XN-NF-83-61

D.C. COOK UNIT 1 LOCA-ECCS ANALYSIS FOR EXTENDED EXPOSURE

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1.0 INTRODUCTION AND SUMMARY

In 1976, Exxon Nuclear Company (ENC) performed a LOCA-ECCS analysis for ENC-fabricated fuel in the Donald C. Cook Unit 1 reactor and established peaking limits[1] assuring conformance to NRC 10 CFR 50.46 and Appendix K criteria.[2] Following the 1976 analysis, ENC performed an updated LOCA-ECCS analysis with the ENC WREM-IIA model and tne ENC ice condenser containment code, ICECON. That analysis was documented in the XN-NF-81-07 report in February of 1981.[3]

This report extends the LOCA-ECCS results presented in XN-NF-81-07 to a peak pellet exposure value of 48.0 GWD/MTU from the current limit of 42.2 GWD/MTU. The analysis was performed using the WREM-IIA ECCS evaluation model, with the following EXEM/PWR ECCS evaluation model[4] modifications:

- Fuel rod stored energy and fission gas release calculations were performed with the RODEX2[5] code.
- Fuel rod swelling and rupture was calculated with the ENC/NUREG-0630 clad rupture/blockage model.[14]
- The EXEM/PWR revised steam cooling model[4] was used in the TOODEE2 heatup calculation.

The LOCA analysis was performed for the previously established limiting break, the equivalent double-ended split break of the cold leg (1.0 DECLS).

Figure 1.1 plots the calculated LOCA-ECCS allowed total peaking versus exposure for ENC fuel in the D.C. Cook Unit 1 reactor. The current analysis is represented by the final point in Figure 1.1. The remaining values are those presented in XN-NF-81-07. The corresponding linear heat generation rates and ECCS results are given in Table 1.1. The end-of-life (EOL) calculated peak cladding temperature (PCT) is 1736°F, occurring at 262 seconds into the accident at a location 9.25 feet from the bottom of the active core. As in the previous analysis, it was assumed that one of the LPSI pumps had failed. An earlier sensitivity study[15] showed that peak clad temperature (PCT) increased 42°F when a conservative estimate of maximum LPSI flow was assumed. Assuming the same PCT increase in the current analysis for the maximum LPSI flow case, the PCT will be 1778°F. Operation of D.C. Cook Unit 1 at or below allowed total peaking F_Q^T of 1.82 and $F_{\Delta H}$ of 1.55 at a peak pellet burnup of 48 GWD/MTU assures compliance with NRC 10 CFR 50.46 LOCA-ECCS licensing requirements.

Details of the analytical models used are described in Section 2.0. Section 3.0 shows the complete calculated results for the system analysis and the end-of-life ENC fuel heatup analysis. Conclusions are given in Section 4.0 and references in Section 5.0.

Table 1.1 D.C. Cook Unit 1 Exposure Sensitivity Results

Peak Pellet Burnup (GWD/MTU)	BOL	12.0	23.5	34.5	42.2	48.0
Total Peaking, F_Q^T	2.07	2.10	2.04	1.98	1.89	1.82
Enthalpy Rise, Nuclear, $F_{\Delta H}^N$	1.55	1.55	1.55	1.55	1.55	1.55
Peak Linear Heat Generation Rate (kW/ft)	14.24	14.45	14.03	13.62	13.00	12.52
Peak Clad Temperature (PCT), ^oF	2199	2177	2195	2185	2186	1736
Max. Local Zr/H_2O-Reaction, %	6.42	6.09	6.25	5.95	5.62	2.26
Core Wide Zr/H_2O-Reaction, %	<1%	<1%	<1%	<1%	<1%	<1%
Hot Rod Burst Time, sec.	47.5	70.9	73.5	85.7	101.1	124.6
Hot Rod Burst Location, ft.	6.0	6.25	6.5	6.5	6.75	9.75
Time of PCT, sec.	230	232	263	271	294	262
PCT Location, ft.	7.81	7.0	7.25	7.25	7.50	9.25
Max. Zr/H_2O-Reaction Location, ft.	7.50	7.0	7.25	7.25	7.50	9.75

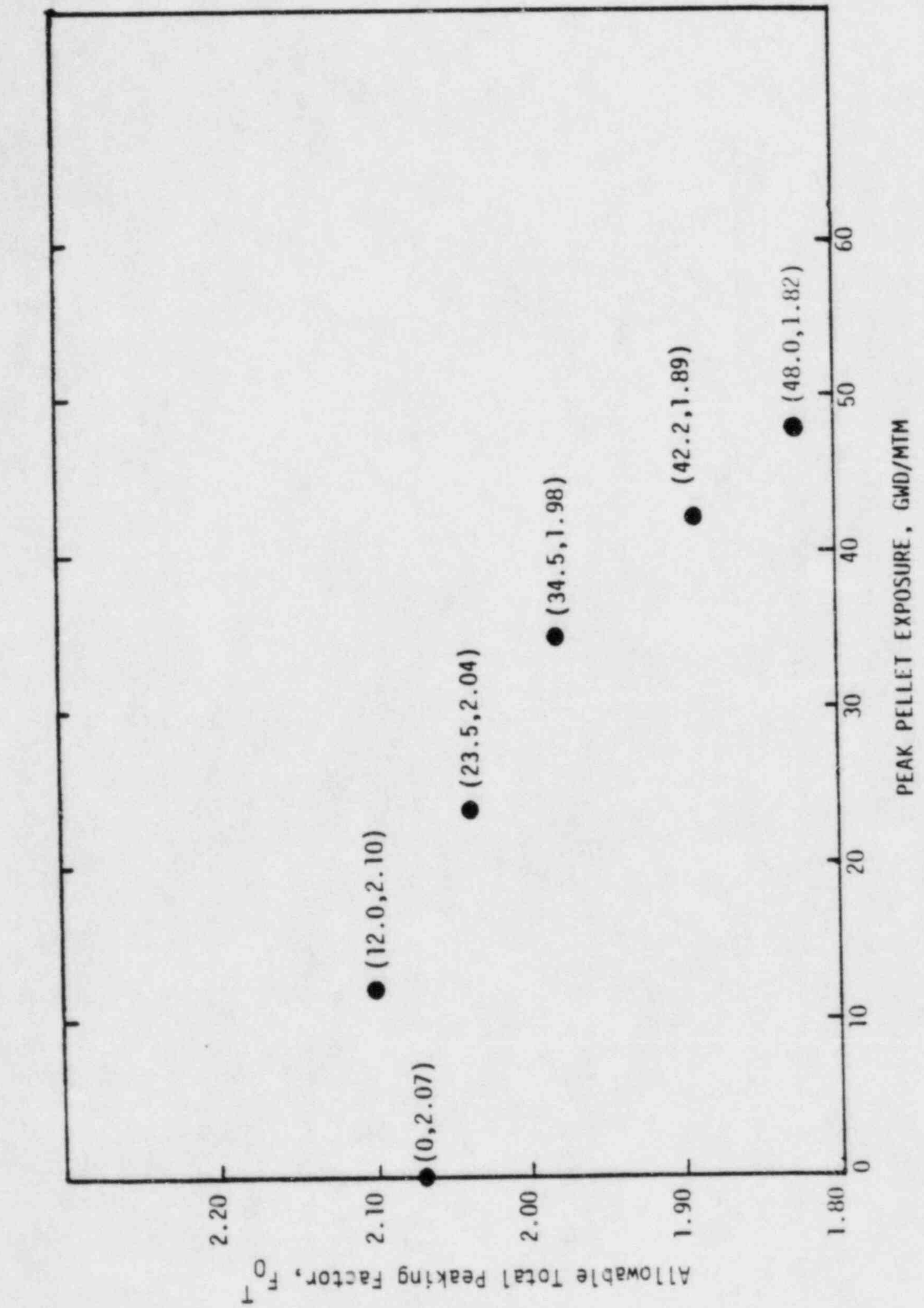


Figure 1.1 D.C. Cook Unit 1, Allowable Total Peaking Factor as a Function of Peak Pellet Exposure

2.0 ANALYTICAL AND SYSTEM MODELS

The D.C. Cook Unit 1 extended burnup analysis used the ENC WREM-IIA PWR ECCS evaluation model[6,7,8,9] and the following EXEM/PWR ECCS models:[4]

- ENC/NUREG-0630 clad rupture/blockage model
- Revised steam cooling model
- RODEX2 stored energy and fission gas release model

The ENC ECCS evaluation model used in this analysis consists of the following computer codes: RODEX2[5] code for initial rod stored energy and internal fuel rod gas inventory calculations; RELAP4-EM[10] for the system and hot channel blowdown calculations; ICECON[11] for the computation of ice condenser containment back pressure; REFLEX[12] for computation of system reflood; and TOODEE2[13] for the calculation of hot fuel rod heatup.

