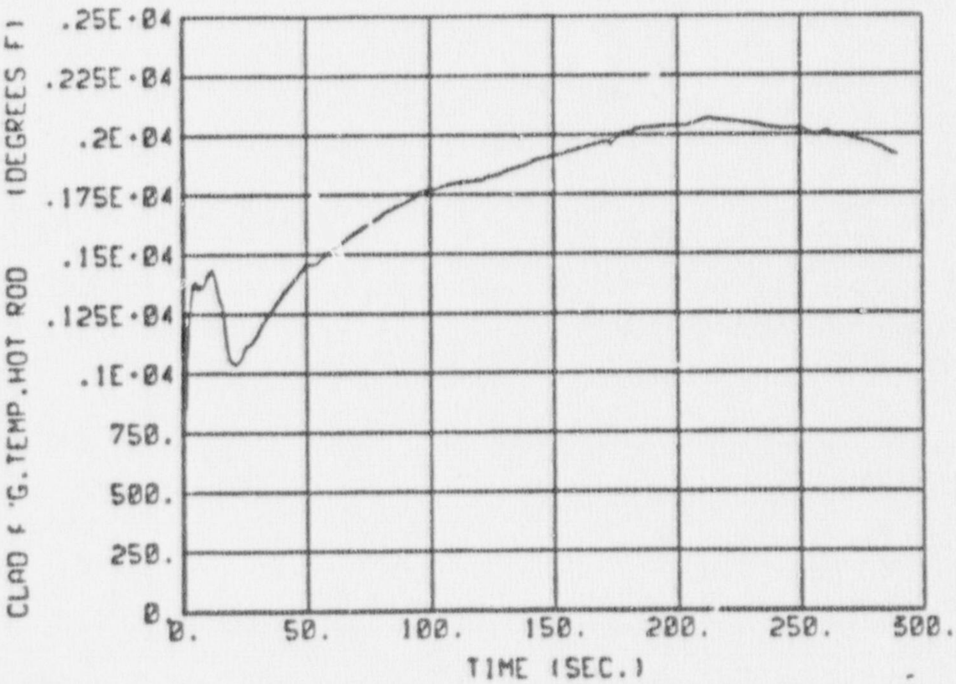


Figure J-12. Peak Cladding Temperature (Four Loop Plant)
(a) Eight foot peak
(b) Ten foot peak

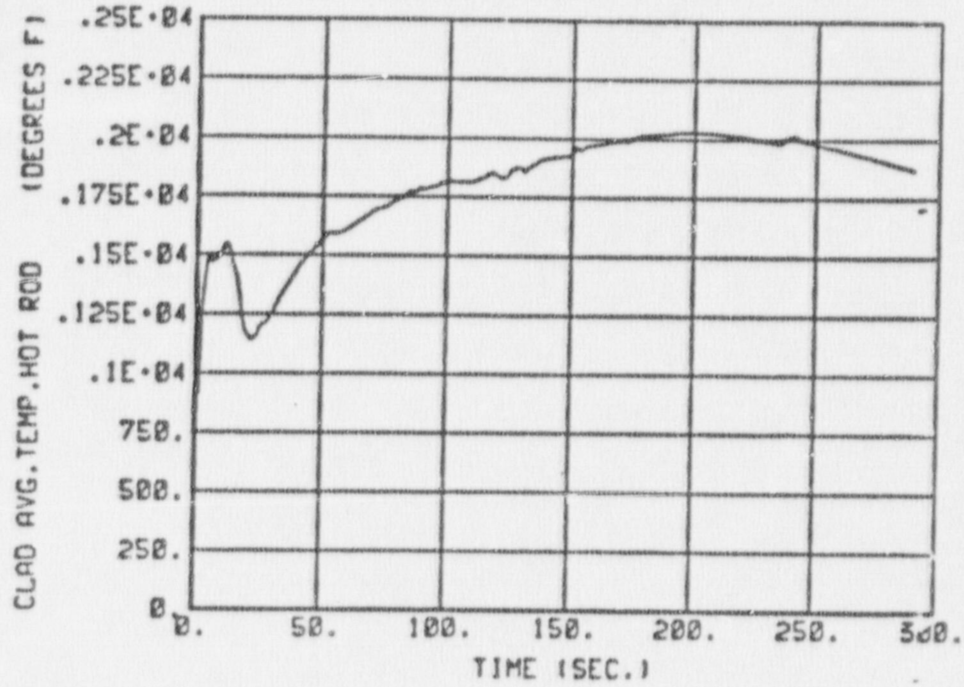


(a)

