XN-NF-84-72
SUPPLEMENT 2

H. B. ROBINSON UNIT 2
LARGE BREAK LOCA-ECCS ANALYSIS WITH INCREASED ENTHALPY RISE FACTOR: K(Z) CURVE

AUGUST 1984

RICHLAND WA 99352

EXXON NUCLEAR COMPANY, INC.

XN-NF-84-72
Supplement 2

Issue Date: 8/30/84

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WITH INCREASED ENTHALPY RISE FACTOR: K(Z) CURVE

Prepared by: T. Tahvili 8/29/84
T. Tahvili
PWR Safety Analysis

Reviewed by: W V Kayser 8/29/84
W. V. Kayser, Manager
PWR Safety Analysis

Concur: J.C. Chandler 8/29/84
J. C. Chandler, Lead Engineer
Reload Fuel Licensing

Approve: R.B. Stout 30 AUG 84
R. B. Stout, Manager
Licensing & Safety Engineering

Approve: George A. Sofer 30 AUG 84
G. A. Sofer, Manager
Fuel Engineering & Technical Services

gf

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1.0 INTRODUCTION

LOCA ECCS analyses were completed by Exxon Nuclear Company (ENC) and documented in XN-NF-84-72[1] in July 1984 and XN-NF-84-72, Supplement 1[2] in August 1984 for H.B. Robinson Unit 2. These analyses were performed as a result of the decision by Carolina Power & Light (CP&L) in 1983 to: (1) replace the H.B. Robinson Unit 2 steam generators, (2) implement a low radial leakage fuel management scheme in order to reduce vessel fluences and thereby allevaite concerns about thermal shock, and (3) to increase the peak assembly discharge exposure for H.B. Robinson fuel to 44 MWD/kgU (49 MWD/kGU peak pellet). To implement the low radial leakage fuel management scheme, the total nuclear enthalpy rise ($F^T_{\Delta H}$) was increased to 1.65 from 1.55. The analysis was performed with a linear heat generation rate (LHGR), including the 1.02 factor for power uncertainty, of 14.16 kW/ft, corresponding to a total power peaking of 2.32 (F^T_Q). The analysis supported operation of the H.B. Robinson Unit 2 reactor at 100% power (2300 MWt) with up to 6% steam tube plugging. The limiting break was identified to be a guillotine break with a discharge coefficient of 0.8 (0.8 DECLG).

This supplement documents results of large break LOCA ECCS calculations performed to determine the permissible limits in linear heat generation rate versus axial location, i.e., the K(Z) curve. The small break portion of the K(Z) curve is based upon results of analyses performed by ENC in 1975.[3] The results of the large break calculations are presented in Section 3.0.

2.0 SUMMARY

The calculational basis and results of the K(Z) determination are presented in Table 2.1. The results of the analysis satisfy the Acceptance Criteria as presented in 10 CFR 50.46, and therefore support operation of H.B. Robinson Unit 2 with a radial peaking corresponding to $F_{\Delta H}$ of 1.65. Two K(Z) curves were determined: the first curve is applicable for fuel rod exposures less than 9 MWD/kgU, and the second curve is applicable for fuel rod exposures greater than 9 MWD/kgU. The reduction in fuel average temperatures at high exposures results in higher allowed LHGRs at the higher fuel rod exposures. The K(Z) curves are given in Figure 2.1. The small break portion of the curve is drawn to provide an equivalent LHGR at the top of the core to that previously analyzed and documented in Reference 3.

Table 2.1 H.B. Robinson Unit 2 K(Z) Determination Results

Calculational Basis

License Core Power, MWt	2300
Power Used for Analysis, MWt**	2346
Break Size, DECLG	0.8
Enthalpy Rise, Nuclear, $F^T_{\Delta H}$	1.65
Steam Generator Tube Plugging, %	6.00

	Peaked X/L = 0.50	Peaked X/L = 0.75	Peaked X/L = 0.75
Hot Rod Exposure Range, MWD/kgU	0 - EOL	0 - 9	9 - EOL
Peak Linear Heat Generation Rate (LHGR)**	14.16	12.39	12.57
Total Peaking Factor, F^T_Q	2.32	2.03	2.06
Peak Cladding Temperature, ^oF	2042	2197	2183
Peak Temperature Location, ft	6.0	10.75	10.75
Local Zr/H_2O Location, ft	6.0	10.75	10.75
Local Zr/H_2O Reaction (Max.), %*	4.65	6.19	5.89
Total Zr/H_2O	<1%	<1%	<1%
Hot Rod Burst Time, sec	39.9	49.37	51.57
Hot Rod Burst Location, ft	6.0	9.0	9.0

* Computer value at 380 seconds.
** Including 1.02 factor for power uncertainties.

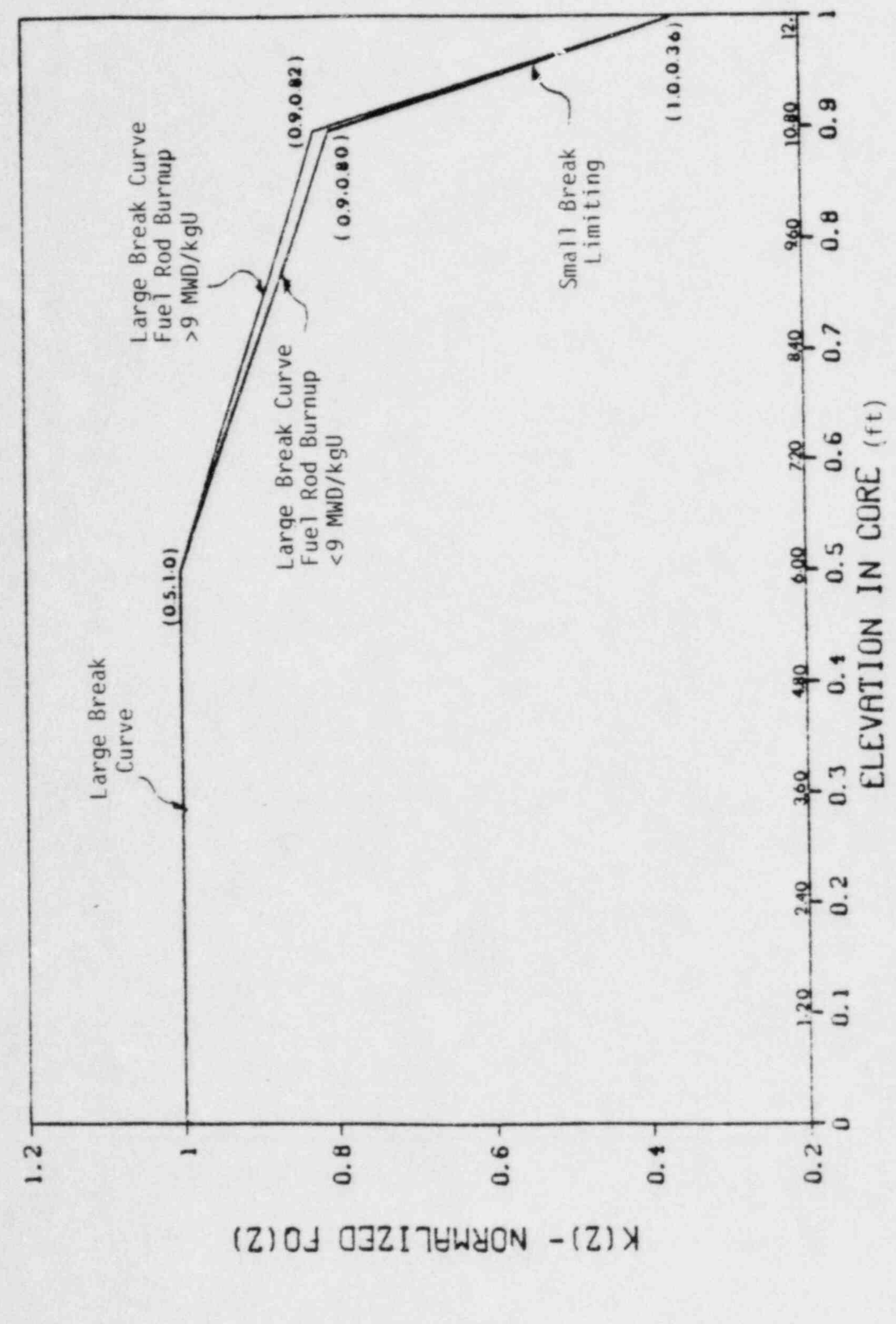

Figure 2.1 Normalized Axial Dependence Factor for $F_Q^T = 2.32$ versus Elevation for $F_{\Delta H} = 1.65$

3.0 K(Z) DETERMINATION

The K(Z) curve defines the limit on linear heat generation rate (LHGR) versus axial elevation in the core. The LHGRs are reduced at the top of the core to offset the effect on peak cladding temperature (PCT) of reduced coolant heat transfer from (1) the short uncovery periods at the top of the core during small break LOCAs, and (2) reduced coolant heat capacity at the top of the core during the reflood period of the large break LOCAs.

The current analysis used the EXEM/PWR LOCA ECCS models[4] with operating conditions and fuel parameters given in Tables 3.1 and 3.2. The operating conditions and fuel parameters are identical to those used in the XN-NF-84-72 analysis. Boundary condition input from the XN-NF-84-72 blowdown, refill and reflood analysis was used to drive the RELAP4/hot channel and TOODEE2/hot rod heatup calculations.

The analyses were performed with a center peaked chopped cosine axial power distribution and two skewed power distributions peaked at three-quarters (X/L=0.75) of core height. The axial power shapes used in the analysis are given in Figures 3.1 to 3.3. The axial power profiles were used to define the large break portion of the K(Z) curve (Figure 2.1). The top peaked profile defined the K(Z) curve above three-quarters of core height (large break portion of K(Z) curve only), while the chopped cosine profile defined the K(Z) curve at X/L=0.5. Between X/L of 0.5 and 0.75, the allowable LHGR is linearly interpreted between the values given at X/L of 0.5 and 0.75. The K(Z) curve in the top tenth of the core is defined by the LHGRs used in the small break analysis performed by ENC in 1975.[3]

3.1 RESULTS OF K(Z) DETERMINATION

The results of the K(Z) determination are summarized in Table 2.1 for the limiting break, the 0.8 DECLG break. RELAP4/hot channel and TOODEE2/hot rod heatup calculations were performed. The results are presented in Figures 3.4 to 3.10 for the center peaked profile. The results are applicable for all exposures. Results for the skewed profile are presented in Figures 3.11 to 3.17 and 3.18 to 3.24 for the less than 9 MWD/kgU and greater than 9 MWD/kgU peak rod exposure cases, respectively. Time zero on all plots correspond to the time of break initiation.

Table 3.1 H. B. Robinson Unit 2 System Data

Primary Heat Output, MWt	2346*
Primary Coolant Flow, lbm/hr	100.3×10^6
Primary Coolant Volume, ft^3	9768**
Operating Pressure, psia	2,250
Inlet Coolant Temperature, ^oF	546.2
Reactor Vessel Volume, ft^3	3660
Pressurizer Volume, Total, ft^3	1300
Pressurizer Volume, Liquid, ft^3	780
Accumulator Volume, Total, ft^3 (each of three)	1200
Accumulator Volume, Liquid, ft^3	825
Accumulator Trip Point Pressure, psia	615
Steam Generator Heat Transfer Area, ft^2 (one)	40,859**
Steam Generator Secondary Flow, lbm/hr (one)	[illegible]$.37 \times 10^6$
Steam Generator Secondary Pressure, psia	800
Reactor Coolant Pump Head, ft	264
Reactor Coolant Pump Speed, rpm	1180
Moment of Inertia, lbm-ft^2/rad	70,000
Cold Leg Pipe, I.D., in	27.5
Hot Leg Pipe, I.D., in	29.0
Pump Suction, Pipe, I.D., in	31.09

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* Primary Heat Output used in RELAP4-EM Model = 1.02 x 2300 = 2346 MWt.