3.0 SYSTEM ANALYSIS RESULTS

The D.C. Cook Unit 1 ECCS extended burnup analysis was performed for the previously identified limiting large break, the large cold leg split break with the break area equal to twice the pipe cross sectional flow area. This break is referred to as the equivalent double-ended cold leg split break (1.0 DECLS). The analysis was performed for a burnup condition with the peak pellet exposure equal to 48 GWD/MTM. The radial peaking was set at 1.55, with a maximum axial peaking factor of 1.17 shown in Figure 3.1.

Calculated event times for the 48 GWD/MTM peak pellet extended burnup ECCS analysis are given in Table 3.1. RELAP4-EM system blowdown results are given in Figures 3.2 through 3.6. Figures 3.7 through 3.12 present results of the RELAP4-EM hot channel calculation. Extended decay power is shown in Figure 3.13, and the ICECON computed containment pressure is given in Figure 3.14. REFLEX reflood results are shown in Figures 3.15 through 3.18. End-of-life TOODEE2 results with F_Q^T of 1.82 and $F_{\Delta H}$ of 1.55 are shown in Figure 3.19.

Table 3.1 D.C. Cook Unit 1 Limiting Break Event Times (1.0 DECLS) for 48 GWD/MTM Peak Pellet Extended Burnup Analysis

Event	Calculated Event Time (sec)
Start	0.0
Initiation of Break	0.05
Safety Injection Signal	0.65
Begin Accumulator Injection, Broken Loop	2.06
Begin Accumulator Injection, Intact Loop	15.50
End-of-Bypass	22.71
Begin Pumped Safety Injection	25.65
Accumulator Empty, Broken Loop	32.76
Bottom of Core Recovery	38.99
Accumulator Empty, Intact Loop	50.36
Hot Rod Burst Time	124.6
Peak Cladding Temperature Time	262.0

