APPENDIX B

RCS
ASYMMETRIC LOADS
EVALUATION

ST. LUCIE 1

APPENDIX B

RCS

ASYMMETRIC LOADS

EVALUATION

ECCS ANALYSIS APPROACH WITH REDUCED AREA COOLANT CHANNELS IN PERIPHERAL ASSEMBLIES

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for

St. Lucie 1

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B.1.0 INTRODUCTION AND SUMMARY

The ECCS performance evaluation demonstrating conformance with 10CFR50.46, which presents the NRC Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Reactors[1], are presented in References 2, 3, and 4. These references provide analyses for Calvert Cliffs Units 1 & 2, and St. Lucie Unit 1. The purpose of this supplementary analysis is to demonstrate acceptable ECCS performance with reduced area coolant channels assumed in the peripheral fuel assemblies. While demonstrating acceptable ECCS performance, the intent of this anlaysis is to also show that the current licensing analysis, pertaining to the hottest fuel rod in the core, is more limiting than that for the hottest rod in a peripheral assembly with reduced area coolant channels. Since this evaluation is to apply to the above plants, a generic analysis was performed. The method of the analysis is discussed in the following sections.

B.2.0 METHOD OF ANALYSIS

In the C-E ECCS evaluation model[5,6], the CEFLASH-4A[7] computer program is used to determine the primary system thermal hydraulic behavior during the blowdown period, and the COMPERC-II[8] program is used to describe the system behavior during the refill and reflood periods. The resulting transient parameters from these computer programs, describing the thermal and hydraulic behavior of the primary system, supply the input to the STRIKIN-II[9] program which is used to calculate the hot rod peak clad temperature and peak local clad oxidation percentage.

The objective of the analysis is to demonstrate that the ECCS performance for a peripheral assembly with reduced area coolant channels is less limiting than a hot rod in a channel without any reduction in flow area. To accomplish this objective it is necessary to evaluate the performance of the limiting fuel rod in the peripheral assembly containing reduced area fuel channels. In evaluating the performance of the limiting fuel rod in the peripheral assembly, blowdown refill/reflood, and temperature calculations were performed using the computer programs described above based on a conservative set of input assumptions. The conservative assumptions are employed in the analysis so that the results will bound the response for Calvert Cliffs Units 1 & 2, and St. Lucie Unit 1 Plants. The details of these assumptions and the analytical methods employed in this analysis are discussed in the subsections below.

B.2.1 Blowdown Hydraulics

The blowdown portion of the transient was analyzed using the CEFLASH-4A computer program. In the CEFLASH-4A calculation, the peripheral assembly was explicitly represented with a 10% reduction in total assembly cross sectional flow area. This reduction in peripheral assembly flow area conservatively exceeds the maximum expected deformation since the testing program identified this maximum blockage to be 9%. This deformation was also assumed to occur along the entire length of the assembly to minimize the flow in this region. In addition, the power level of the peripheral assembly was conservatively assumed to be at the core average power level. This assumption is conservative since the peripheral assemblies are approximately 5% to 10% lower than that for the core average which results in maximizing the heat

addition to this region.

In performing the blowdown calculation, the Calvert Cliffs plant, a representative 2700 Mwt class NSSS, is used. This plant was chosen since its' core power level is highest of all the plants considered in this evaluation.

B.2.2 Refill/Reflood Hydraulics

Since the containment pressure and core average reflood rates are unaffected by the flow area reduction in a single peripheral assembly, no new COMPERC-II calculations were necessary. As a consequence, the COMPERC-II refill/reflood hydraulics calculations from a representative 2700 Mwt class NSSS was chosen for use in this portion of the evaluation. This particular analysis was chosen since the evaluation resulted in the lowest containment pressure, the lowest reflood rate, and hence the lowest reflood heat transfer coefficients, for the plants considered in this report.

B.2.3 Temperature Analysis

The STRIKIN-II and PARCH[10] computer programs were used to evaluate the temperature transient and peak local cald oxidation percentage for the hottest rod in the peripheral assembly.

For conservatism, in modeling rod-to-rod thermal radiation, the power distribution surrounding the hot rod in the peripheral assembly was assumed to be a relatively flat distribution. As a consequence, the rods surrounding the hot rod in the peripheral assembly will be very nearly the same temperature as the hot rod during the entire

transient thereby minimizing the benefits from rod-to-rod thermal radiation. This radiation enclosure is conservative since it bounds all power distributions encountered in all of the operating plants experienced to date.

In evaluating the response of the hottest rod in the peripheral assembly, the channel surrounding this rod was assumed to be reduced in flow area with percentage reductions in the range from 0 to 35% which covers the maximum expected flow area reduction of 34% obtained from the testing program. The results are presented as a curve of allowable linear heat rate, for a peripheral assembly, as a function of percent reduction in single channel flow area for the hottest pin in this assembly.

B.3.0 SUMMARY OF CONSERVATISMS

A summary of the conservatisms for this analysis is presented below:

1. The power level of 2754 Mwt (102% of 2700 Mwt) was assumed.
2. The peripheral assembly power level was assumed to be at the core average power level. The peripheral assembly power levels for all the plants considered in this evaluation are lower than the core average power levels.
3. The thermal radiation enclosure assumed a nearly uniform power distribution surrounding the hot rod to minimize radiation heat transfer during refill and reflood.
4. Radiation to the guide tubes was neglected. All of the hot rods in the peripheral assemblies for the plants considered herein are located near the guide tubes.

5. The analysis was performed at the time-in-life of minimum gap conductance or maximum fuel stored energy.
6. The assembly and channel flow area reductions were applied along the entire length of the core. Actual deformations are expected to occur only near the core mid-plane.

Some of the significant parameters selected for use in this evaluation, compared with the more appropriate specific plant parameter, are listed in Table B.3.1.