** Includes 6% SG tube plugging.

Table 3.2 Fuel Design Parameters

Parameter	ENC Fuel
Cladding, O.D., in	0.424
Cladding, I.D., in	0.364
Cladding Thickness, in	0.030
Pellet O.D., in	0.3565
Diametral Gap, in	0.0075
Pellet Density, % TD	94.0
Active Fuel Length, in	144
Enriched UO_2, in	132
Upper Blanket, in	6.0
Lower Blanket, in	6.0
Cell Water/Fuel Ratio	1.76
Rod Pitch	0.563

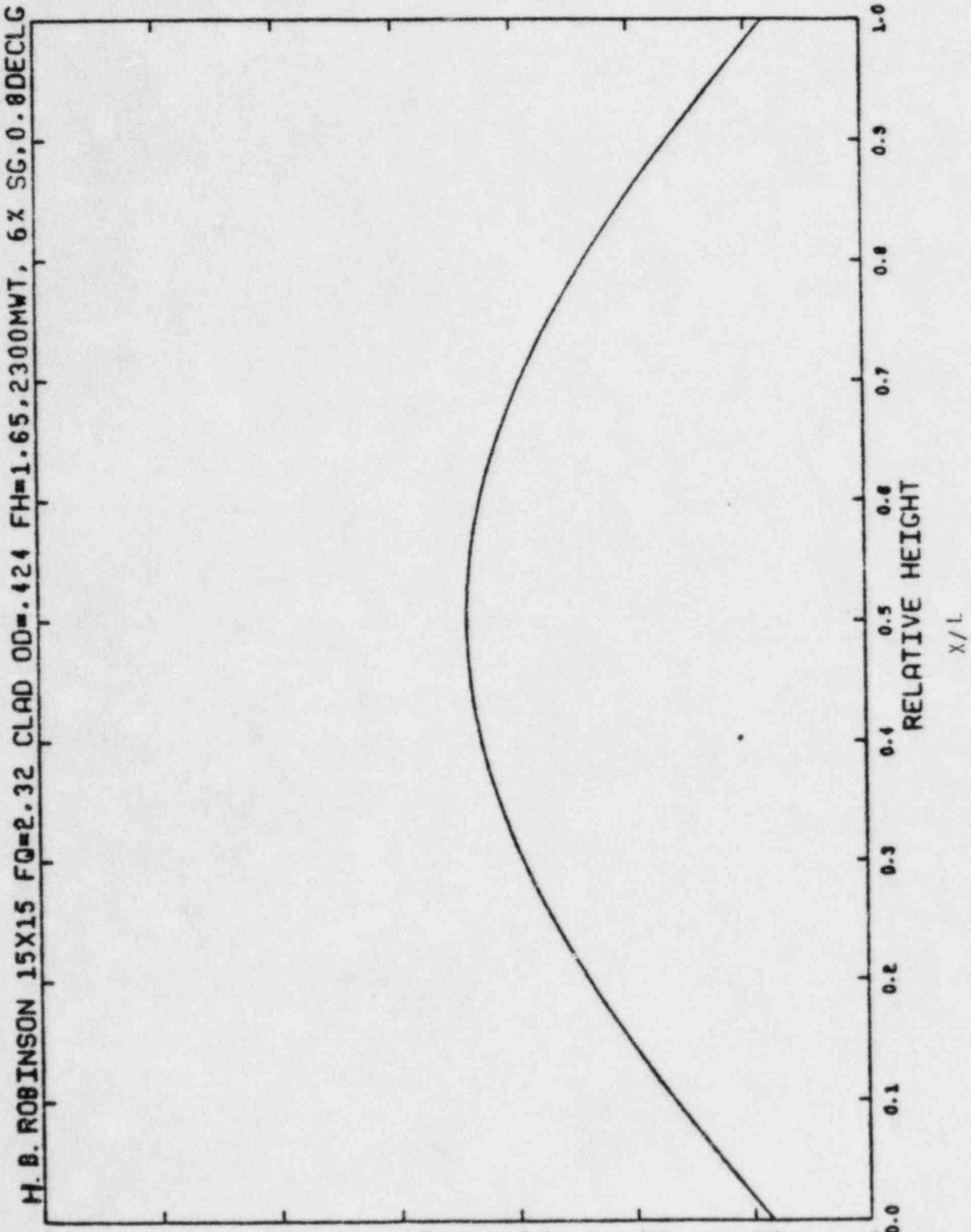

Figure 3.1 Axial Peaking Factor vs Rod Length, 0.8 DECLG Break, Peaked at X/L=0.50, 0-EOL Exposure

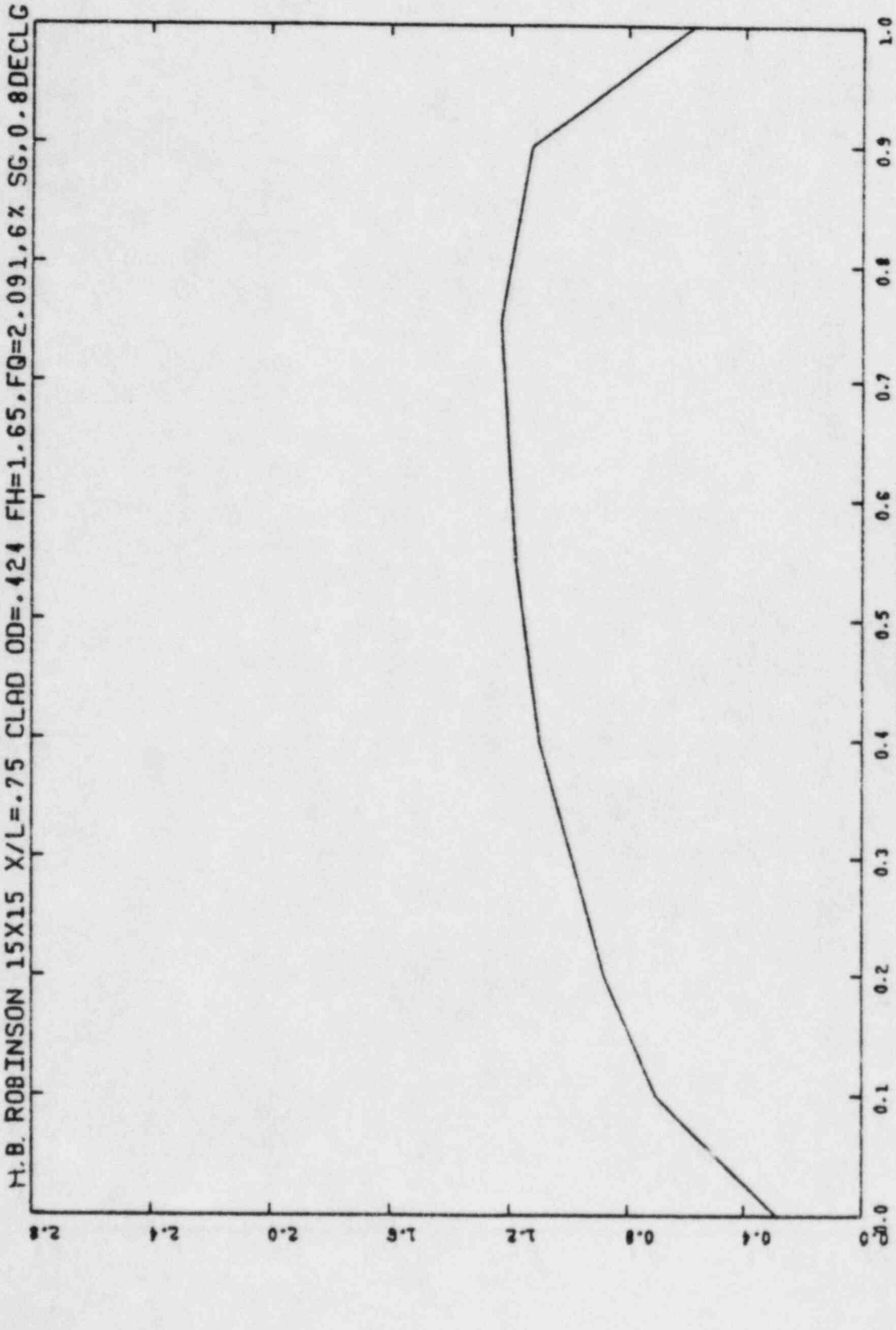

Figure 3.2 Axial Peaking Factor vs Rod Length, 0.8 DECLG Break, Peaked at X/L=0.75, 0-9 MWD/kgU

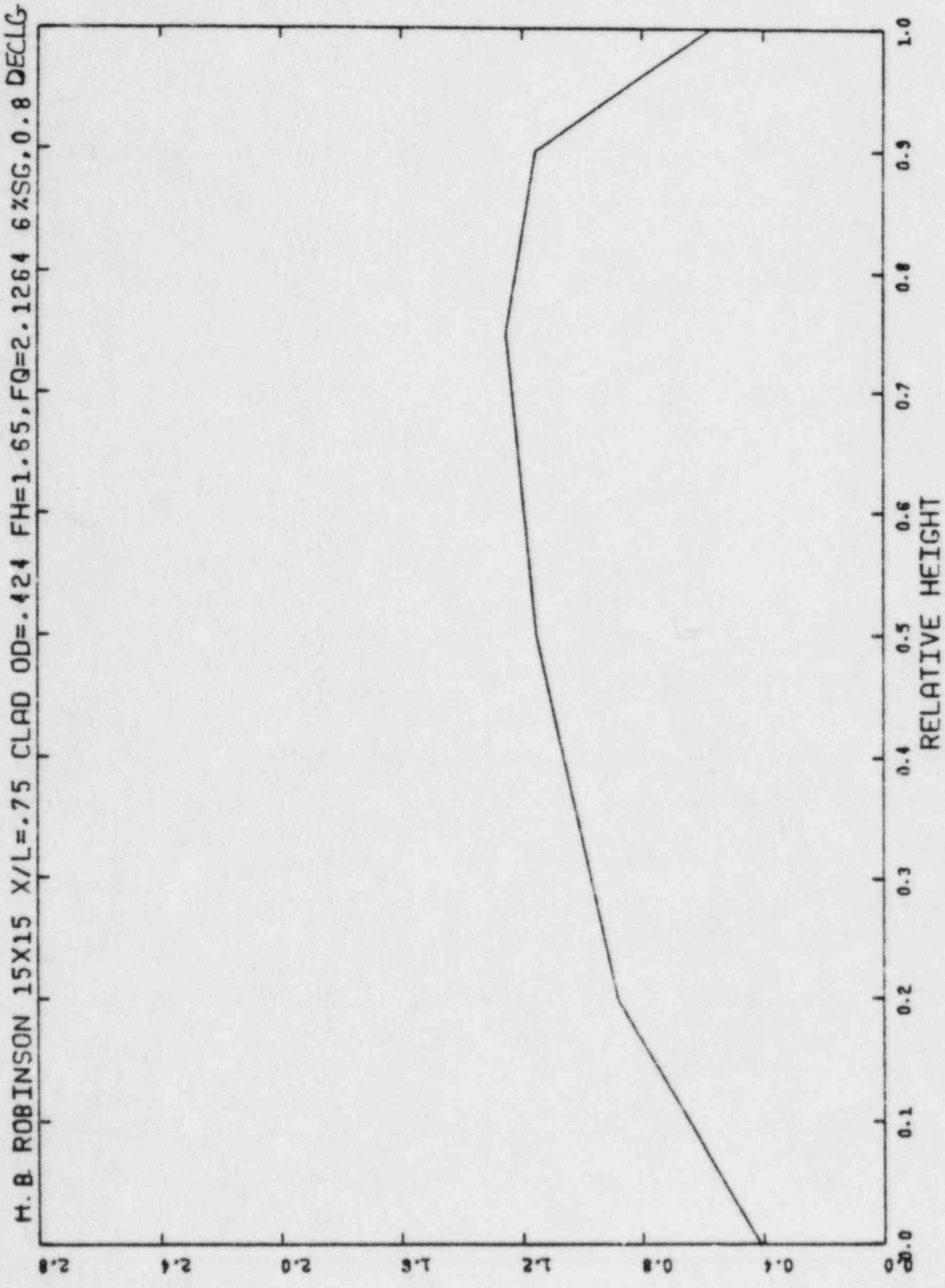

Figure 3.3 Axial Peaking Factor vs Rod Length, 0.8 DECLG Break, Peaked at X/L=0.75, 9-EOL MWD/kgU