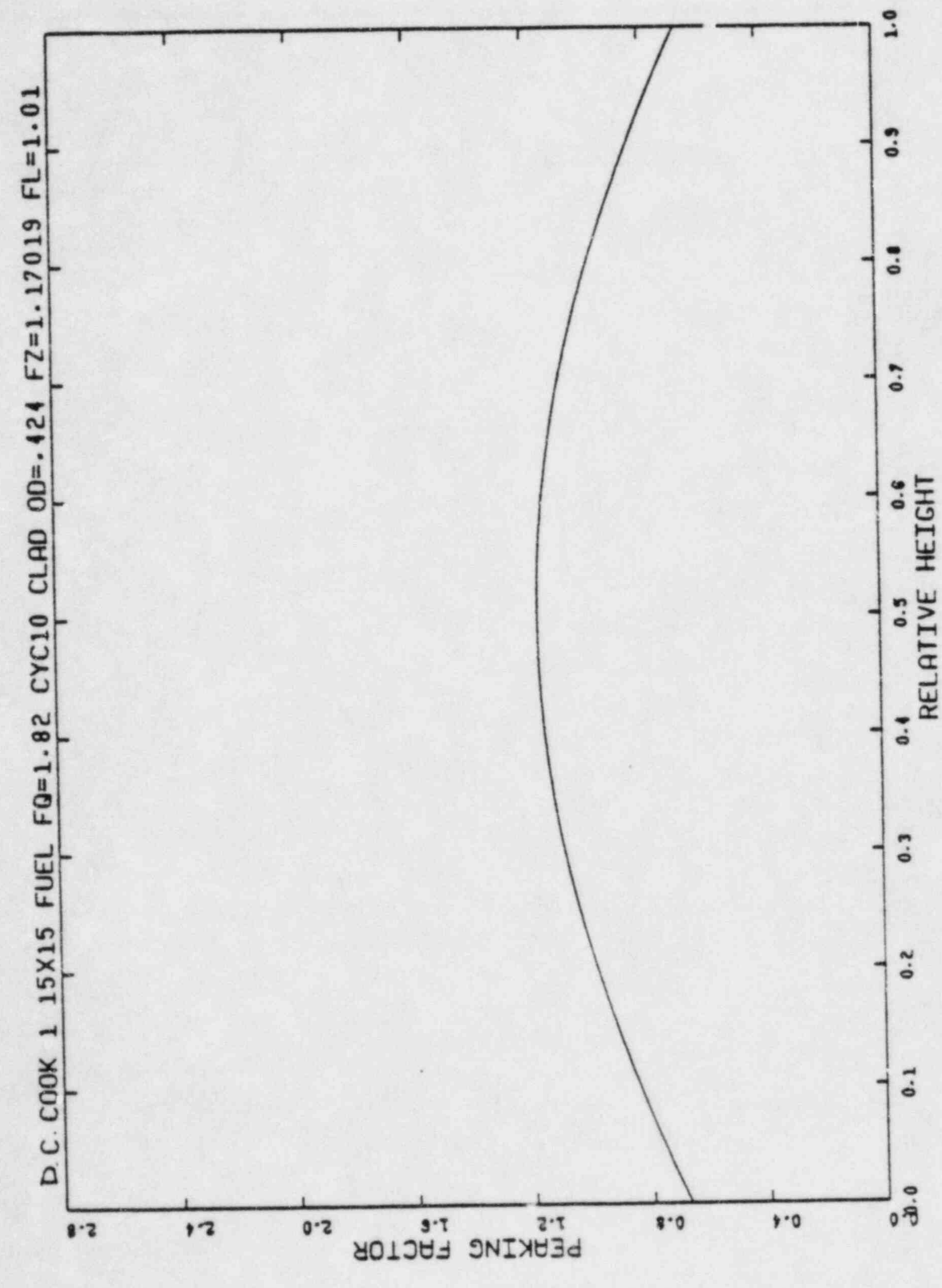


Figure 3.1 Axial Peaking Factor versus Rod Length

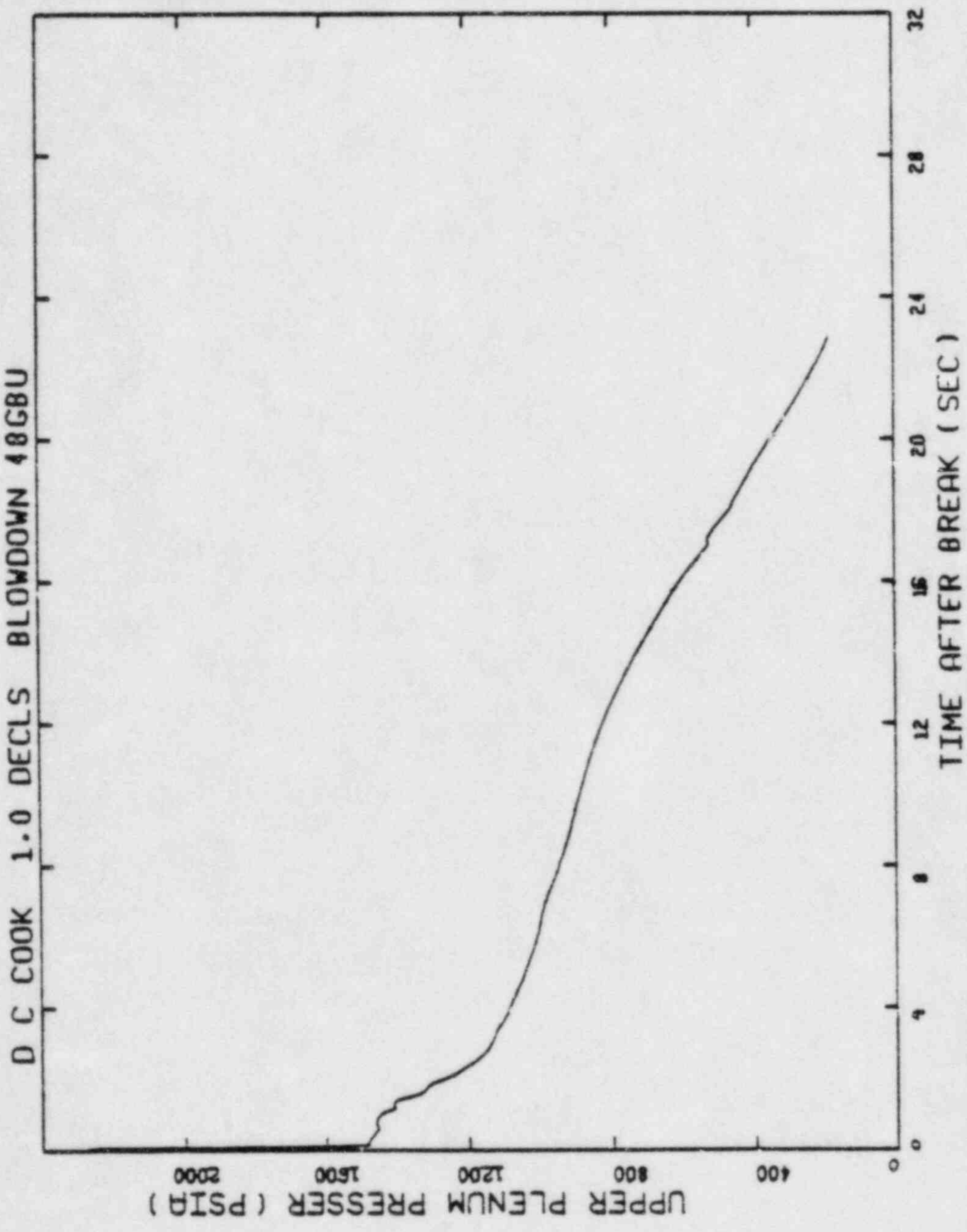


Figure 3.2 Blowdown System Pressure

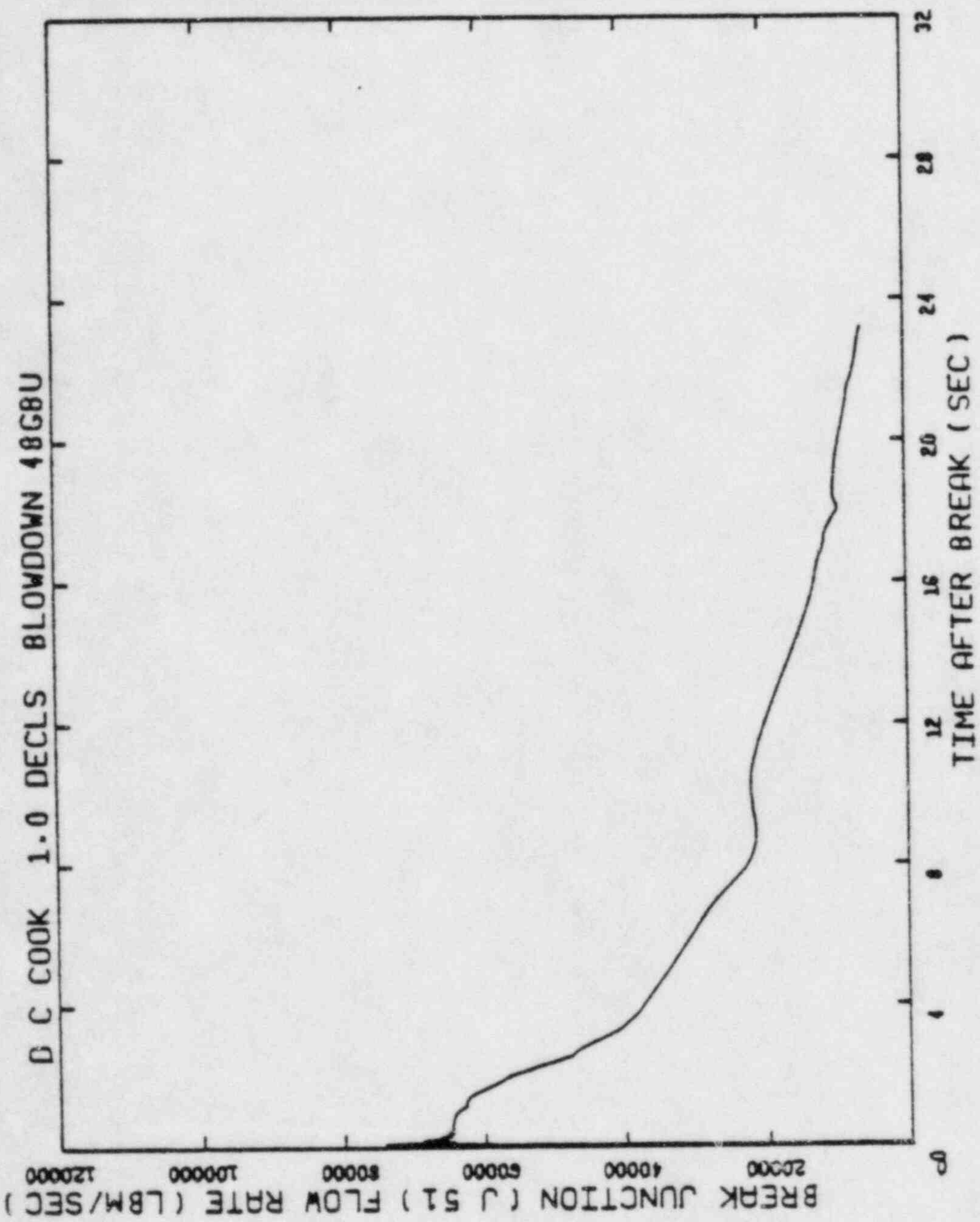


Figure 3.3 Blowdown Break Flow Rate