B.4.0 RESULTS

The results of the analysis demonstrate acceptable ECCS performance for the plants considered for reductions in single channel flow area of 35% in a peripheral assembly. Figure B.4-1 illustrates the relationship between linear heat generation rate and reduction in single channel flow area for a peripheral assembly and demonstrate an acceptable linear heat generation rate of 14.9 kw/ft when the reduction in channel flow area is as high as 35%.

Table B.4.1 presents the results of three analysis considerations. In identifying an acceptable linear heat generation rate in a peripheral assembly for the various channel area reductions, the peak clad temperatures and peak local clad oxidation percentages were maintained below $2100^{\circ}F$ and 15% respectively for additional conservatism.

Table B.4-2 lists the various parameters presented graphically for the three cases.

The results of this study show acceptable ECCS performance with a

maximum assembly flow area reduction of 10% and a maximum channel reduction of 35%.

E.5.0 EVALUATION OF RESULTS

Despite the many conservative assumptions inherent in this evaluation, the results were well below the Acceptance Criteria Limits[1]. The peak clad temperatures were calculated to occur during the late reflood period and were due to the very conservative assumptions in regard to the limited heat transfer imposed during this period. Without utilizing the conservative assumptions described in Section B.3.0, it is estimated that the resulting peak clad temperature would have been several hundred degrees lower than those reported herein.

In the analysis, the Calvert Cliffs plant, representative of the 2700 Mwt class of plants, was used since it's power level is highest of all the plants considered. In addition, this particular plant was used since the response during the reflood portion of the transient results in the lowest containment pressure, the lowest reflood rate, and hence the lowest reflood heat transfer coefficients of the plants considered in the evaluation. Table B.3.1 presents some of the major parameters used in the analysis and demonstrates that the parameters used in the evaluation bound those for the plants considered in this report.

Table B.3.1 presents the peak linear heat generation rate for the hottest fuel rod in the core and for the hottest fuel rod in a peripheral assembly for all the plants considered in this evaluation. Since the difference in power level between the hottest core fuel rod and the hottest fuel rod in a peripheral assembly varies throughout the cycle

for all plants, the values presented for these linear heat rates correspond to the time in life wherein the separation in power, between these two locations, is at a minimum. This evaluation is therefore conservative since during the cycle, the separation in power between the hottest peripheral fuel rod and the hottest rod in the core is much greater than that assumed in the analysis. Insepction of Table B.3.1 demonstrates that the Calvert Cliffs Unit II plant produces the highest linear heat rate, for a fuel rod in a peripheral assembly, of 14.3 kw/ft when the hottest fuel rod in the core is at 15.5 kw/ft at the most limiting time-in-life. Furthermore, with a 35% reduction in channel flow area for the hottest peripheral fuel rod, the ECCS performance is less limiting than that for the hottest fuel rod in the core with no channel deformation.

It should also be mentioned that the results of this analysis apply equally to those plants listed in Table B.3.1 so that, in effect, the linear heat rate of the hottest rod in a Combustion Engineering peripheral assembly can be as high as 14.9 kw/ft for each of these plants regardless of whatever the core peak linear heat rate is.

The peak linear heat generation rate in a peripheral assembly in St. Lucie Unit 1 is 13.9 kw/ft. Therefore, even with a 35% reduction in channel flow area in the hottest load rod in a peripheral assembly, the limiting rod will remain the hottest rod in the core with the peak linear heat rate of 15.0 kw/ft.

It is also of particular importance to note that the analysis of the peripheral fuel rod contained in this report includes the various

uncertainties and associated engineering factors associated and applied to the hottest fuel rod in the core. With this factor also applied to the peripheral fuel rod, the evaluation still demonstrated that the limiting fuel rod remains the hottest rod in the core so that application of the factors to the peripheral fuel rod represents considerable additional conservatism.

B.6.0 CONCLUSIONS

The results of this analysis demonstrate an acceptable linear heat generation rate of 14.9 kw/ft for a reduction in channel flow area of 35% in a peripheral assembly. In Table B.3.1 the peak linear heat generation rate in the peripheral assemblies for the plants considered in this evaluation are presented to demonstrate the difference in power between the hottest rod in the core and the hottest rod in a peripheral assembly. As identified in Table B.3.1 of the plants considered, the highest power level of a pin in a peripheral assembly is 14.3 kw/ft when the limiting rod in the hot assembly is operating at 15.5 kw/ft. Since the results of this evaluation demonstrate acceptable ECCS performance at the linear heat rate of 14.9 kw/ft, there is no impact on the present peak linear heat generation rate for the plants considered in this evaluation so that the analysis results reported in References 2, 3, and 4 remain limiting.

B.7.0 COMPUTER CODE VERSION IDENTIFICATION

The following NRC approved versions of Combustion Engineering ECCS Evaluation Model computer codes were used in this analysis:

CEFLASH-4A:	Version No. 76041
STRIKIN-II:	Version No. 77036
PARCH :	Version No. 77004

[illegible]

B.8.0 REFERENCES

1. Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Cooled Nuclear Power Reactors, Federal Register, Vol. 39, No. 3 - Friday, January 4, 1974.
2. BG&E Letter, J. W. Core to L. M. Muntzing, dated 9/12/74.
3. BG&E Letter, A. E. Lundwall Jr. to A. Giambusso, dated 7/17/71.
4. FP&L Letter to NRC L-79-42, dated February 22, 1979
5. CENPD-132, "Calculative Methods for the CE Large Break LOCA Evaluation Model", August 1974 (Proprietary).
   CENPD-132, Supplement 1, "Updated Calculative Methods for the CE Large Break LOCA Evaluation Model", December 1974 (Proprietary).
6. CENPD-132, Supplement 2, "Calculational Methods for the CE Large Break LOCA Evaluation Model", July 1975 (Proprietary).
7. CENPD-133, "CEFLASH-4A, A FORTRAN IV Digital Computer Program for Reactor Blowdown Analysis", April 1974 (Proprietary).
   CENPD-133, Supplement 2, "CEFLASH-4A, A FORTRAN IV Digital Computer Program for Reactor Blowdown Analysis (Modification)", December 1974 (Proprietary).
8. CENPD-134, "COMPERC-II, A Program for Emergency Refill-Reflood of the Core", April 1974 (Proprietary).
   CENPD-134, Supplement 1, "COMPERC-II, A Program for Emergency Refill-Reflood of the Core (Modification)", December 1974 (Proprietary).
9. CENPD-135, "STRIKIN, A Cylindrical Geometry Fuel Rod Heat Transfer Program", April 1974 (Proprietary).
   CENPD-135, Supplement 2, "STRIKIN-II, A Cylindrical Geomegry Fuel Rod Heat Transfer Program (Modification)", February 1975.
   CENPD-135, Supplement 4, "STRIKIN-II, A Cylindrical Geometry Fuel Rod Heat Transfer Program", August 1976 (Proprietary).