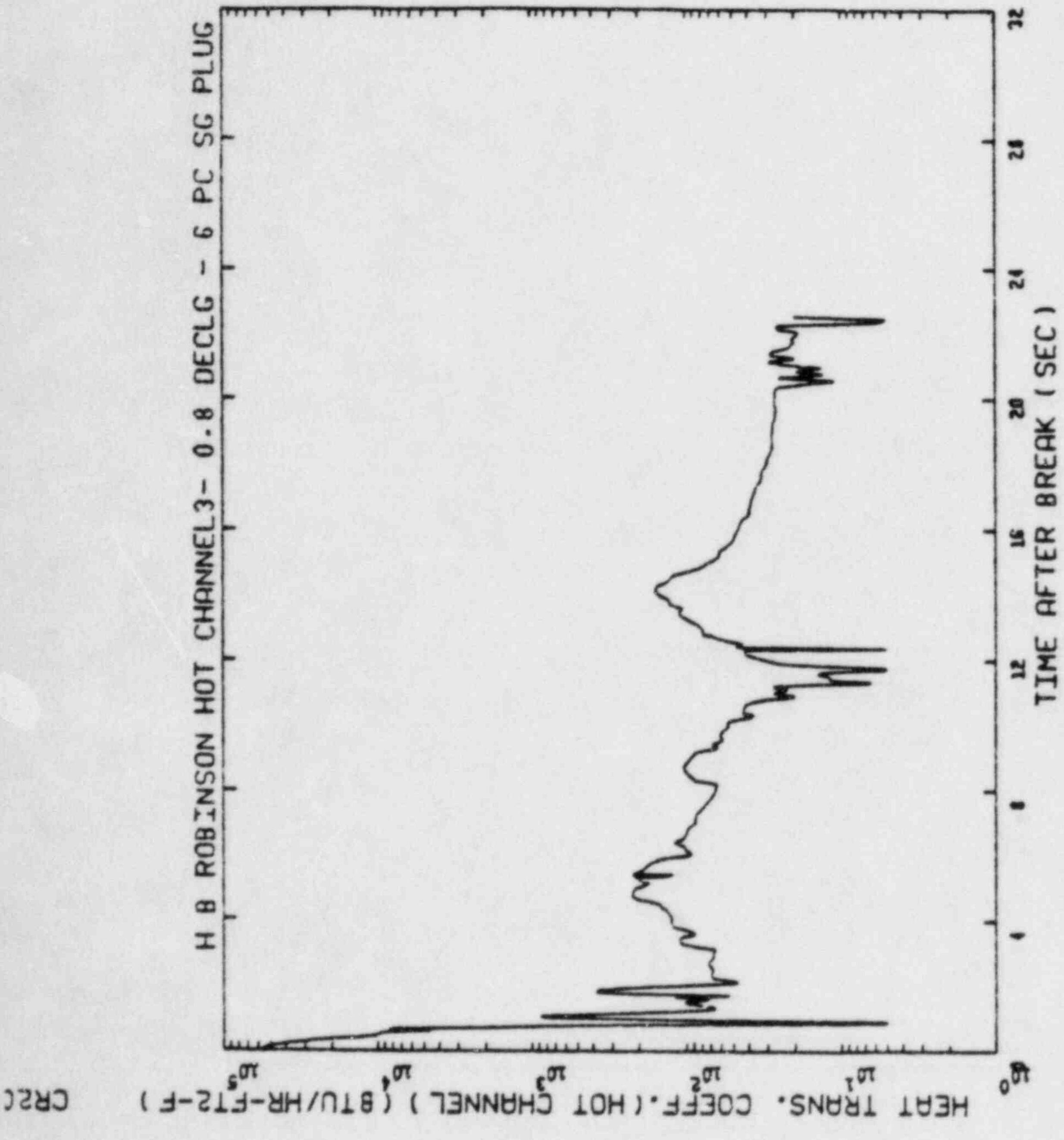

Figure 3.4 Heat Transfer Coefficient During Blowdown Period at PCT Node, 0.8 DECLG Break, X/L=0.50, 0-EOL Exposure

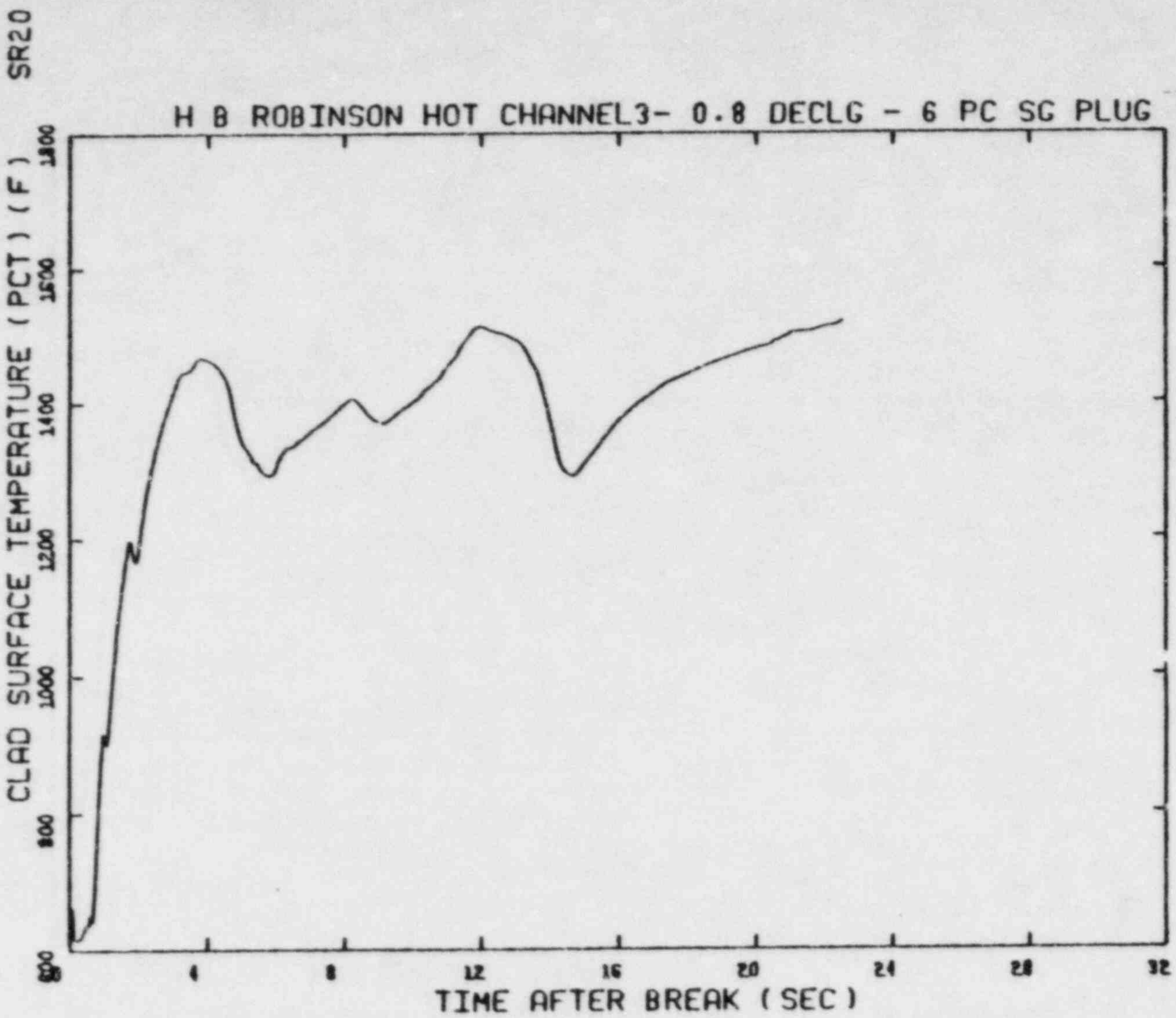

Figure 3.5 Clad Surface Temperature during Blowdown Period
PCT Node, 0.8 DECLG Break, X/L=0.50, 0-EOL Exposure

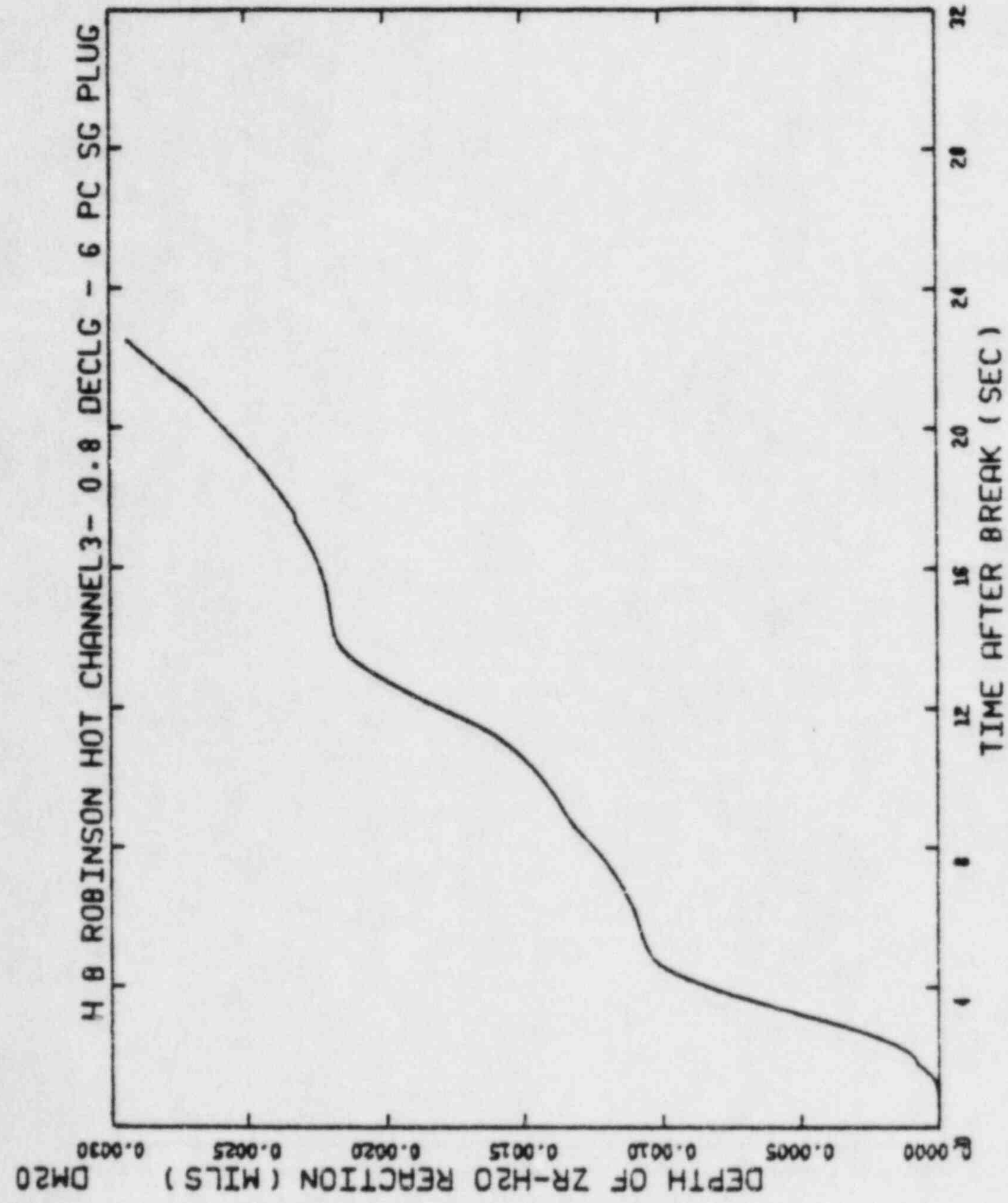

Figure 3.6 Depth of Metal-Water Reaction During Blowdown Period at PCT Node, 0.8 DECLG Break, X/L=0.50, 0-EOL Exposure