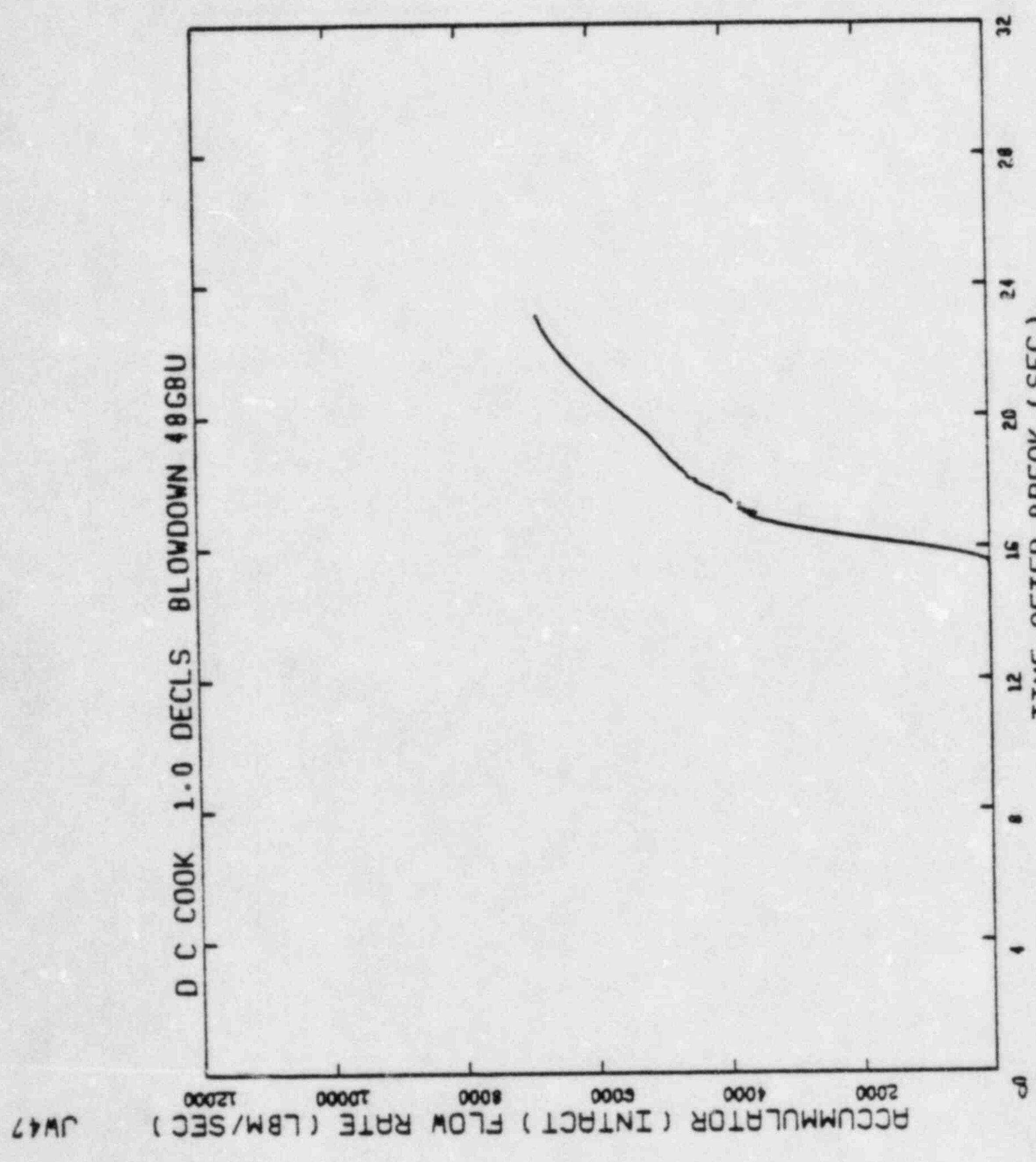


Figure 3.4 Accumulator Flow Rate to Intact Loop

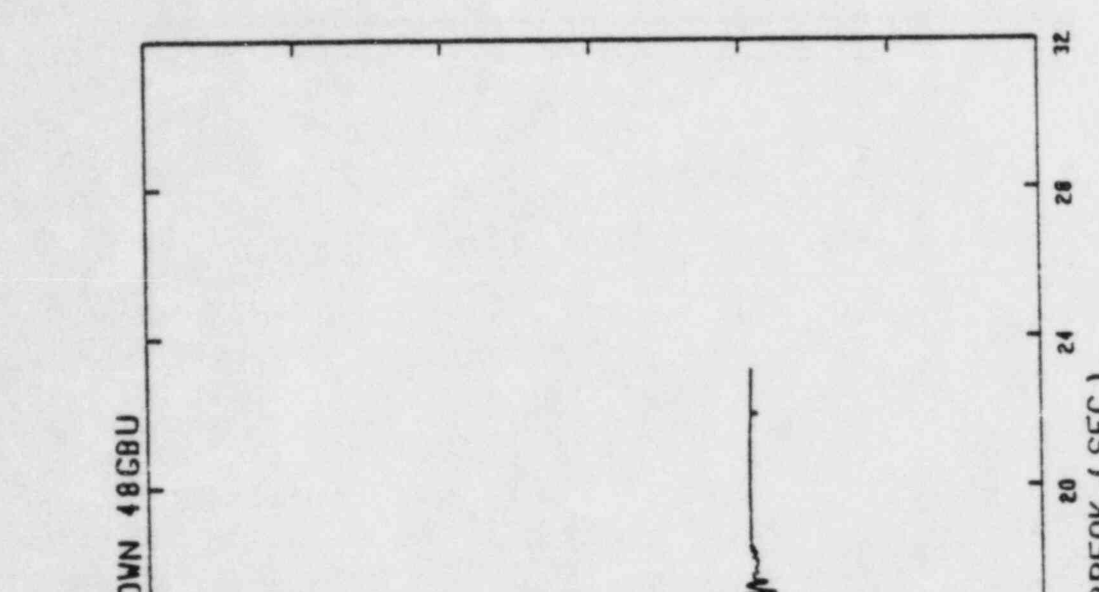


Figure 3.5 Blowdown Core Inlet Flow Rate

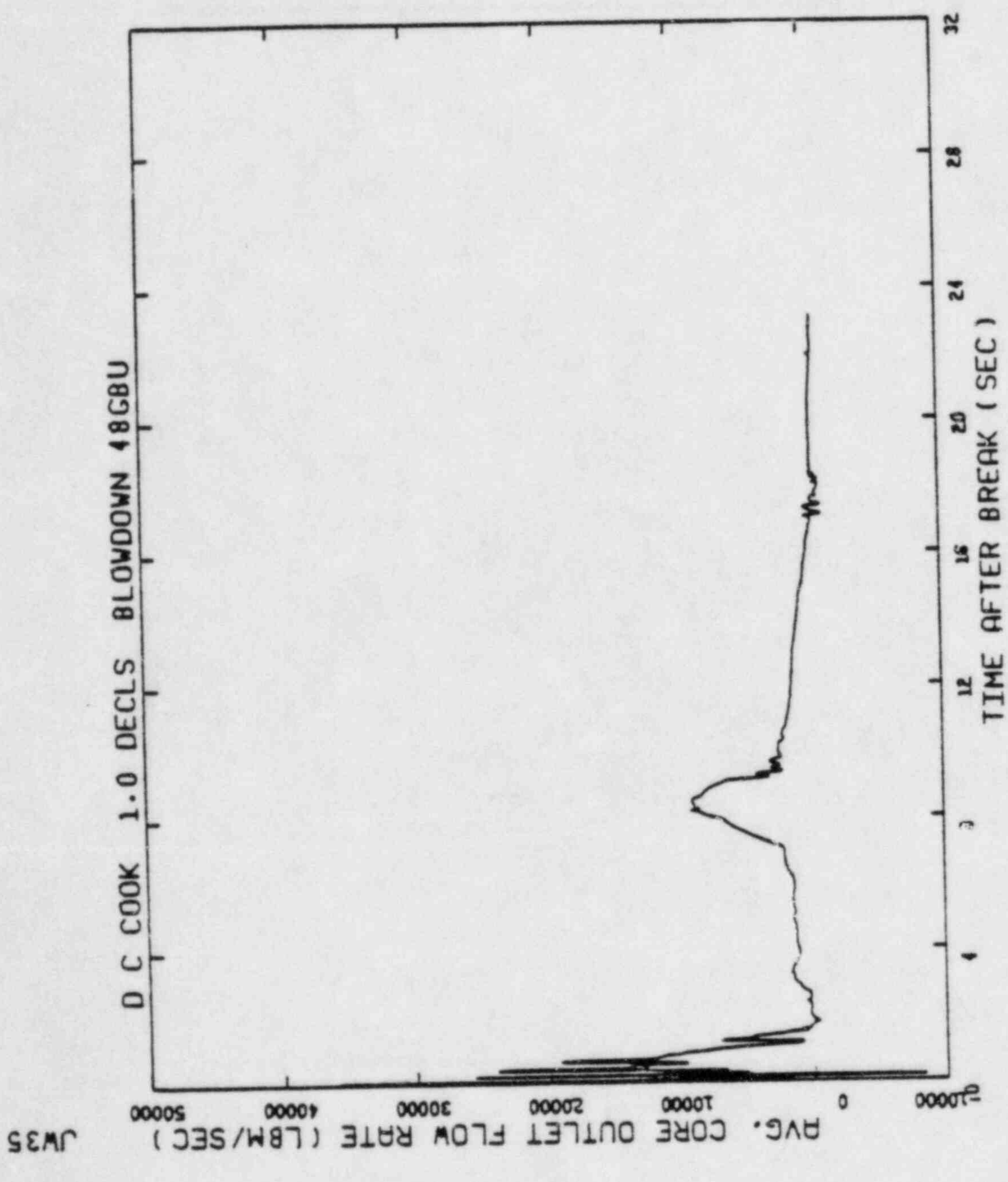