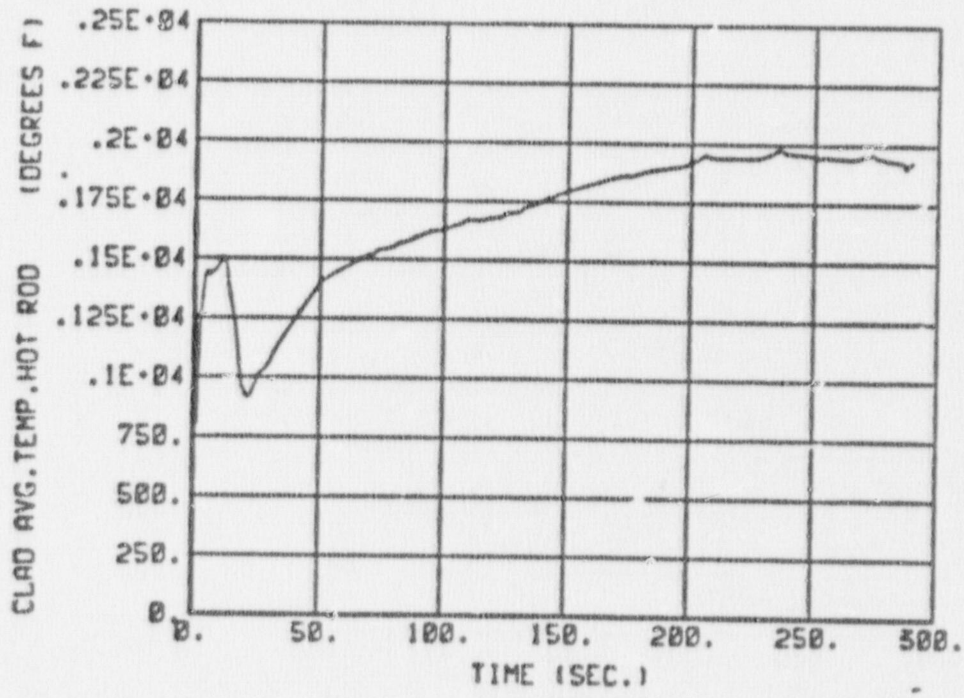


(b)

Figure J-13. Peak Cladding Temperature (Three Loop Plant)
(a) Four foot peak
(b) Six foot peak



(a)



(b)

Figure J-14. Peak Cladding Temperature (Three Loop Plant)
(a) Eight foot peak
(b) Ten foot peak

TABLE J-1

PEAK CLADDING TEMPERATURE FOR DIFFERENT POWER SHAPES (FQ = 2.32)