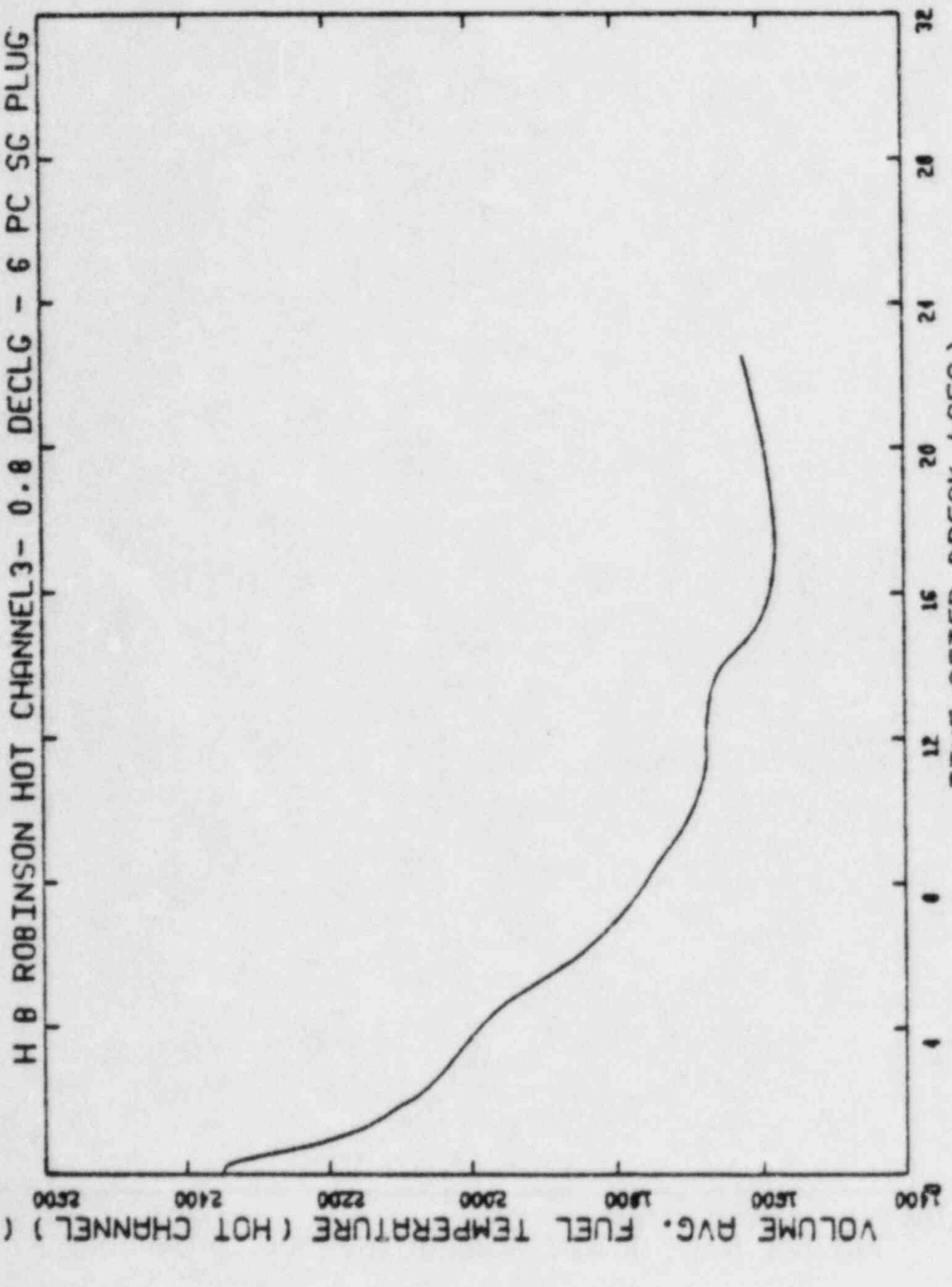

Figure 3.7 Average Fuel Temperature During Blowdown Period at PCT Node, 0.8 DECLG Break, X/L=0.50, 0-EOL Exposure

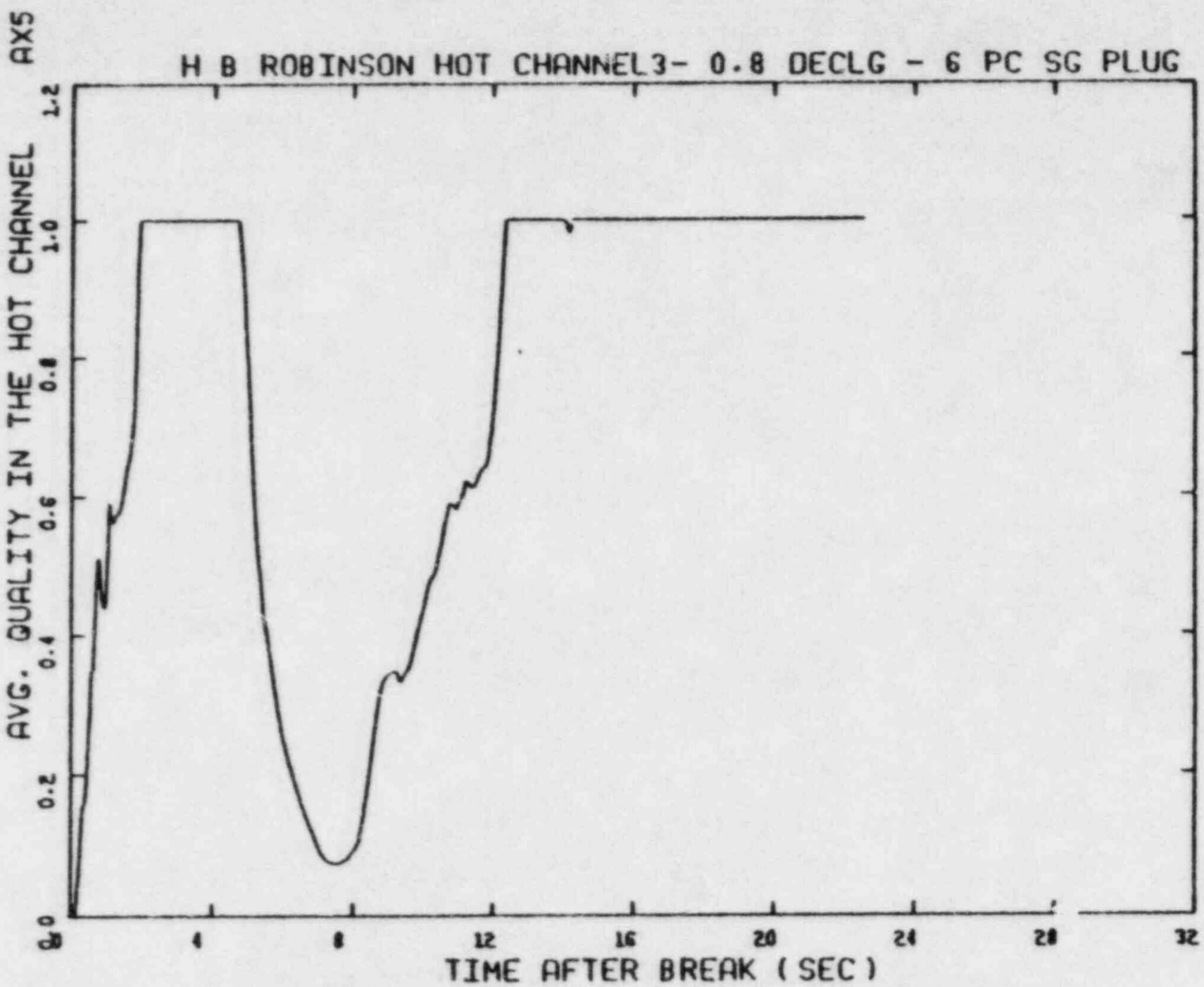

Figure 3.8 Hot Channel Average Quality, Center Volume
0.8 DECLG Break, X/L=0.50, 0-EOL Exposure

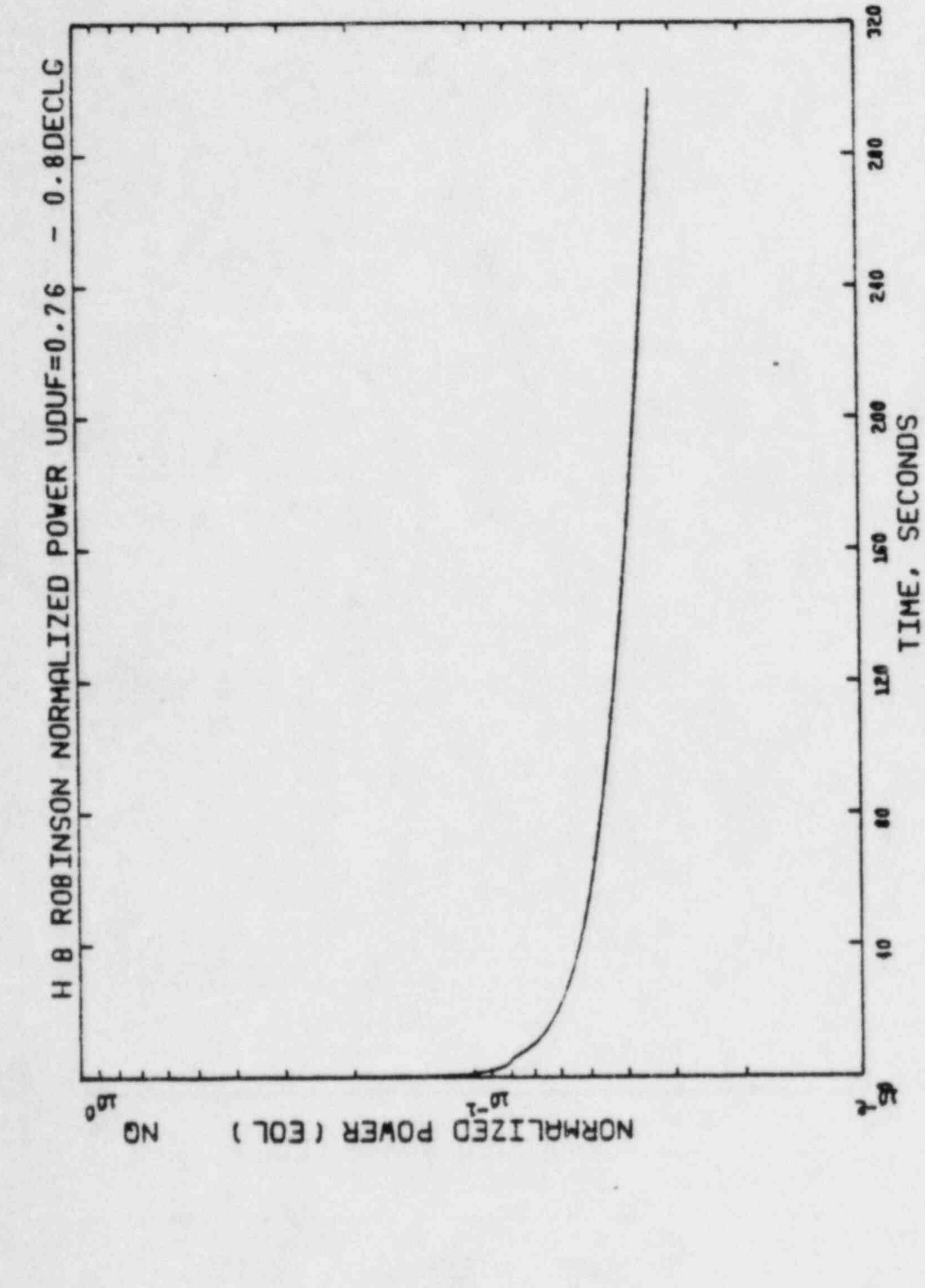

Figure 3.9 Normalized Power, 0.8 DECLG Break, X/L=0.50, 0-EOL Exposure

H.B. ROBINSON UNIT 2 0.8 DECLG BREAK FQ=2.32, FH=1.65 6%SG

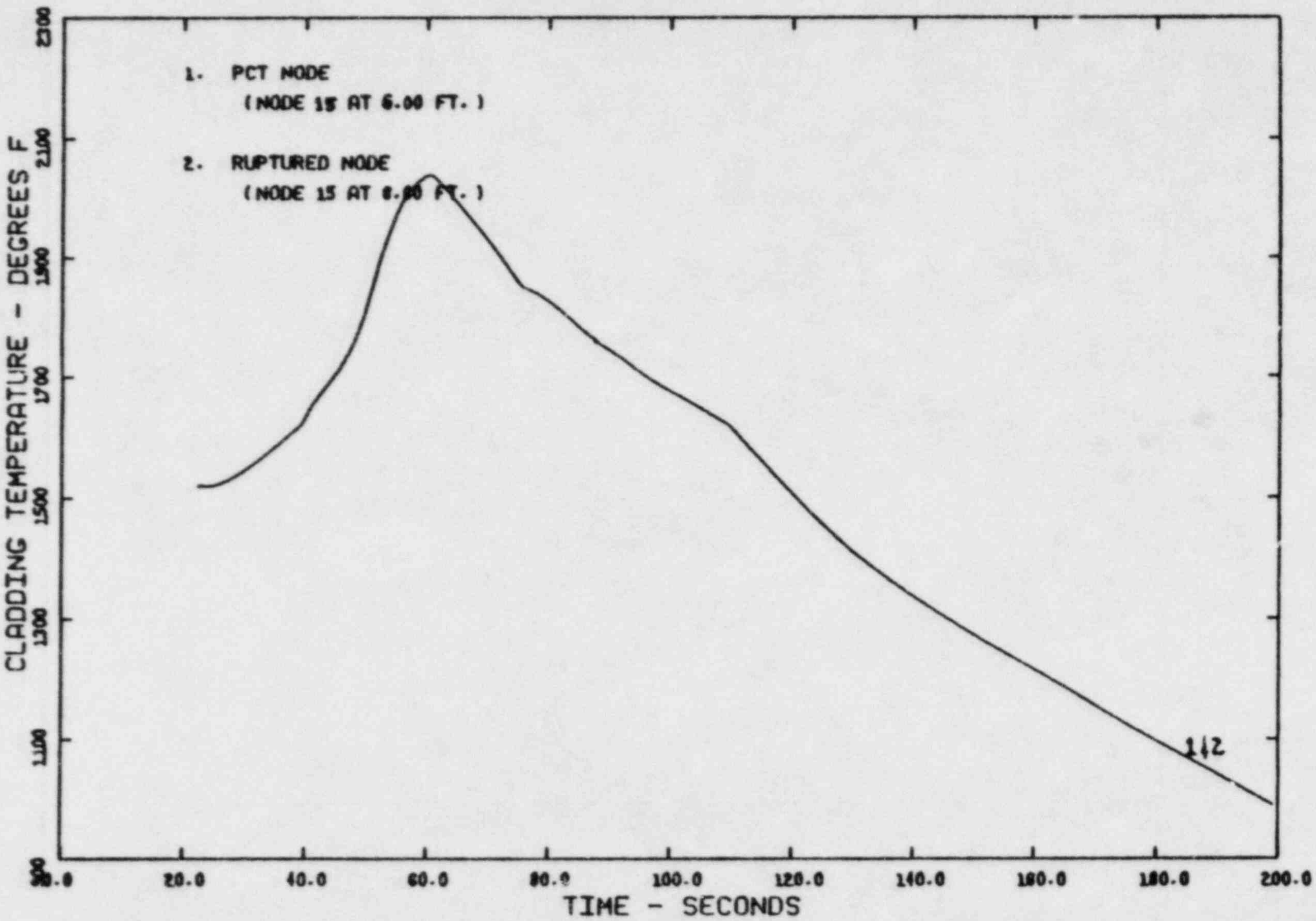

Figure 3.10 TOODEE2 Cladding Temperature vs. Time, 0.8 DECLG Break, X/L=0.50, 0-EOL Exposure