Figure 3.6 Blowdown Core Outlet Flow Rate

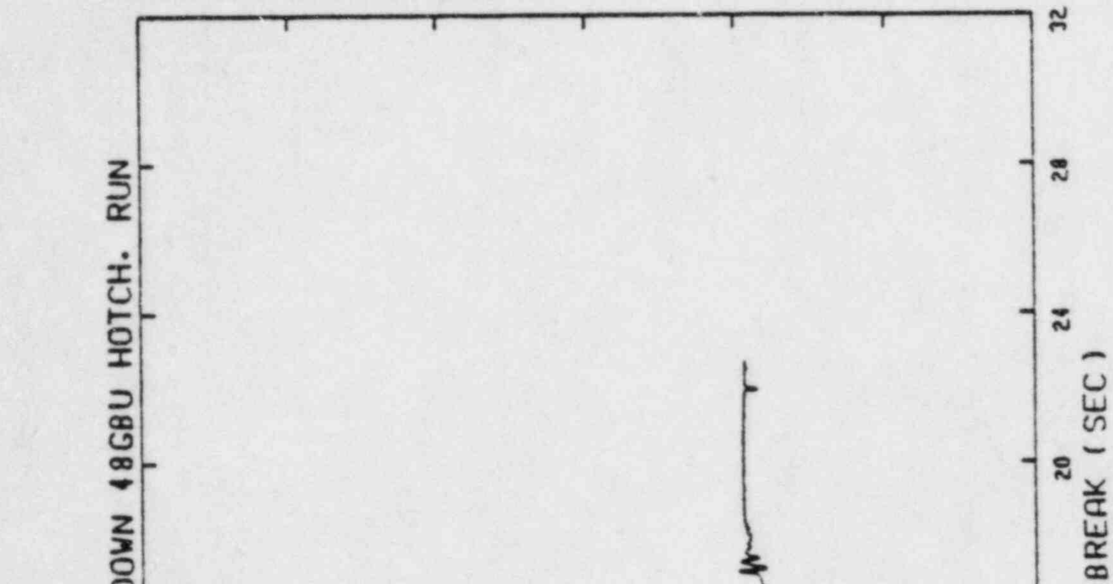


Figure 3.7 Blowdown Hot Assembly Inlet Flow Rate

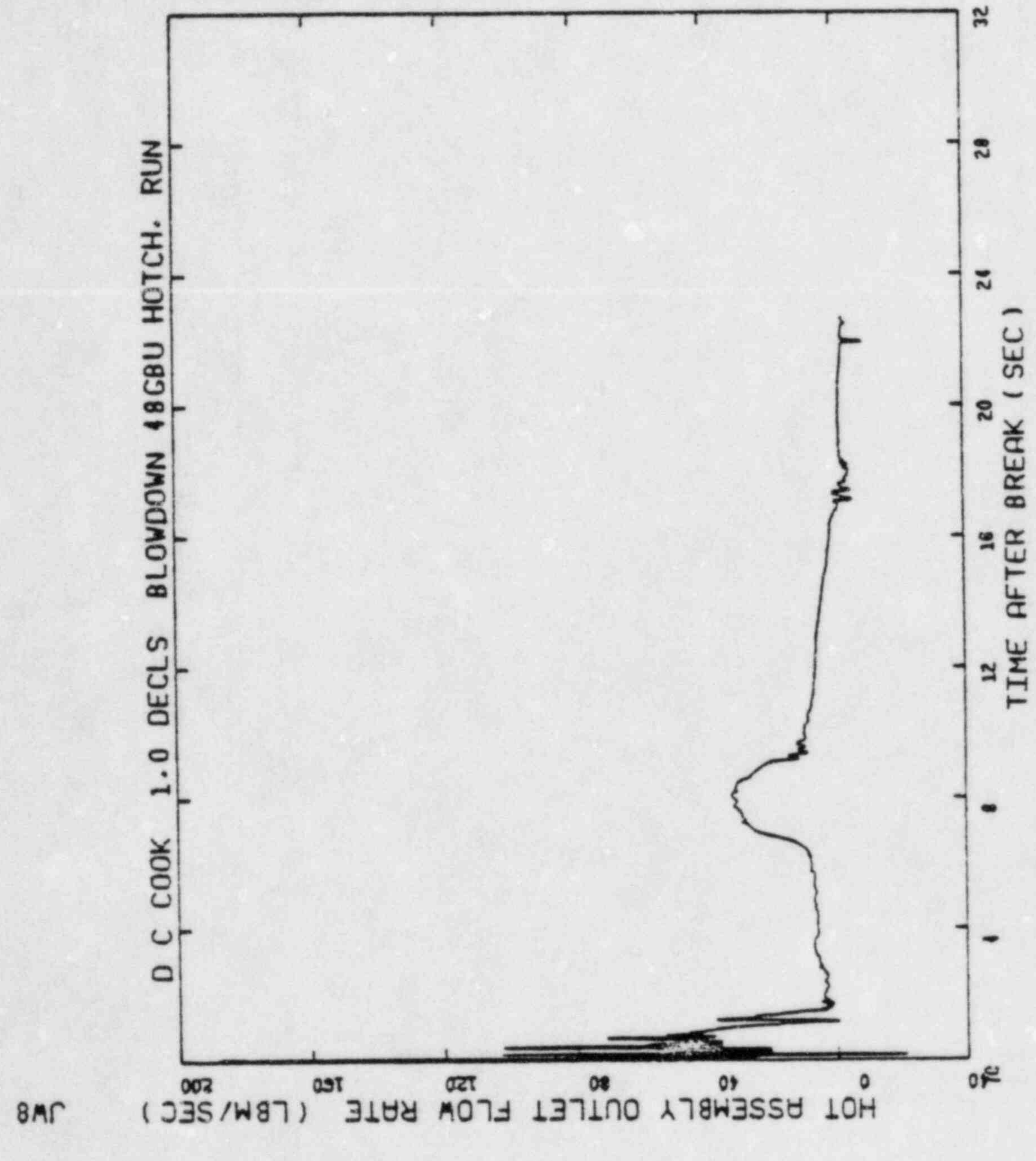


Figure 3.8 Blowdown Hot Assembly Outlet Flow Rate