CENPD-135, Supplement 5-P, "STRIKIN-II, A Cylindrical Geometry Fuel Rod Heat Transfer Program", April 1977 (Proprietary).

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

TABLE B.3-1

PARAMETERS USED IN DEFORMED ASSEMBLY ANALYSIS

		PLANT		
PARAMETER	ANALYSIS ASSUMPTION	CALVERT CLIFFS UNIT I	CALVERT CLIFFS UNIT II	ST. LUCIE 1
Total Reactor Power (Mwt)	2754	2754	2754	2754
PLHGT (kw/ft)	15.6	14.2	15.5	15.0
PLHGR In Peripheral Assembly (kw/ft)	*	12.2	14.3	13.9
Average LHR (kw/ft)	6.548	6.333	6.52	6.427
Fuel Average Temperature at PLHGR (^{o}F)	2300	2151	2233	2203

*Varies with channel deformation (15.6 - 14.9 kw/ft)

TABLE B.4-1

RESULTS OF DEFORMED ASSEMBLY ANALYSIS

CASE	PLHGR (kw/ft)	PEAK CLAD TEMPERATURE (°F)	PEAK LOCAL CLAD OXIDATION (%)
Undeformed Assembly	15.6	2053	< 15.0
20% Deformation	15.2	1940	< 6.0
35% Deformation	14.9	2036	< 14.5

TABLE B.4-2

VARIABLES PLOTTED AS A FUNCTION OF TIME

VARIABLE	FIGURE DESIGNATION
Assembly Flow Rate	B.4-2
Undeformed Case:	
Peak Clad Temperature	B.4-3
Local Clad Oxidation	B.4-4
20% Reduction Case	
Peak Clad Temperature	B.4-5
Local Clad Oxidation	B.4-6
30% Reduction Case:	
Peak Clad Temperature	B.4-7
Local Clad Oxidation	B.4-8