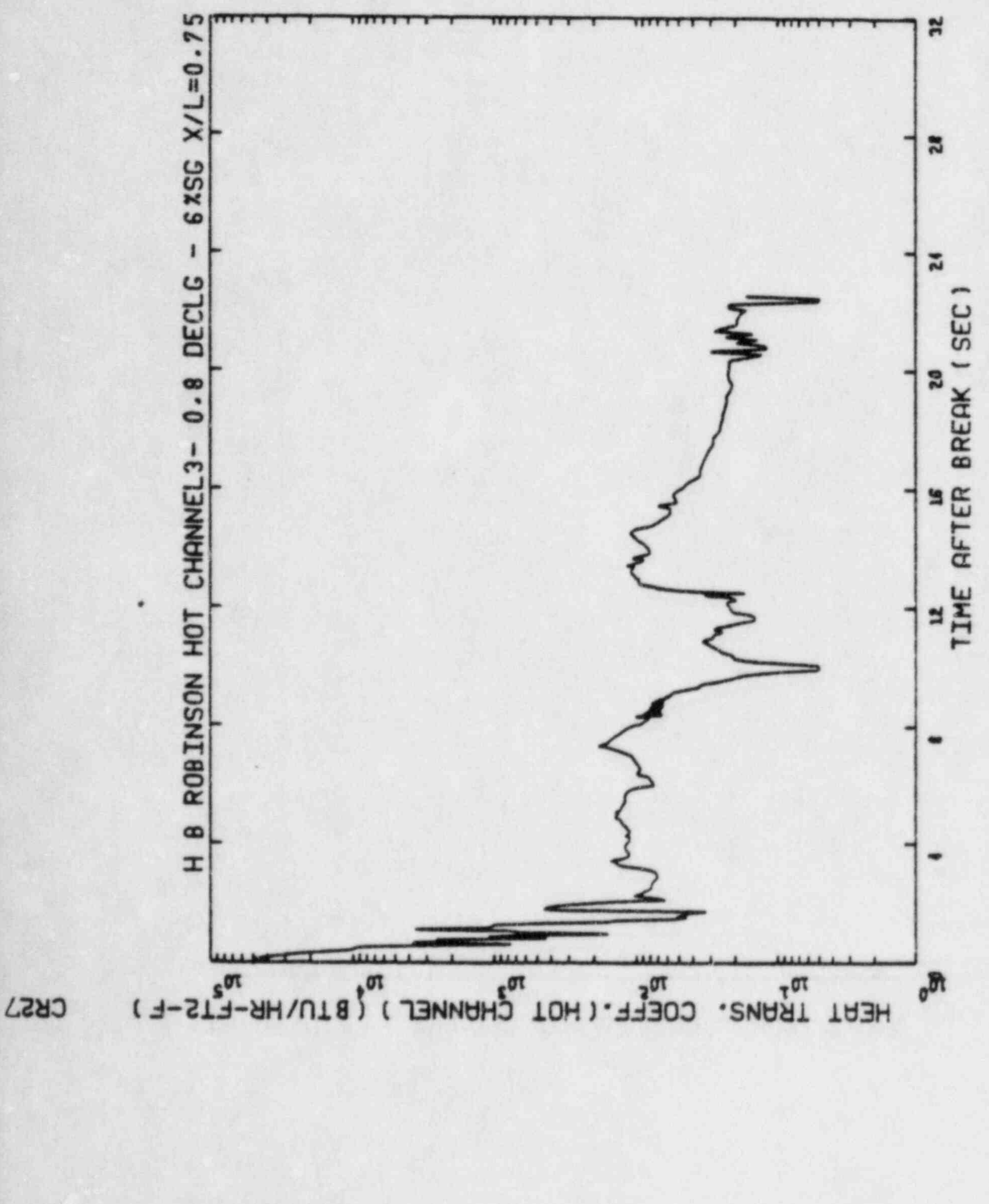

Figure 3.11 Heat Transfer Coefficient During Blowdown Period at PCT Node, 0.8 DECLG Break, X/L=0.75, 0-9 MWD/kgU

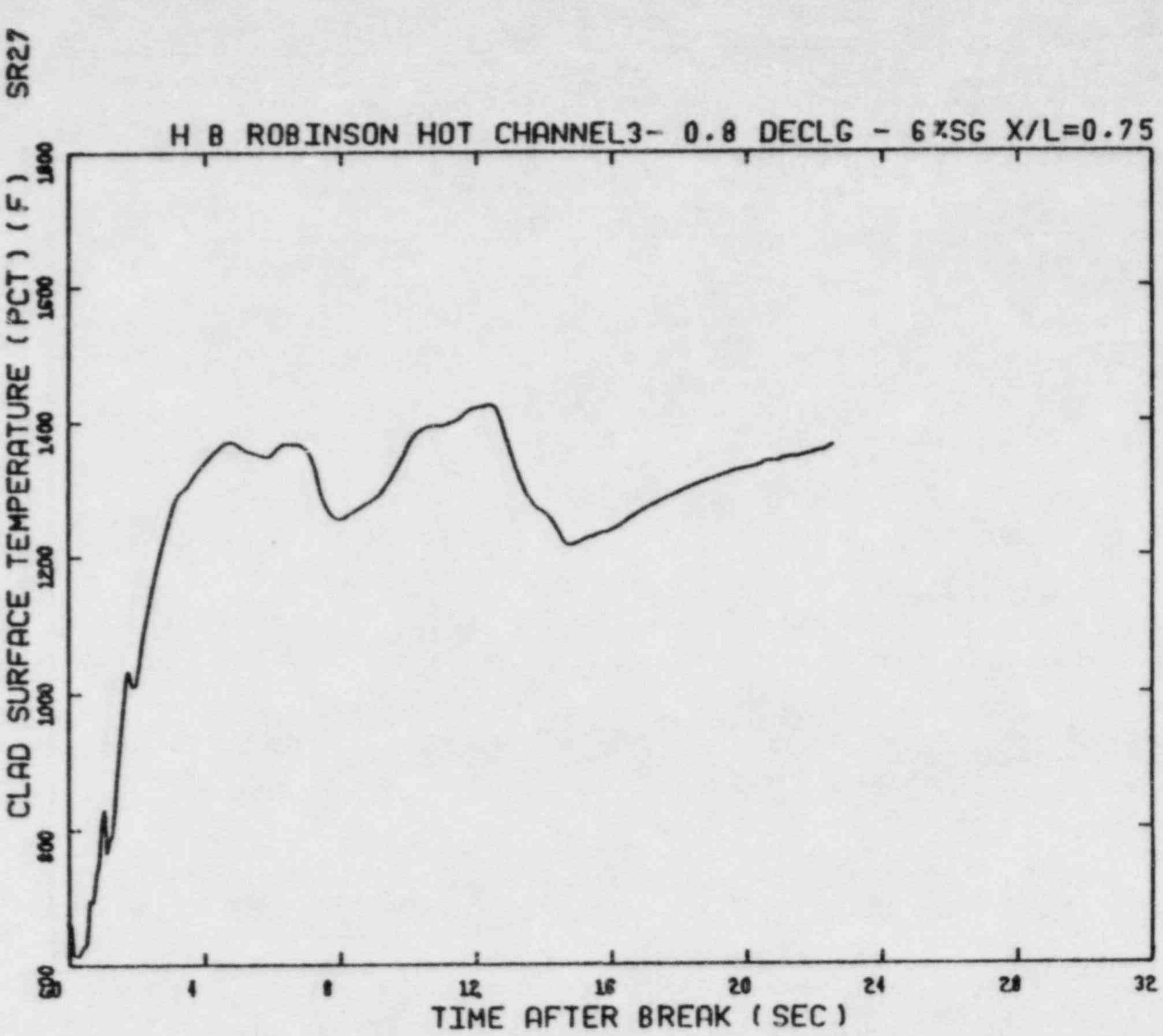

Figure 3.12 Clad Surface Temperature during Blowdown Period PCT Node, 0.8 DECLG Break, X/L=0.75, 0-9 MWD/kgU

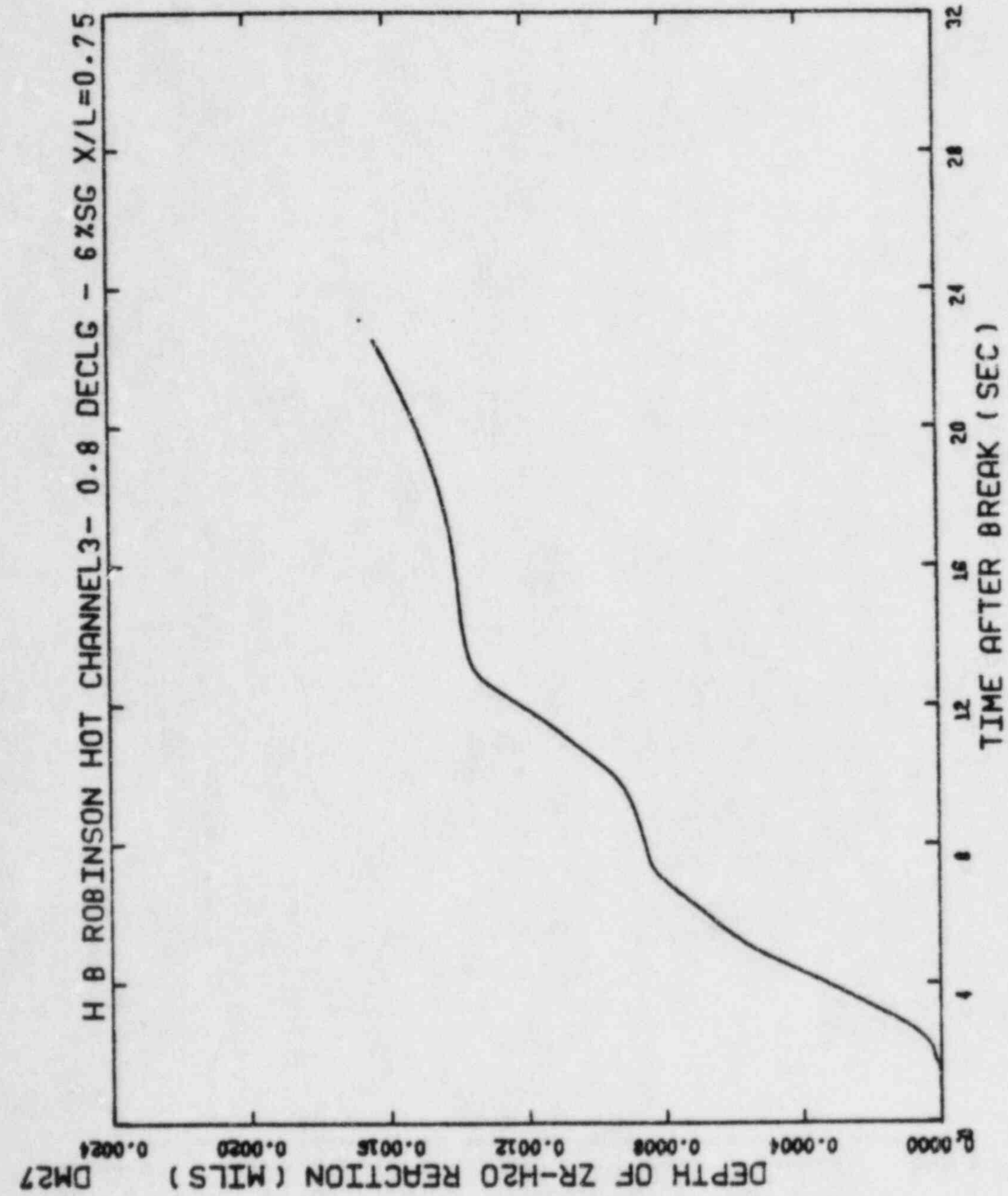

Figure 3.13 Depth of Metal-Water Reaction During Blowdown Period at PCT Node, 0.8 DECLG Break, X/L=0.75, 0-9 MWD/kgU