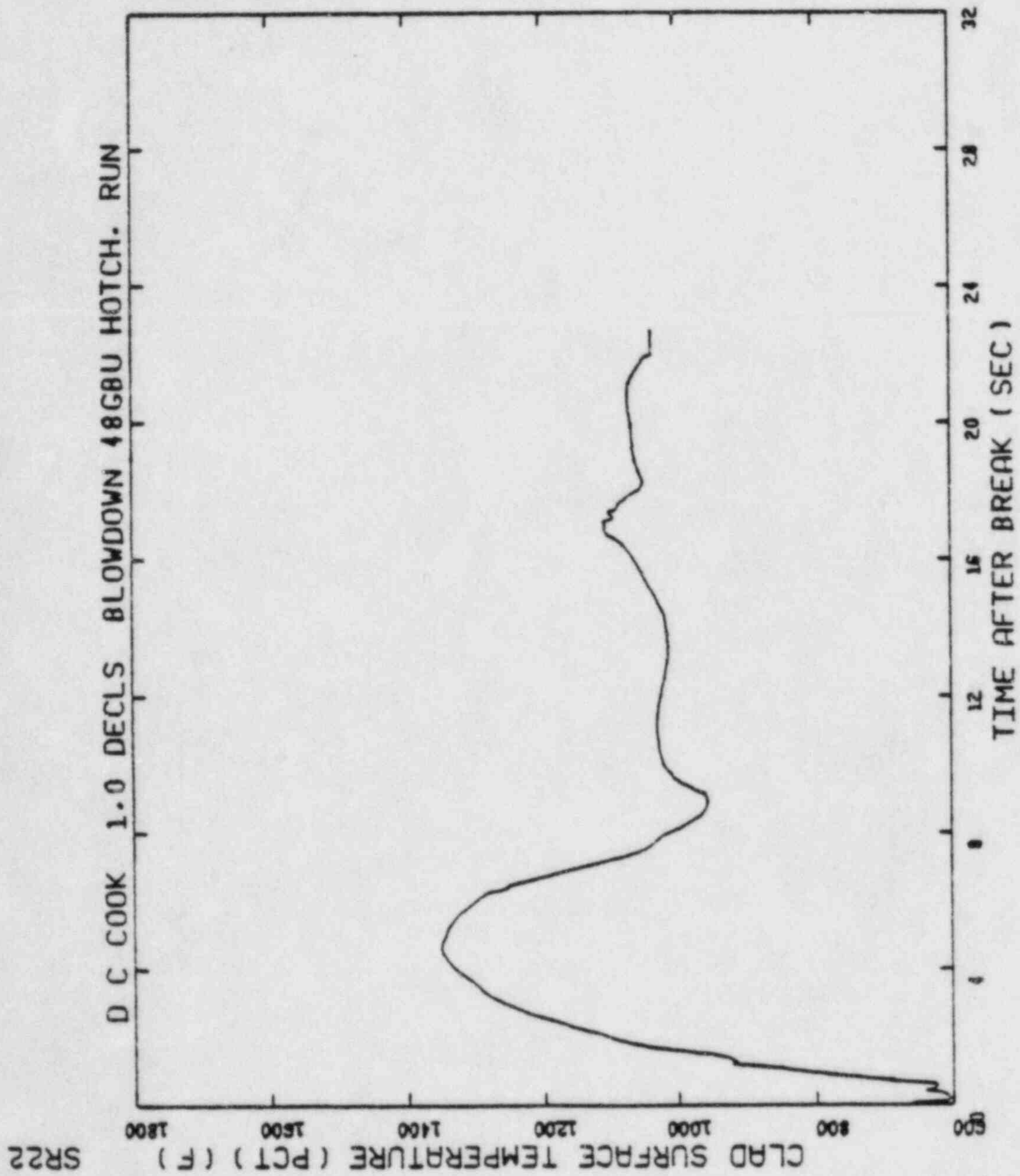


Figure 3.9 Blowdown PCT Node Cladding Temperature

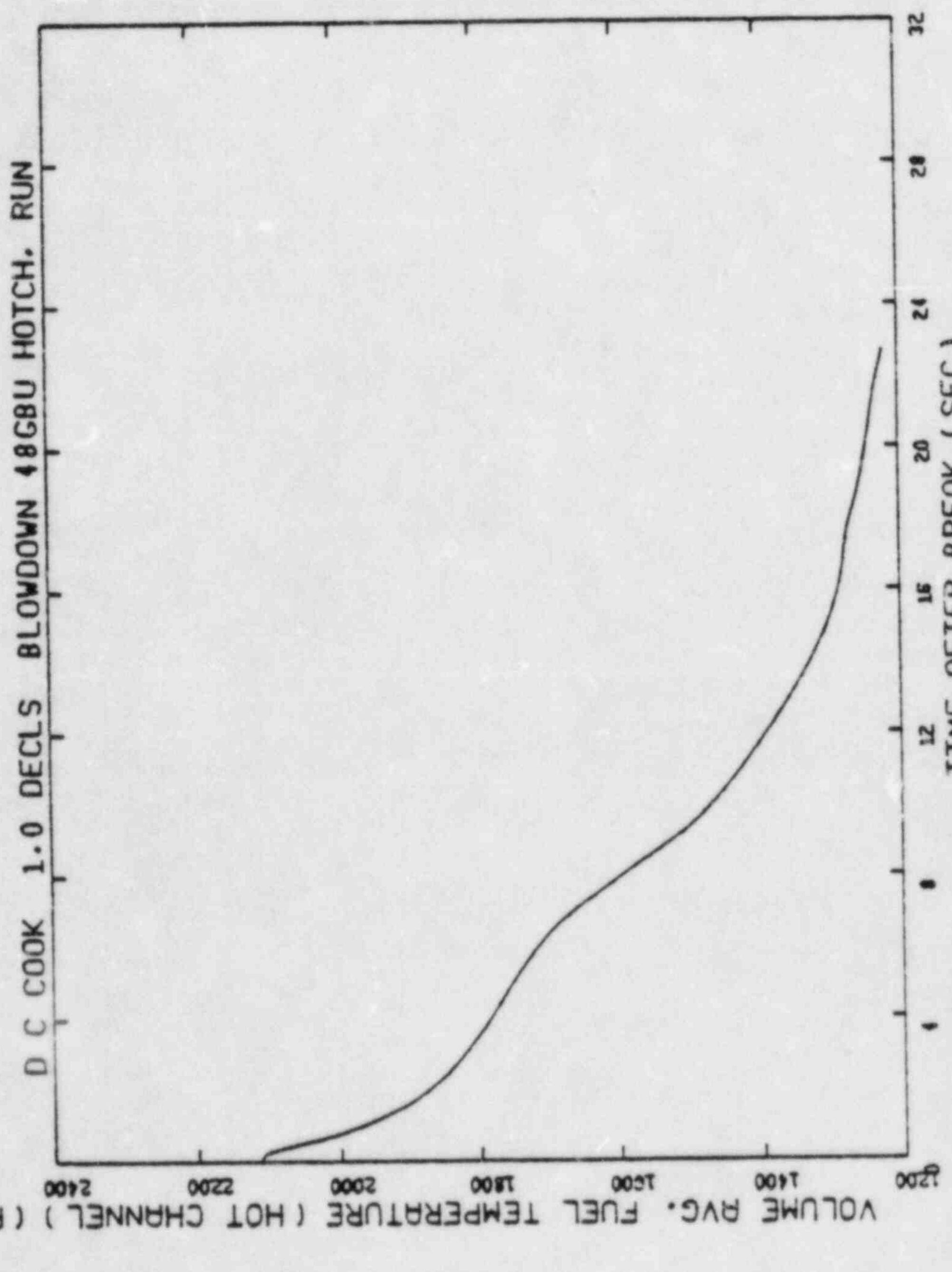


Figure 3.10 Blowdown PCT Node Volume Average Fuel Temperature

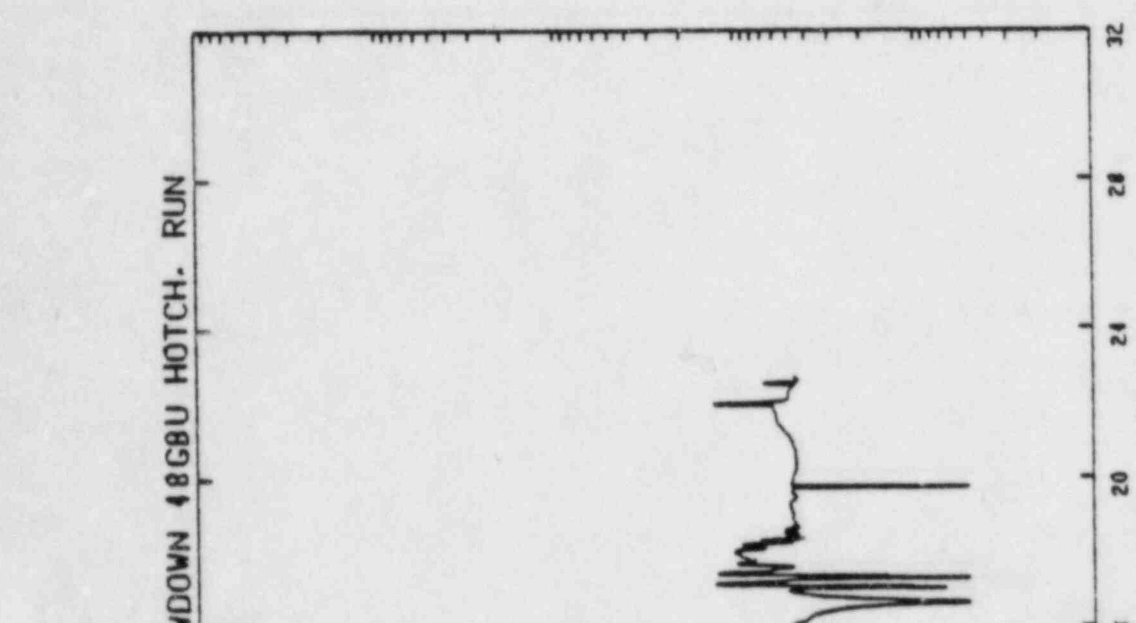