FIGURE B.4-1

PLHGR vs FLOW AREA REDUCTION

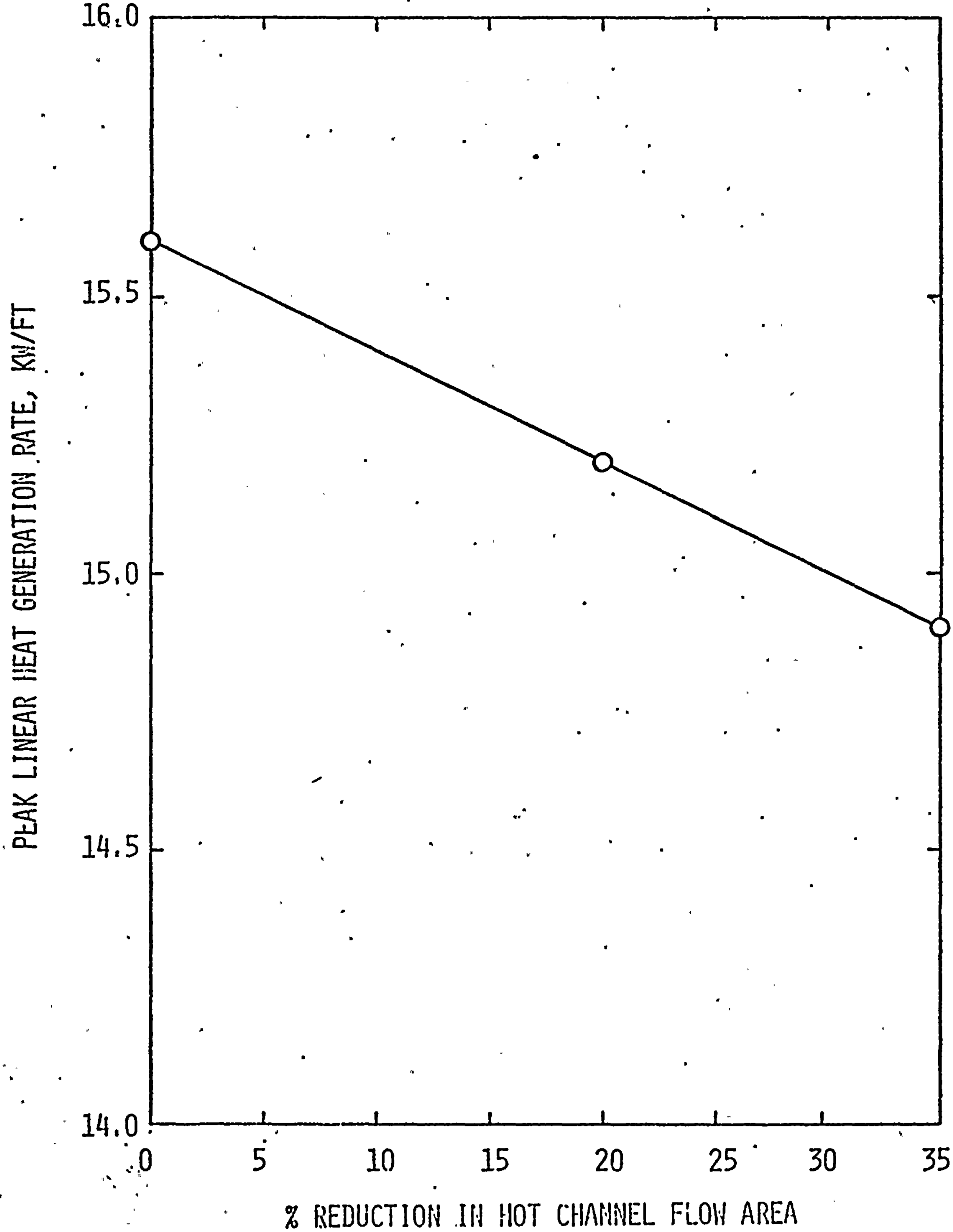
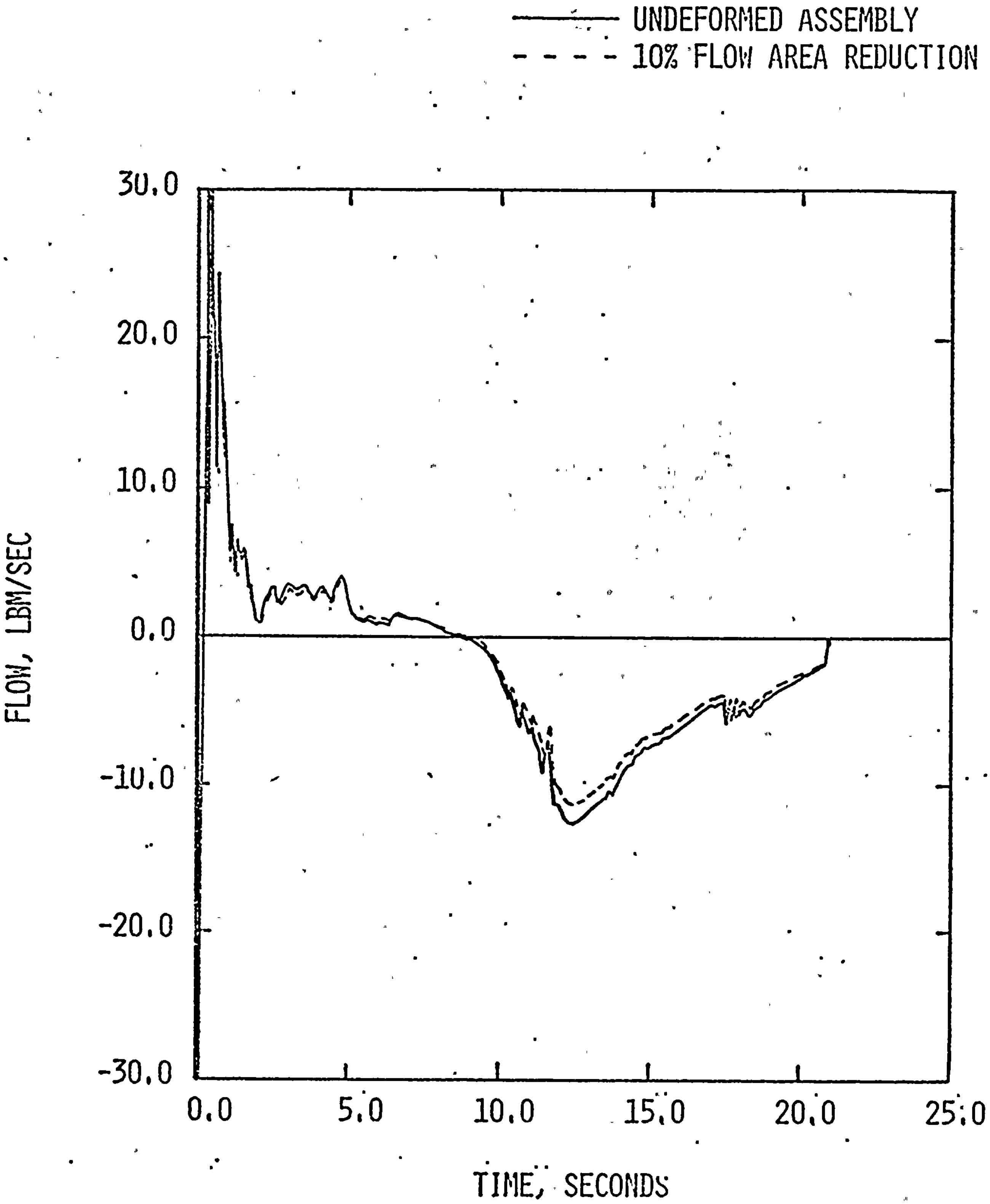