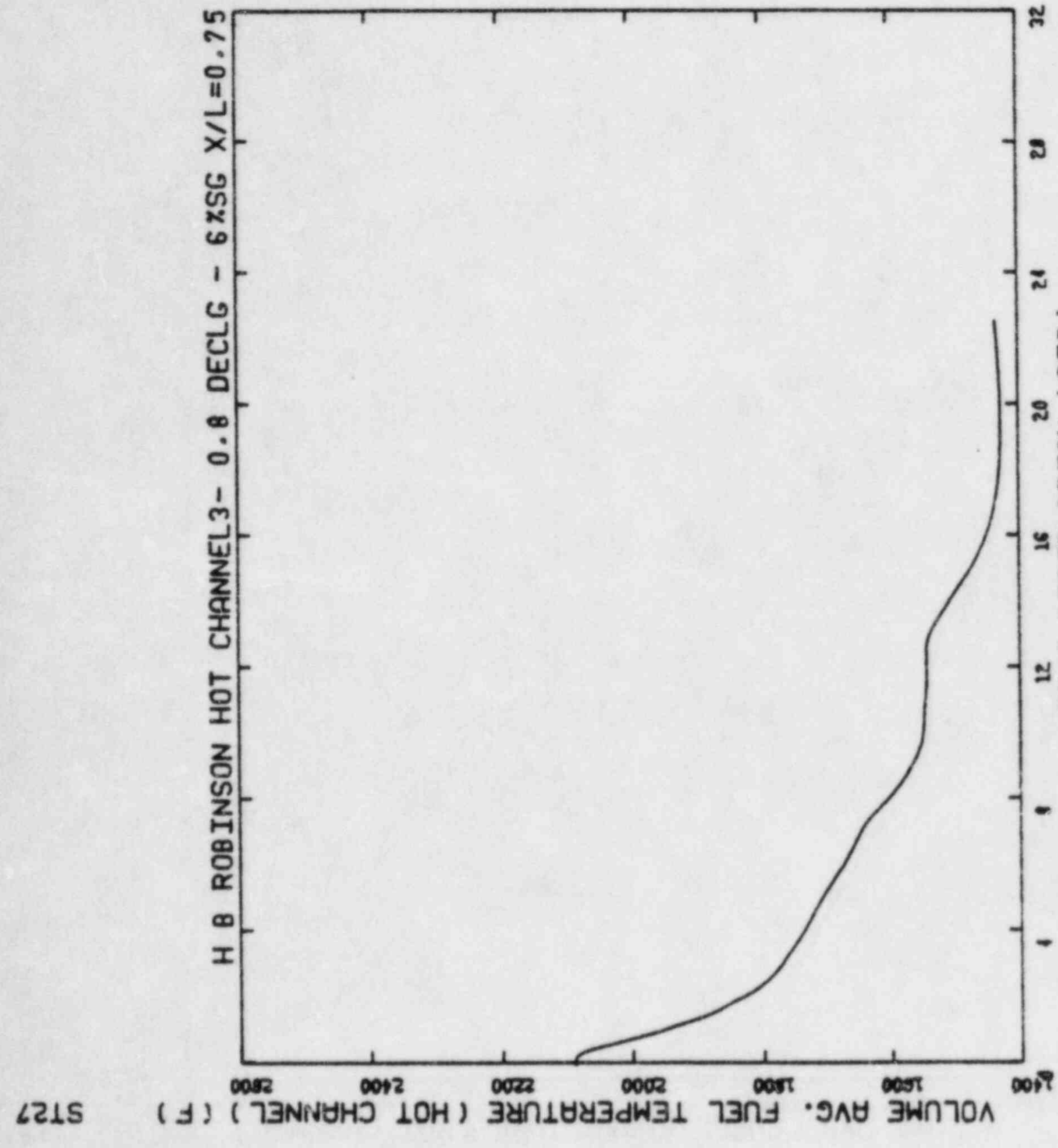

Figure 3.14 Average Fuel Temperature During Blowdown Period at PCT Node, 0.8 DECLG Break, X/L=0.75, 0-9 MWD/kgU

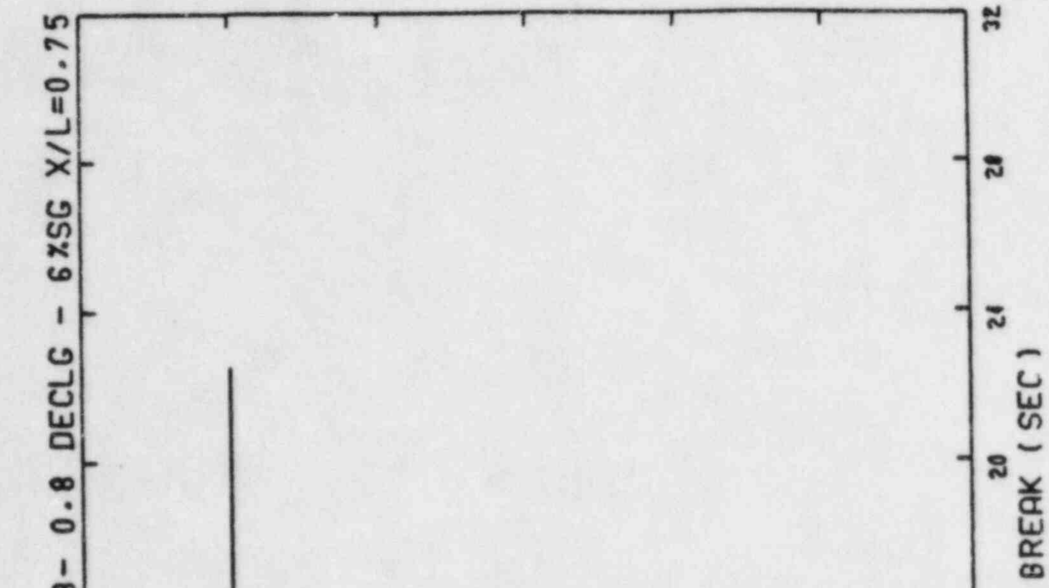

Figure 3.15 Hot Channel Average Quality, Center Volume, 0.8 DECLG Break, X/L=0.75, 0-9 MWD/kgU

Figure 3.16 Normalized Power, 0.8 DECLG Break, X/L=0.75, 0-9 MWD/kgU

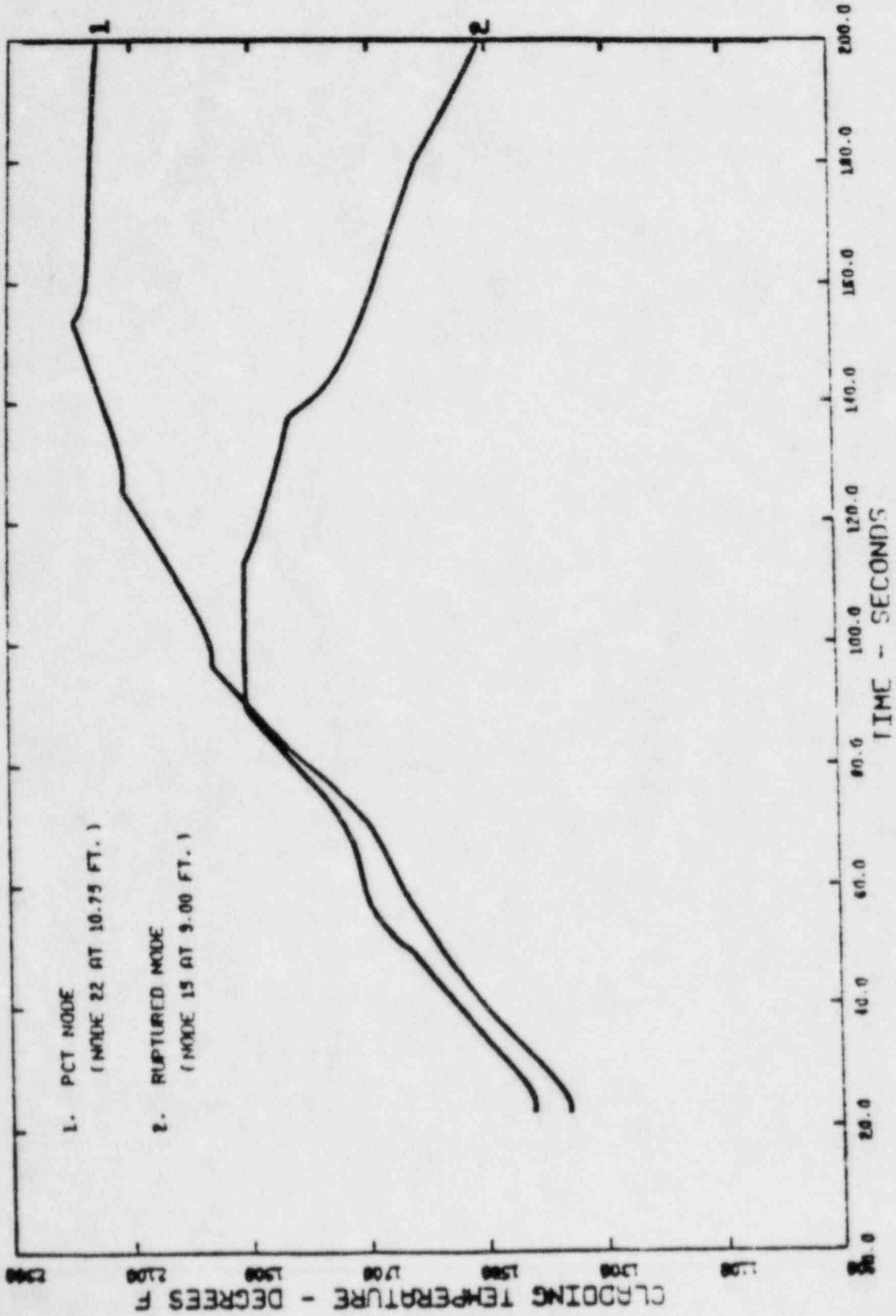

Figure 3.17 TOODEE2 Cladding Temperature vs. Time, 0.8 DECLG Break, X/L=0.75, 0-9 MWD/kgU