Four Loop Plant

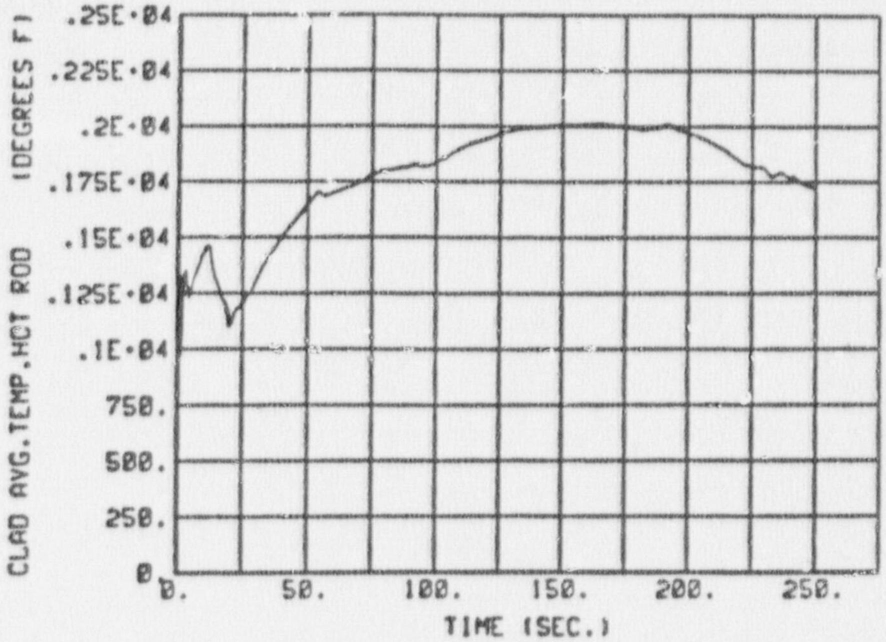
Power Shape	PCT (°F)	Location (ft)
4 ft peak	1767	4.75
6 ft peak	1864	7.0
8 ft peak	1814	8.75
10 ft peak	1813	10.25

Three Loop Plant

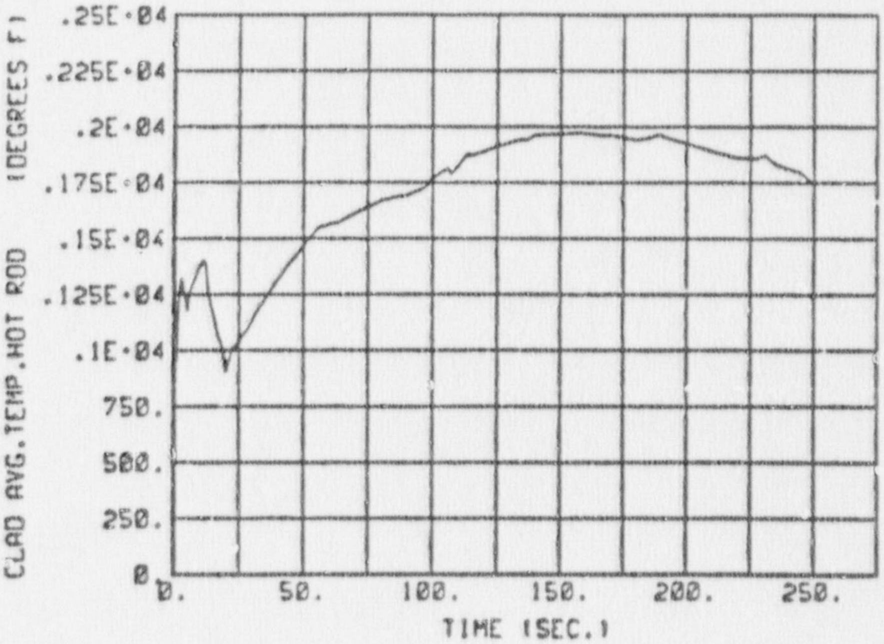
Power Shape	PCT (°F)	Location (ft)
4 ft peak	1752	5.25
6 ft peak	2070	8.5
8 ft peak	2030	8.75
10 ft peak	1985	10.75

a,c

Figure J-15. Power Shape Peaked at 7.5 Feet



(a)



(b)

Figure J-16. Peak Cladding Temperature (Four Loop Plant at FQ = 2.5)
(a) Six Foot Peak
(b) 7.5 Foot Peak

TABLE J-2

PEAK CLADDING TEMPERATURE FOR DIFFERENT POWER SHAPES AT INCREASED PEAKING FACTOR (FQ = 2.5)

Four Loop Plant

Power Shape	PCT (°F)	Location (ft)
6 ft peak	2014	8.0
7.5 ft peak	1974	9.5