FIGURE B.4-2

REDUCED FLOW AREA IN PERIPHERAL ASSEMBLY
ASSEMBLY FLOW RATE



[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

FIGURE B.4-3

REDUCED FLOW AREA IN PERIPHERAL ASSEMBLY
UNDEFORMED ASSEMBLY
PEAK CLAD TEMPERATURE

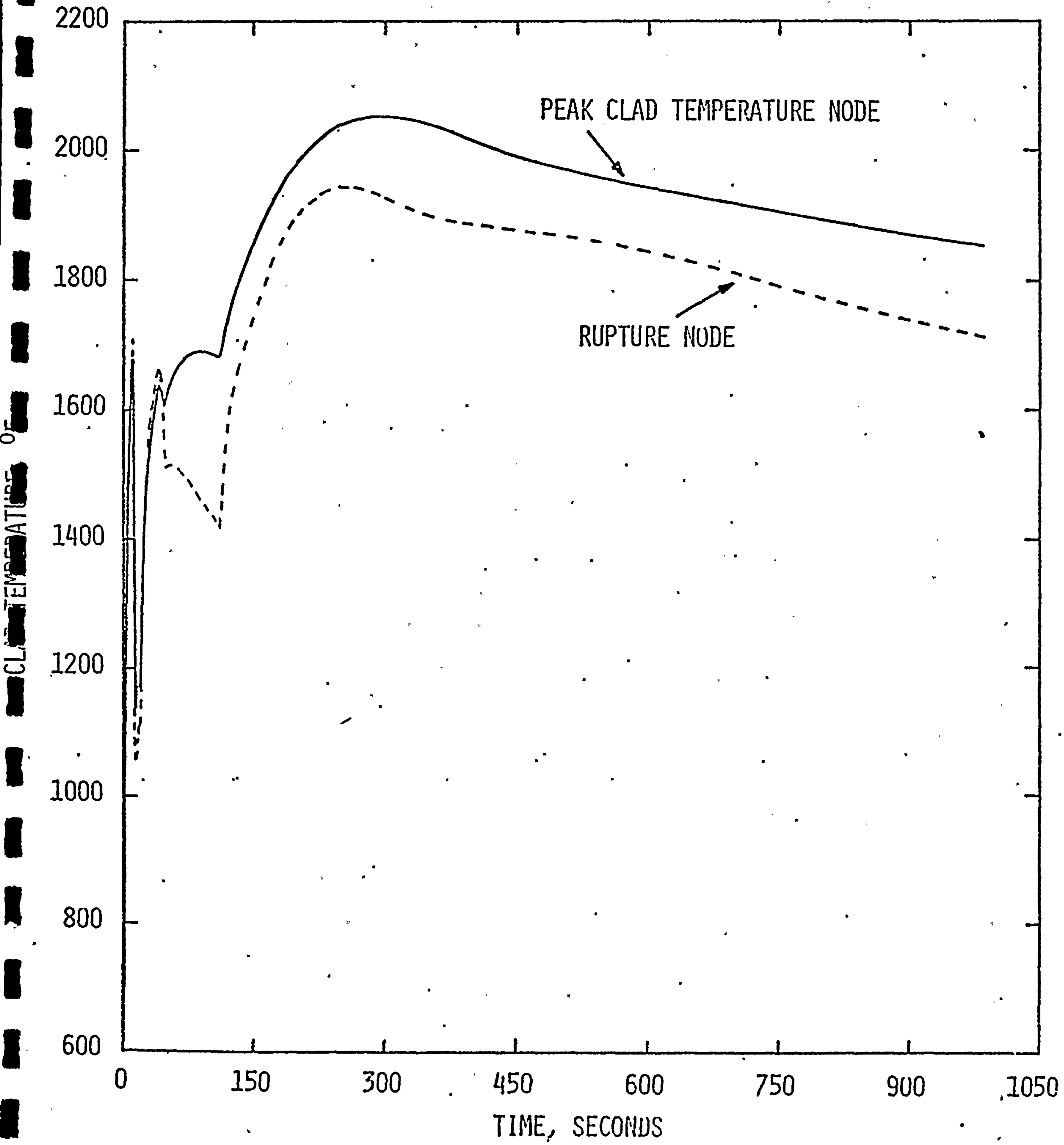