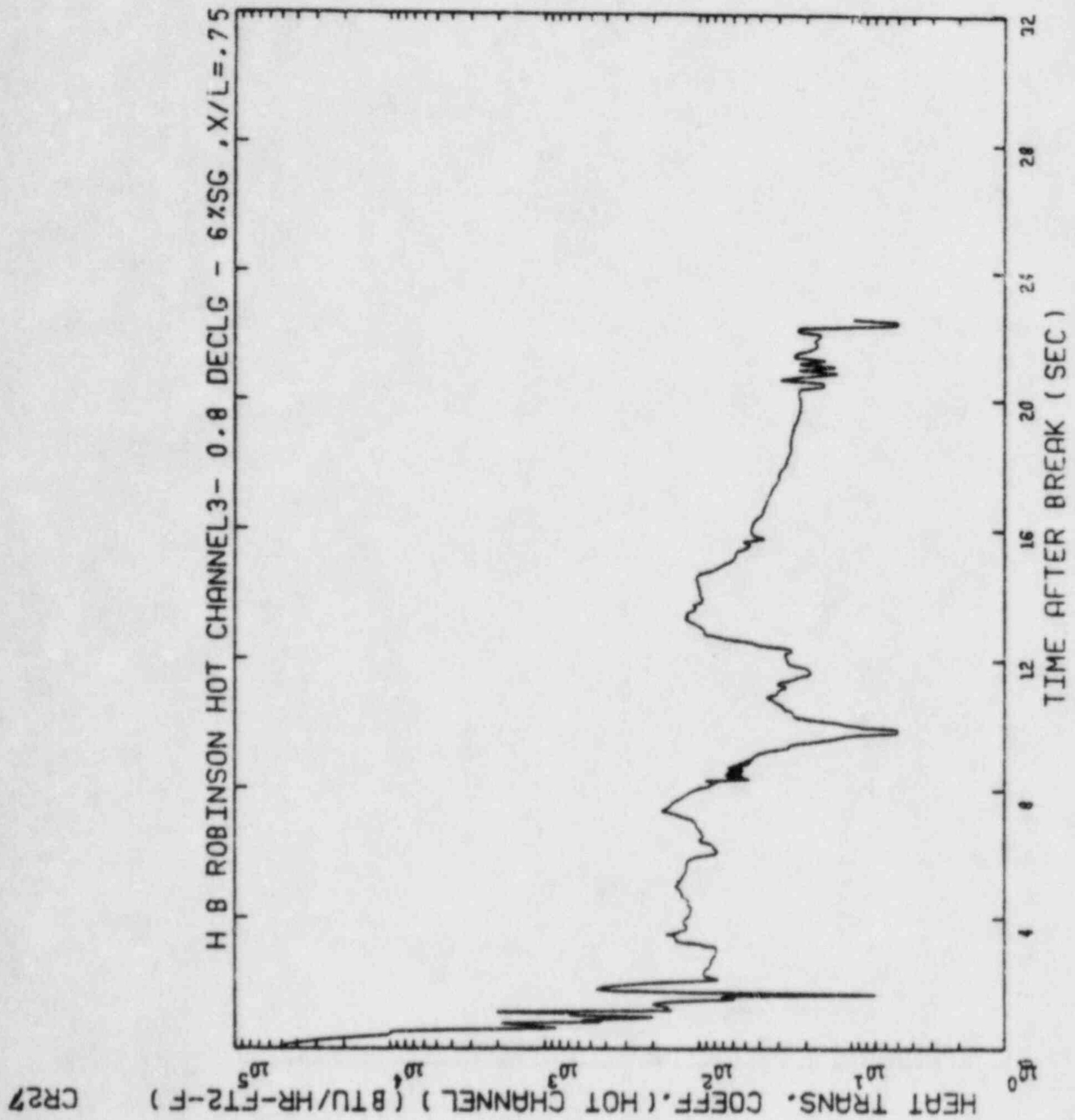

Figure 3.18 Heat Transfer Coefficient During Blowdown Period at PCT Node, 0.8 DECLG Break, X/L=0.75, 9-EOL MWD/kgU

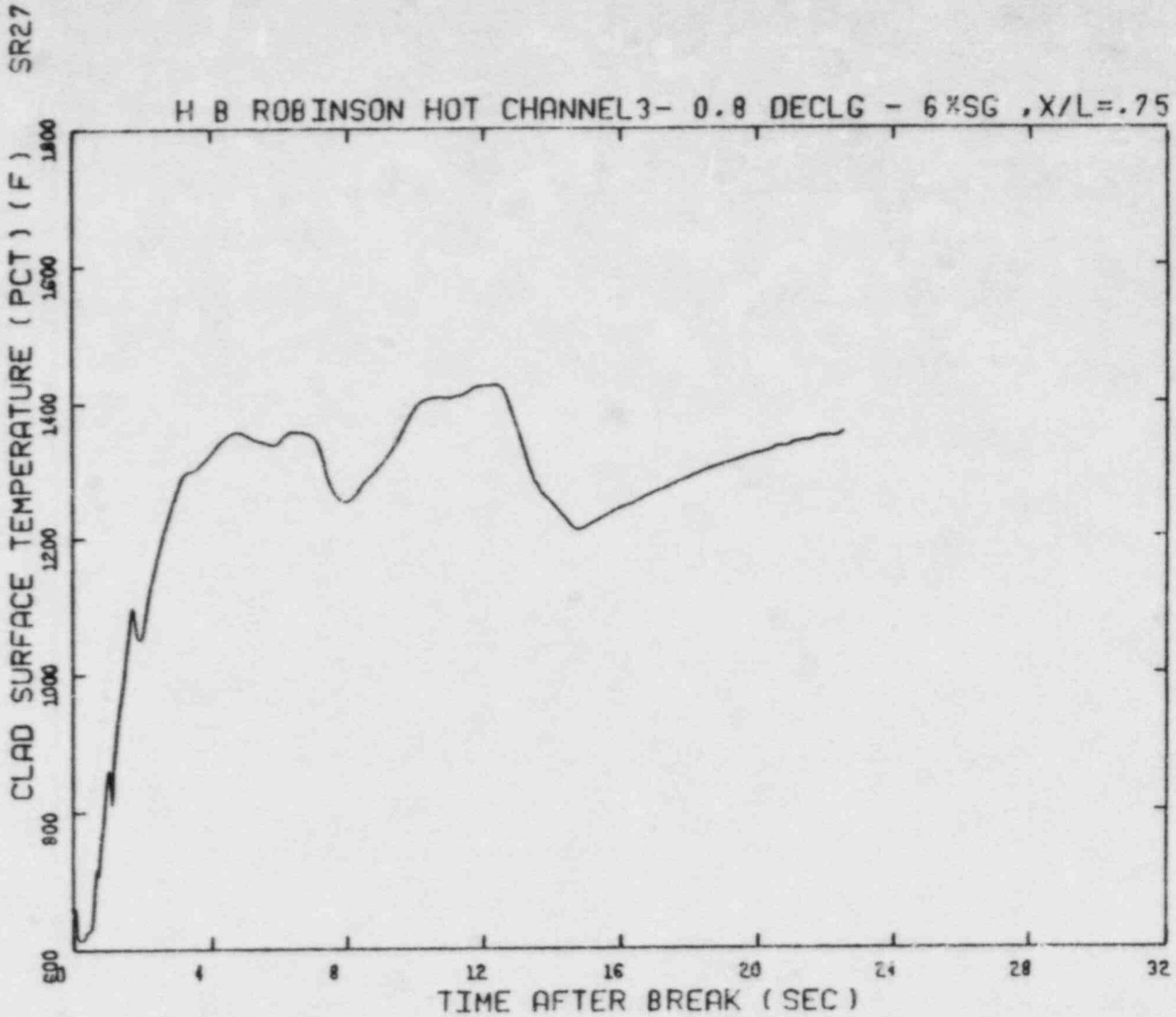

Figure 3.19 Clad Surface Temperature during Blowdown Period PCT Node, 0.8 DECLG Break, X/L=0.75, 9-EOL MWD/kgU

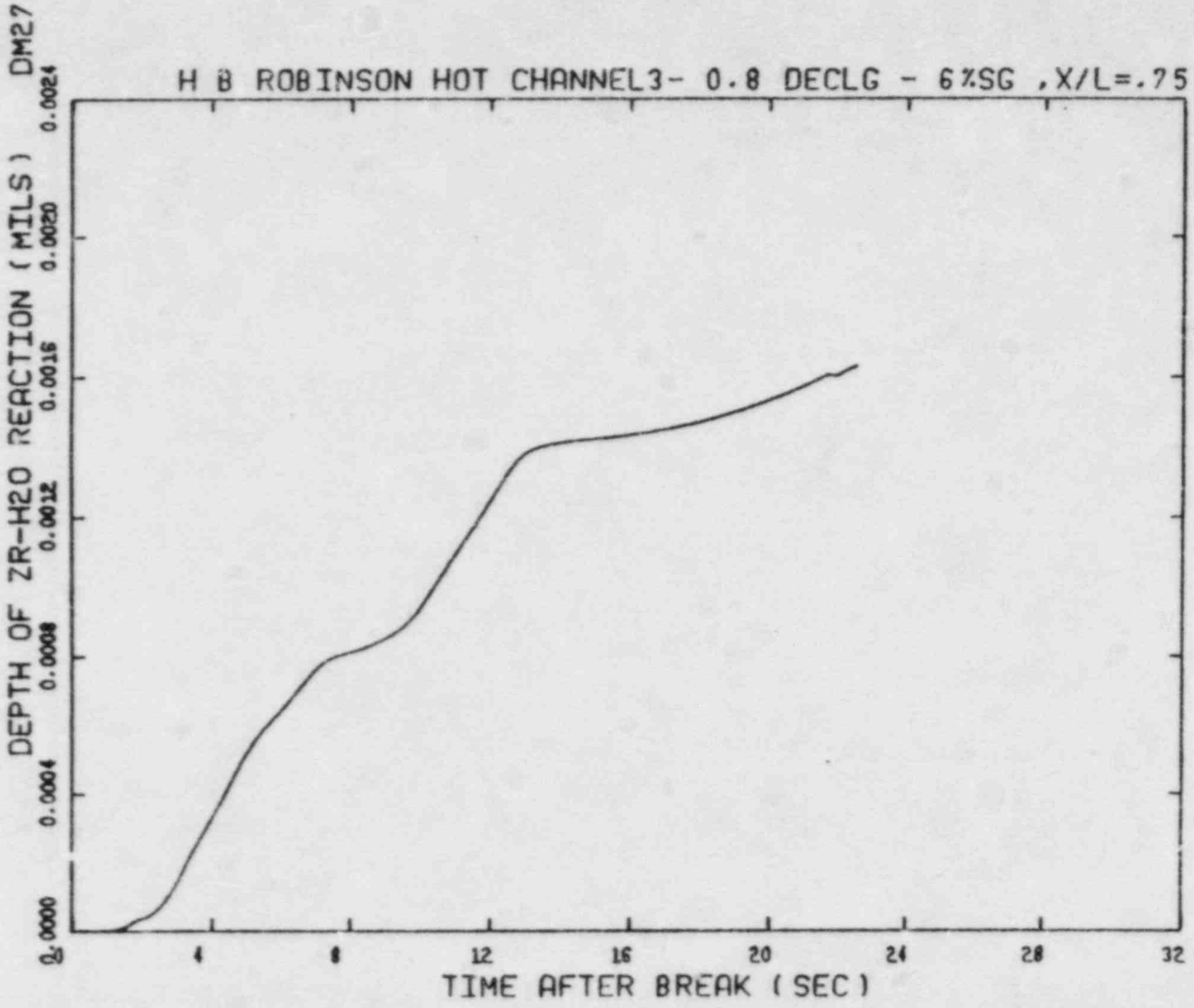

Figure 3.20 Depth of Metal-Water Reaction during Blowdown Period at PCT Node, 0.8 DECLG Break, X/L=0.75, 9-EOL MWD/kgU

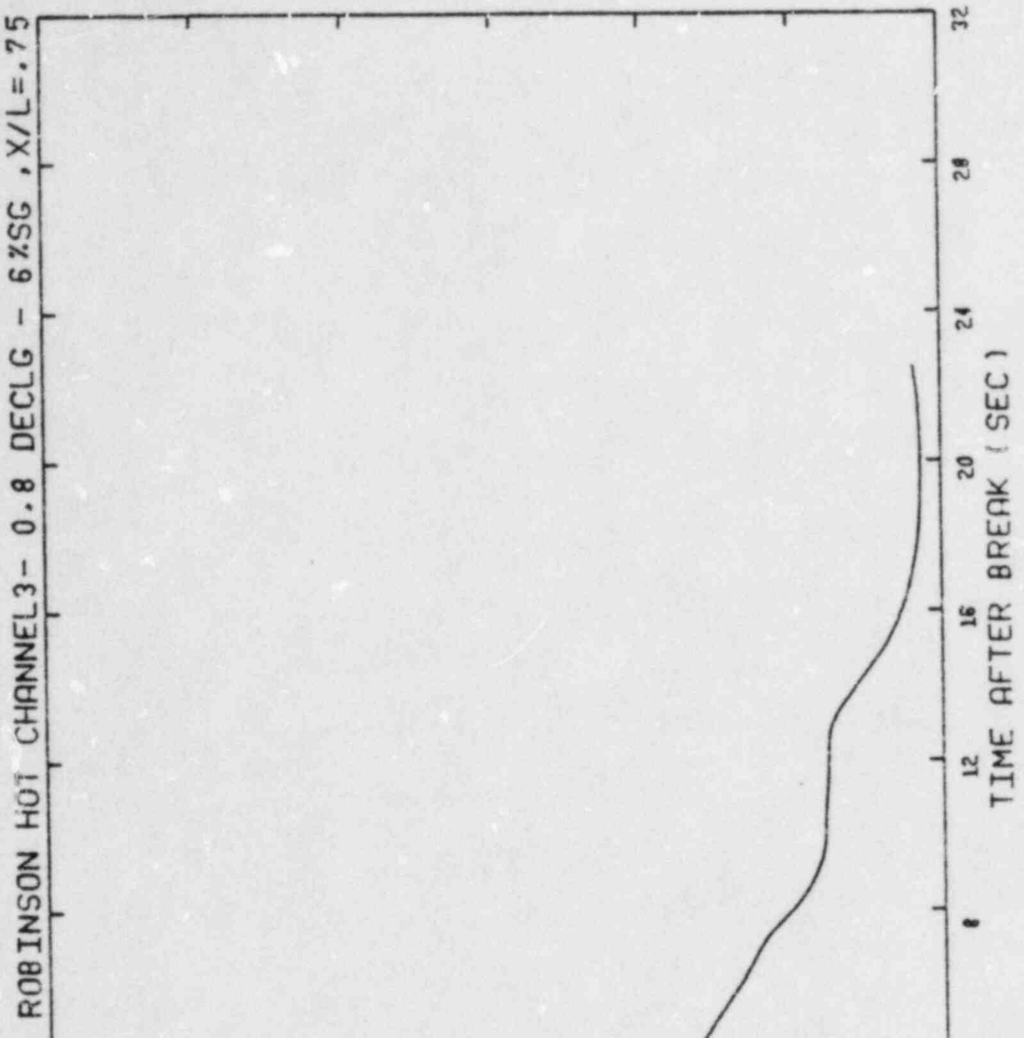

Figure 3.21 Average Fuel Temperature During Blowdown Period at PCT Node, 0.8 DECLG Break, X/L=0.75, 9-EOL MWD/kgU