Figure 3.11 PCT Node Blowdown Heat Transfer Coefficient

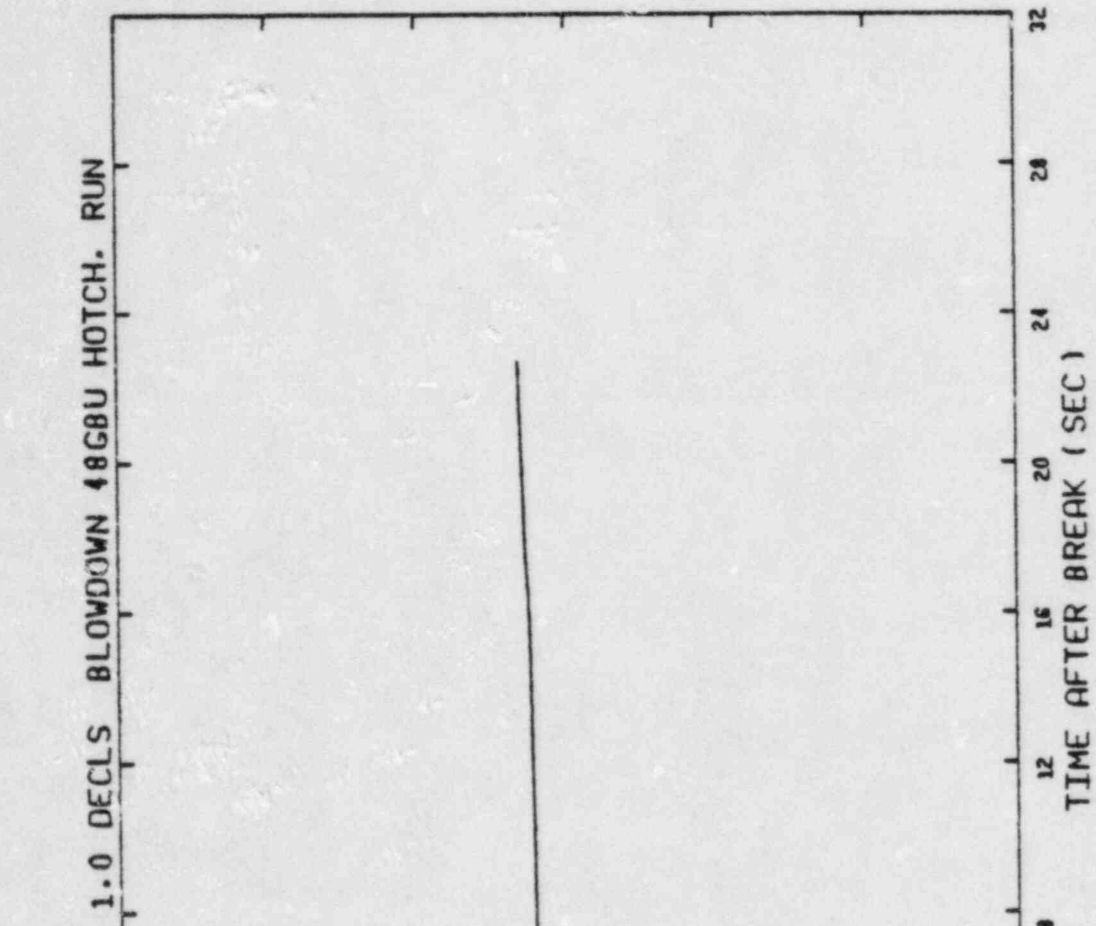


Figure 3.12 PCT Node Blowdown Depth of Zirconium-Water Reaction

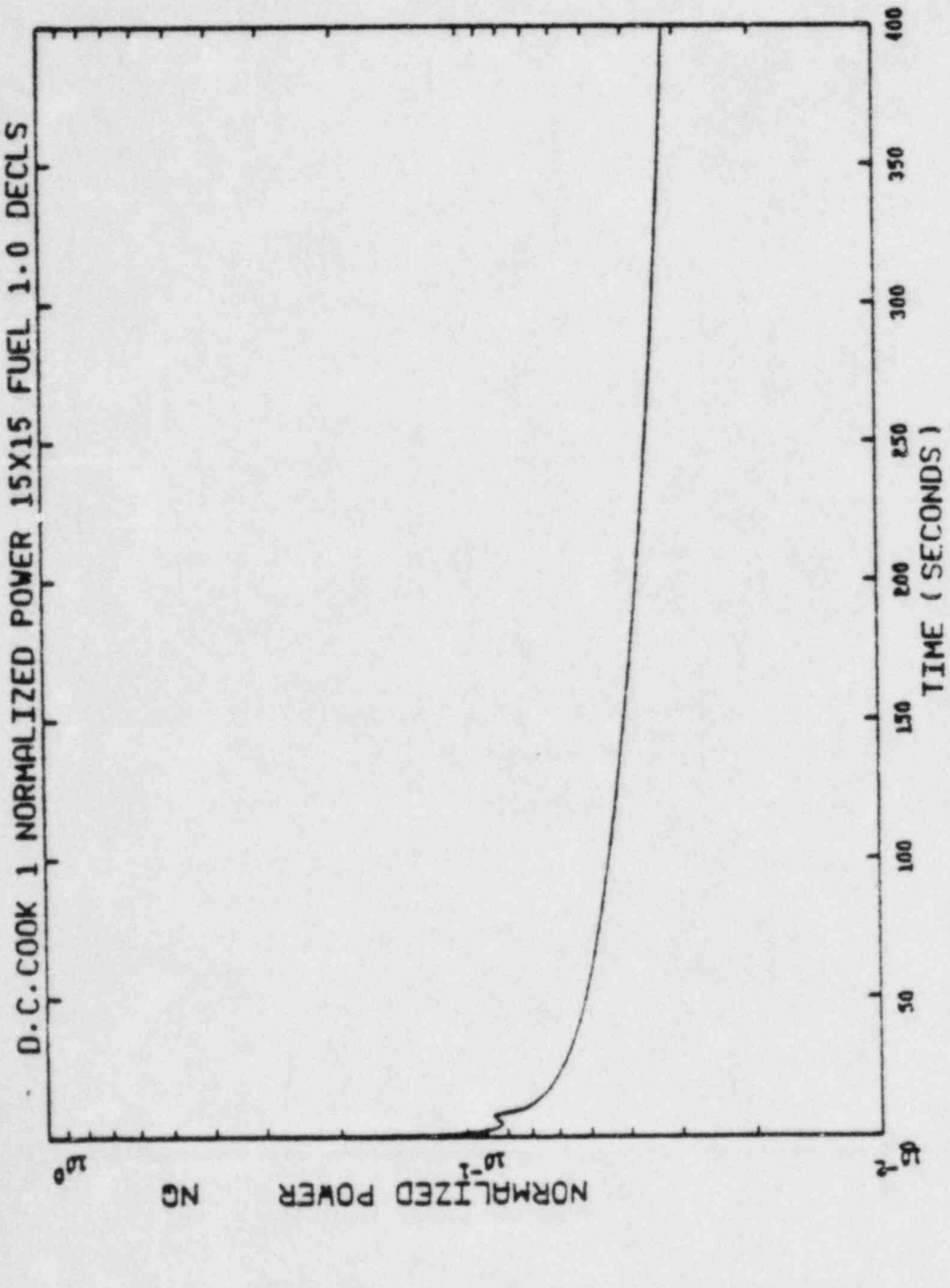
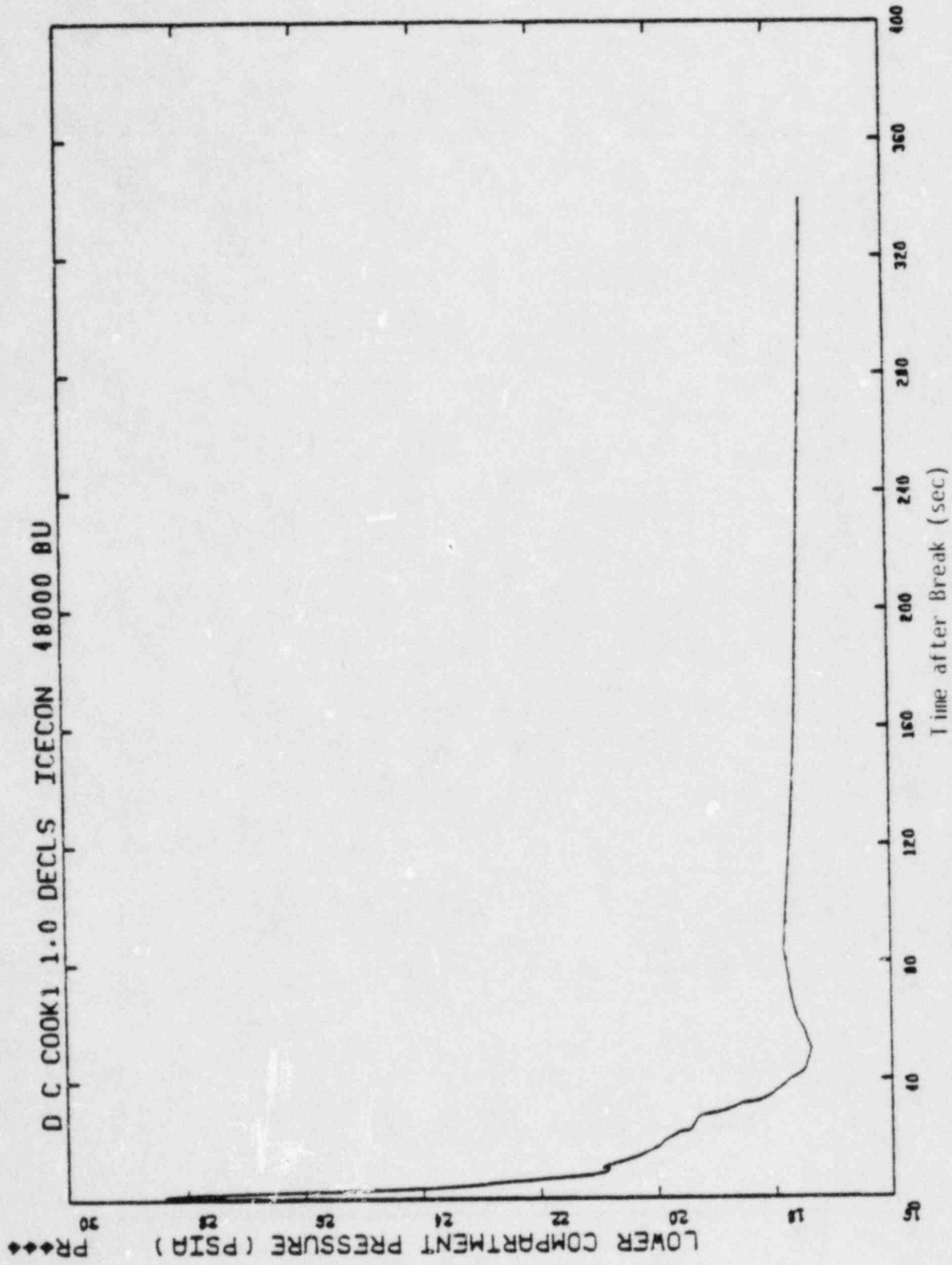