FIGURE B.4-4

REDUCED FLOW AREA IN PERIPHERAL ASSEMBLY
UNDEFORMED ASSEMBLY
PEAK LOCAL CLAD OXIDATION

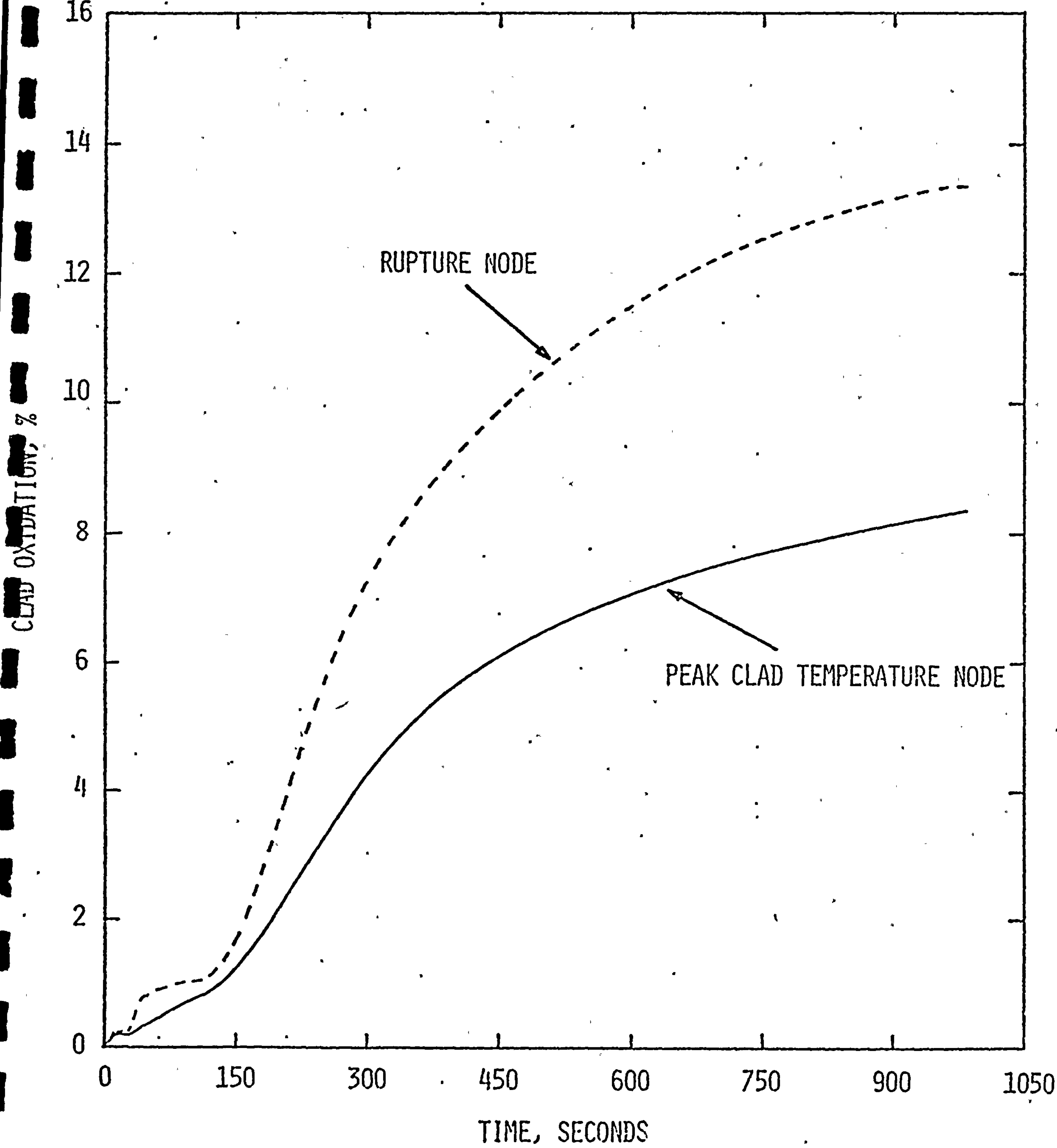


FIGURE B.4-5

REDUCED FLOW AREA IN PERIPHERAL ASSEMBLY

20% FLOW AREA REDUCTION

PEAK CLAD TEMPERATURE

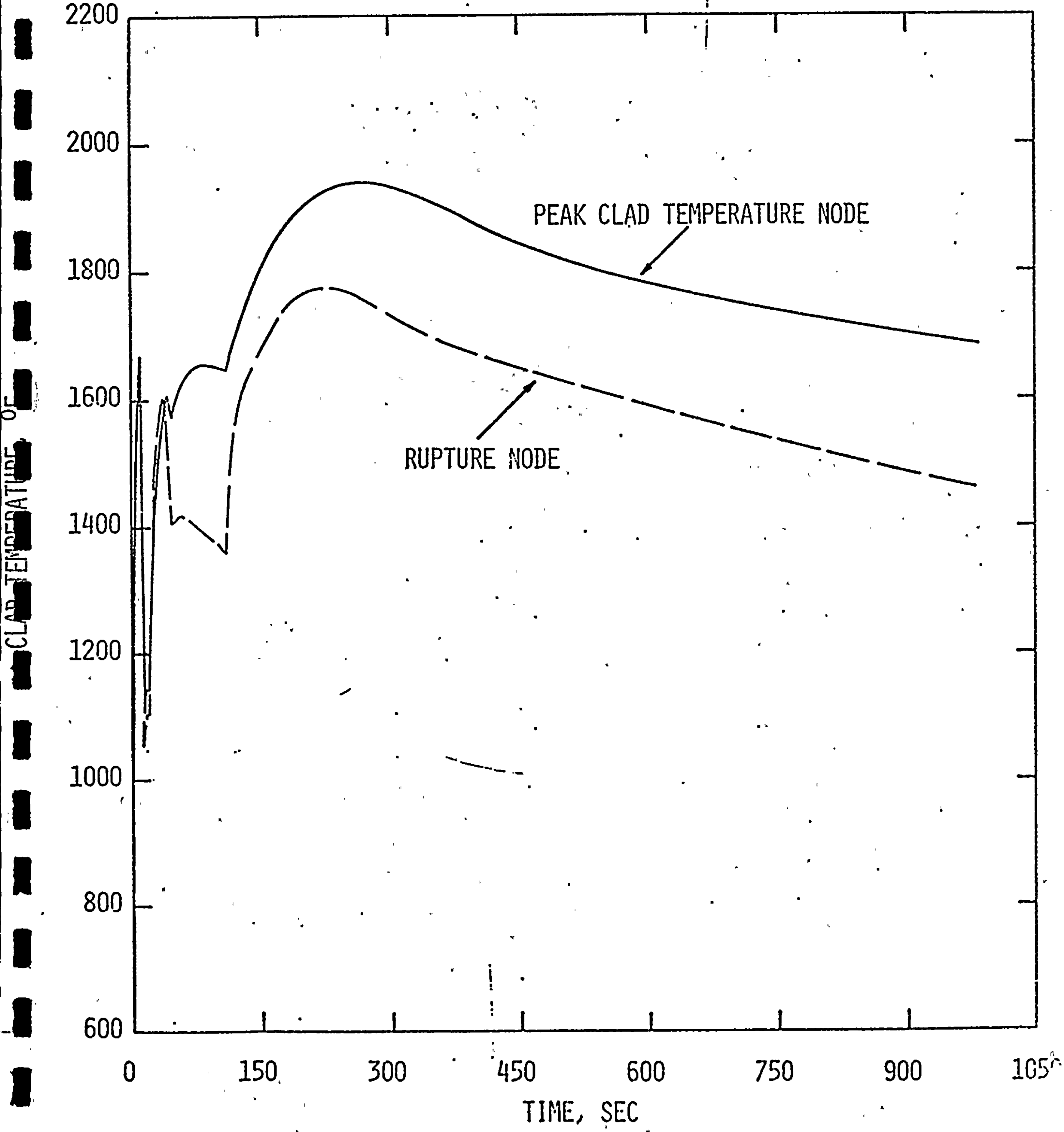