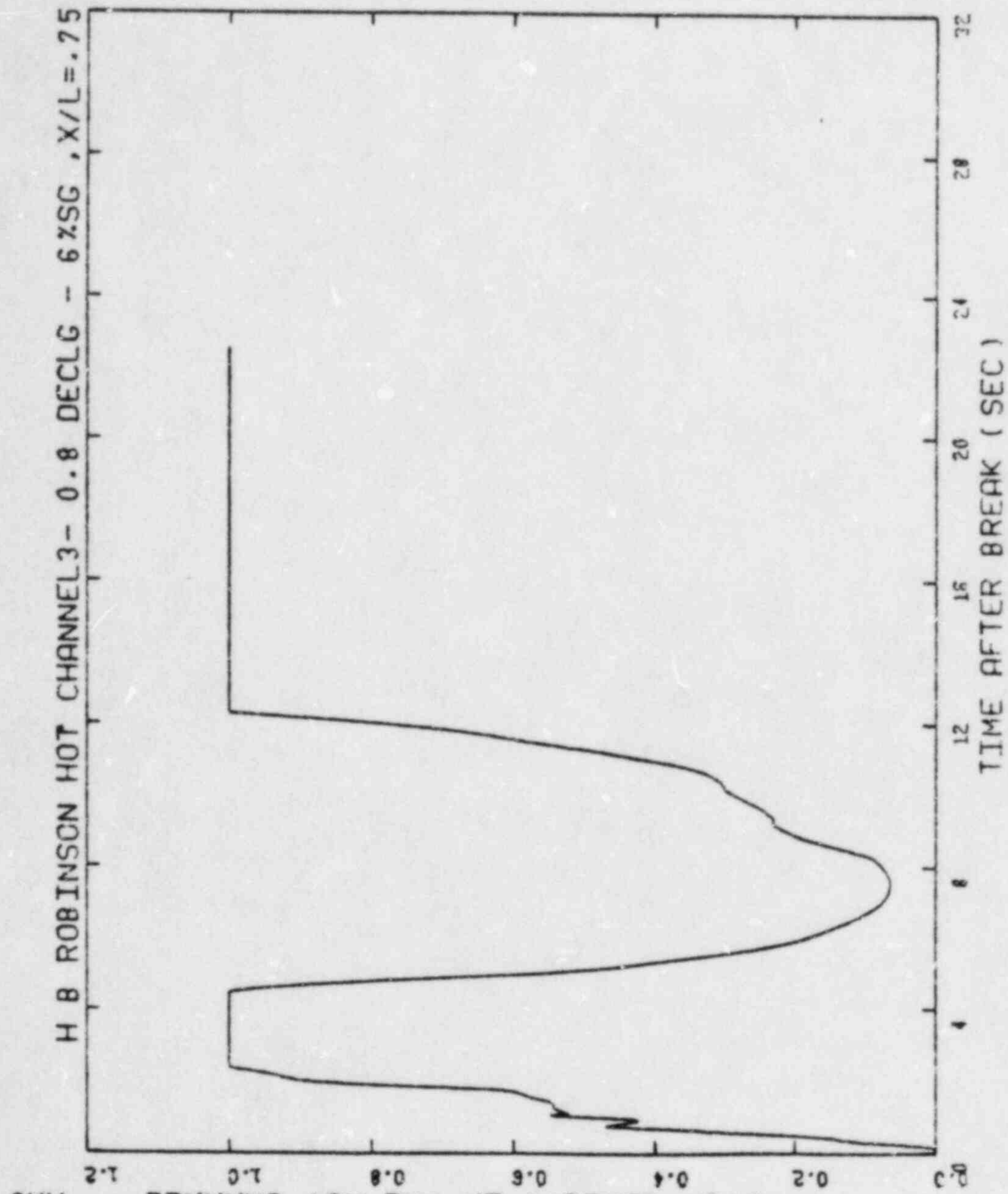

Figure 3.22 Hot Channel Average Quality, Center Volume, 0.8 DECLG Break, X/L=0.75, 9-EOL MWD/kgU

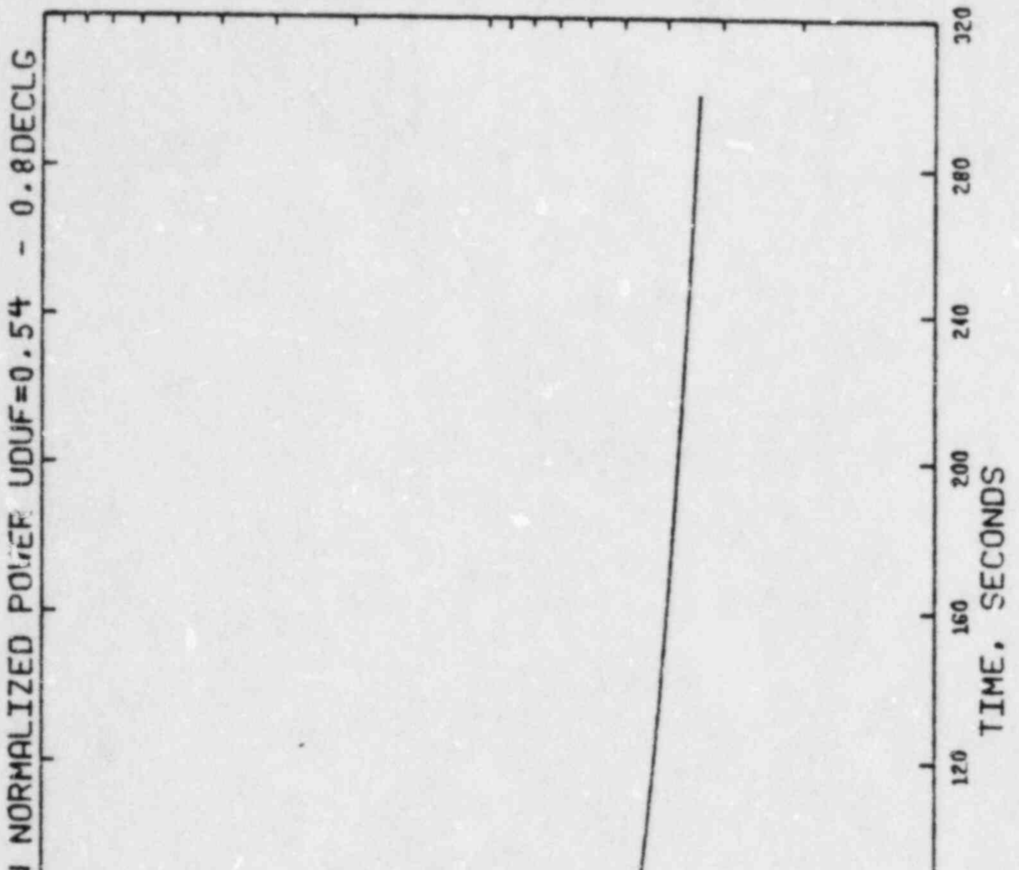

Figure 3.23 Normalized Power, 0.8 DECLG Break, X/L=0.75, 9-EOL MWD/kgU

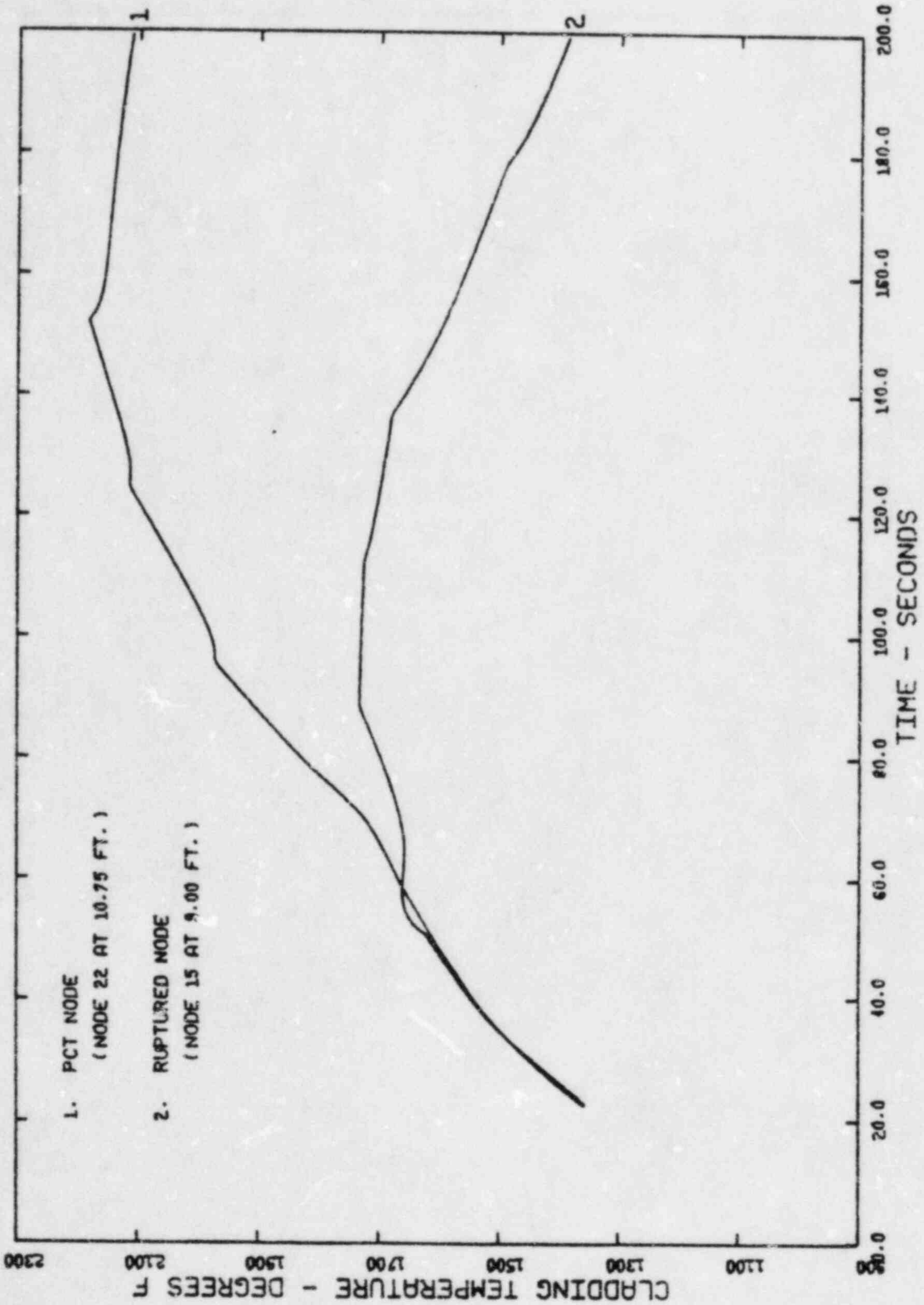

Figure 3.24 TOODEE2 Cladding Temperature vs. Time, 0.8 DECLG Break, X/L=0.75, 9-EOL MWD/kgU

4.0 REFERENCES

(1) "H.B. Robinson Unit 2 Large Break LOCA-ECCS Analysis with Increased Enthalpy Rise Factor," XN-NF-84-20, Exxon Nuclear Company, Richland, WA 99352, July 1984.

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(3) "Exxon Nuclear Company WREM-Based Generic PWR ECCS Evaluation Model: Volume III Small Break Model," XN-75-41, Volume III, Revision 2, Exxon Nuclear Company, Richland, WA 99352, August 1975.

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XN-NF-84-72
Supplement 2

Issue Date: 8/30/84

H. B. ROBINSON UNIT 2

LIMITING BREAK LOCA-ECCS ANALYSIS

WITH INCREASED ENTHALPY RISE FACTOR: K(Z) CURVE

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