FIGURE B.4-6

REDUCED FLOW AREA IN PERIPHERAL ASSEMBLY

20% FLOW AREA REDUCTION

PEAK LOCAL CLAD OXIDATION

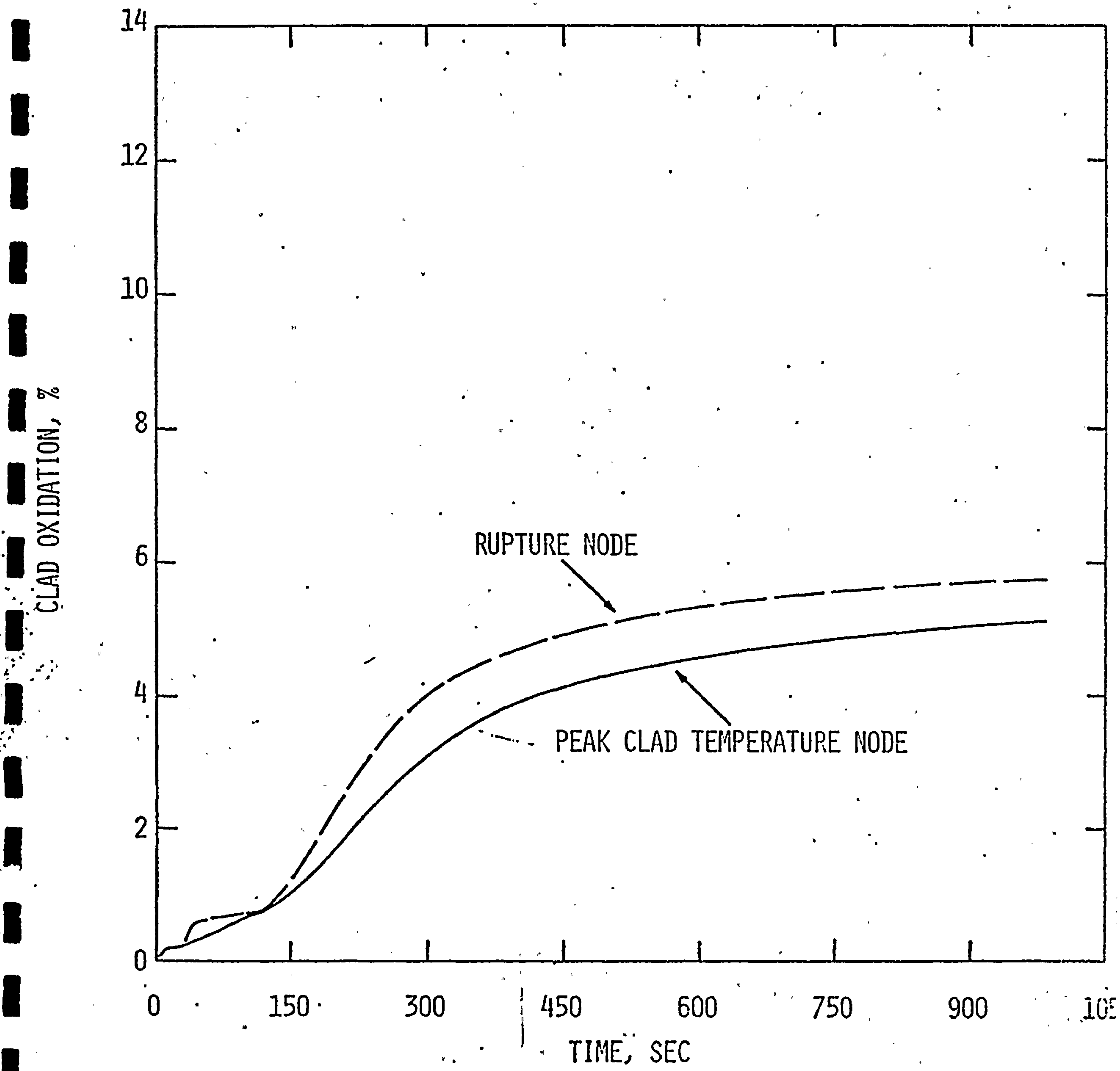


FIGURE B.4-7

REDUCED FLOW AREA IN PERIPHERAL ASSEMBLY
35% FLOW AREA REDUCTION
PEAK CLAD TEMPERATURE NODE

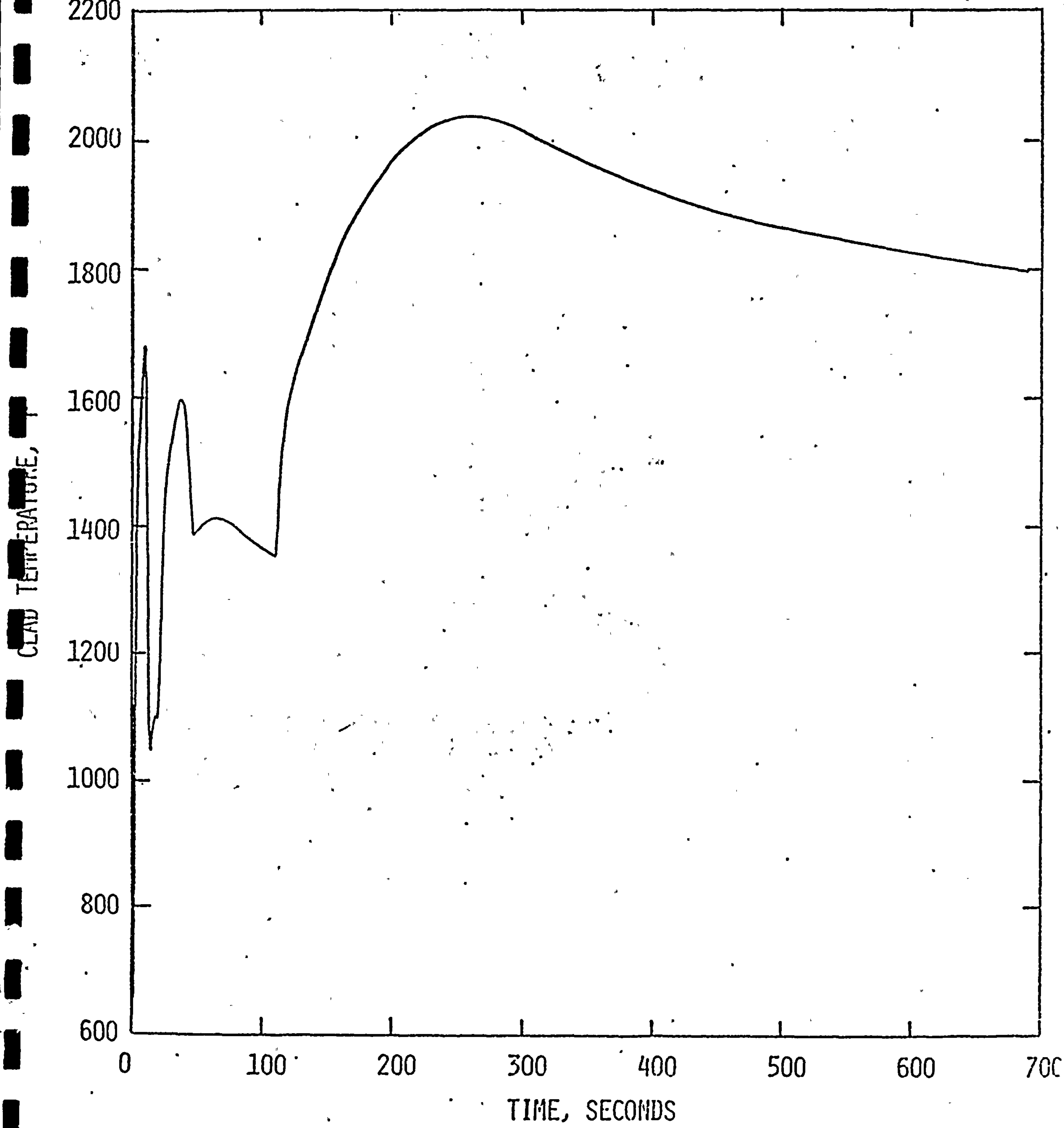
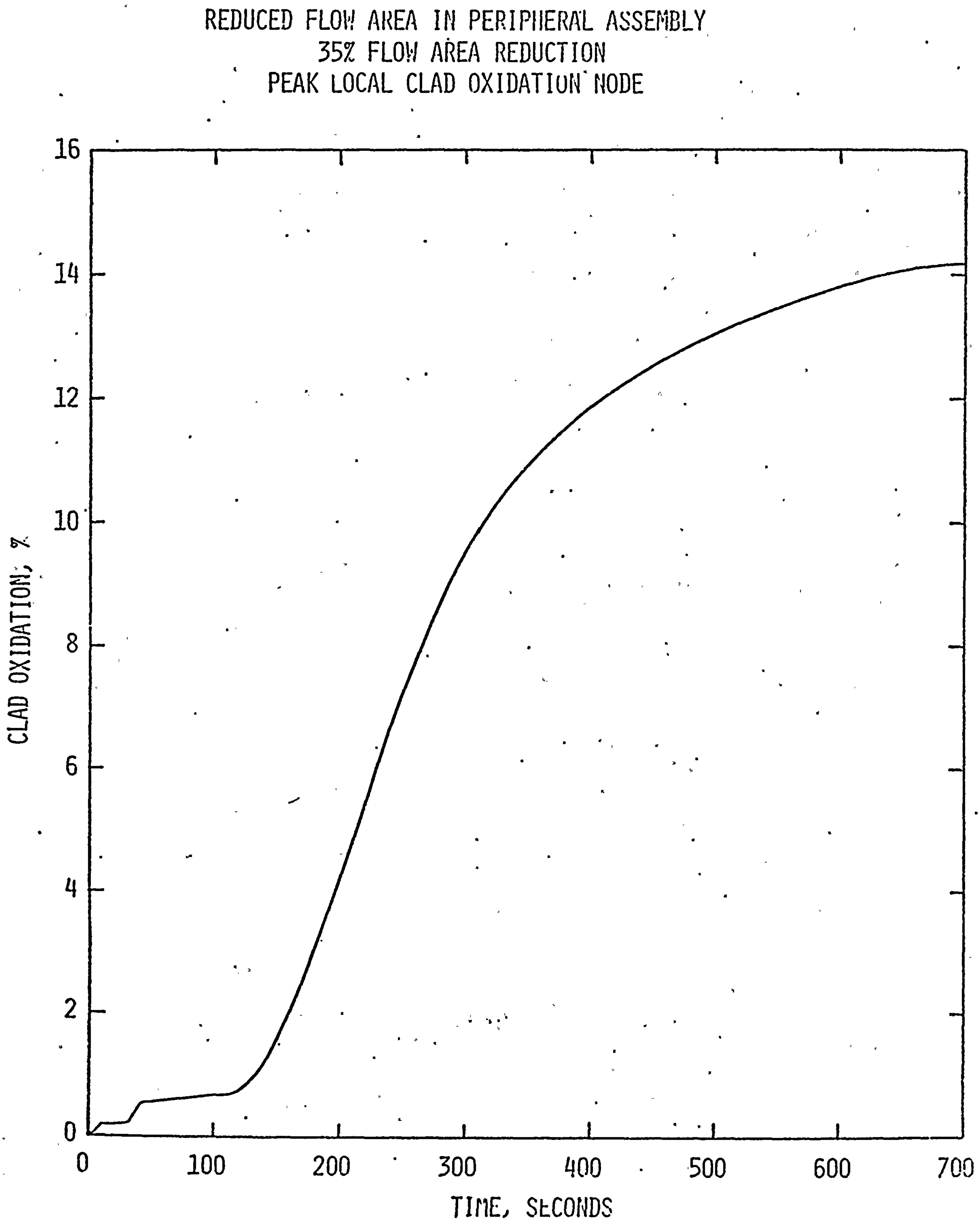


FIGURE B.4-8


REDUCED FLOW AREA IN PERIPHERAL ASSEMBLY
35% FLOW AREA REDUCTION
PEAK LOCAL CLAD OXIDATION NODE
CLAD OXIDATION, %
0
2
4
6
8
10
12
14
16
0
100
200
300
400
500
600
700
TIME, SECONDS