Figure 3.13 Normalized Core Power


D C COOK1 1.0 DECLS ICECON 48000 BU
LOWER COMPARTMENT PRESSURE (PSIA)
PR***
Time after Break (sec)
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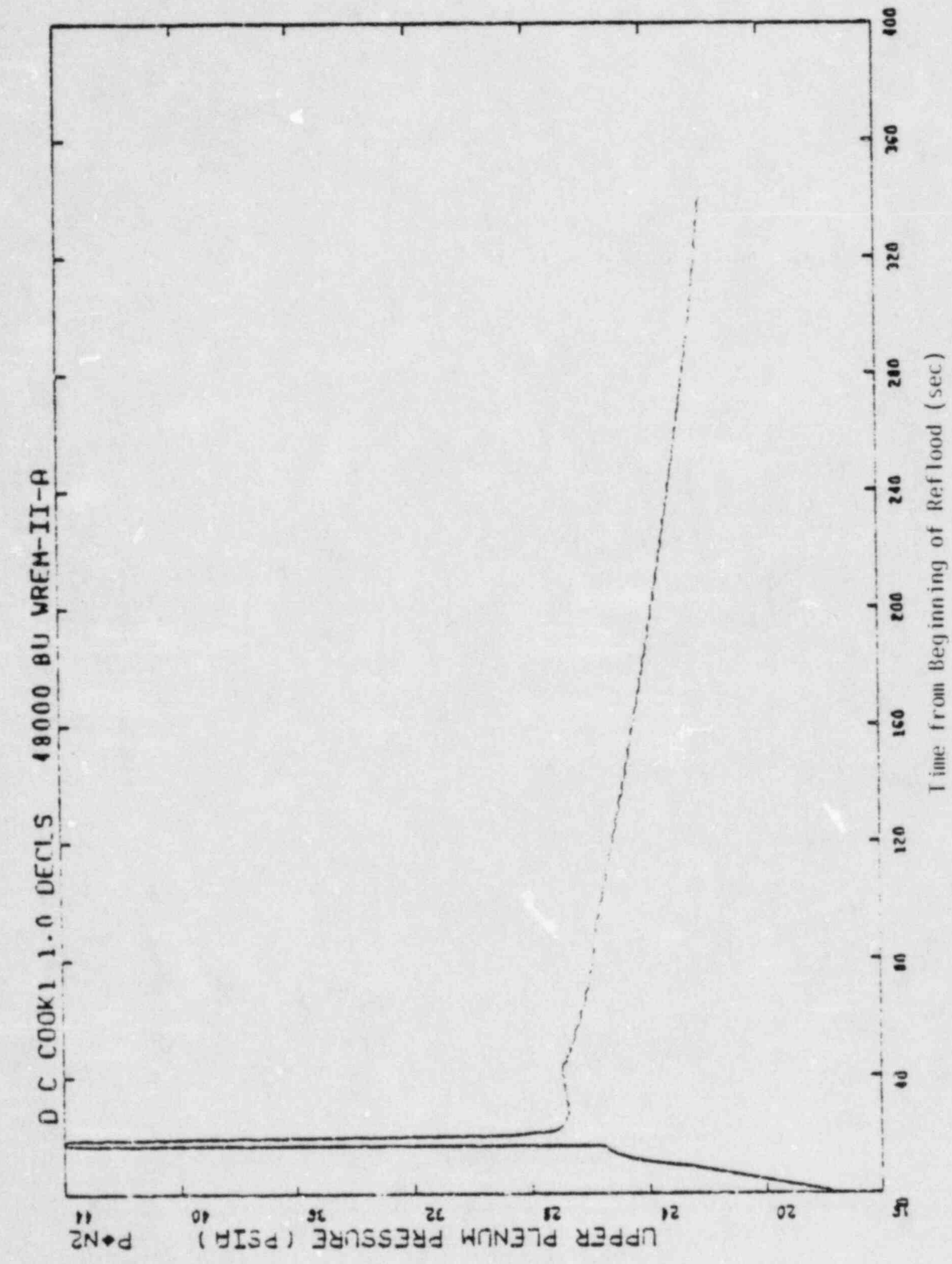

Figure 3.15 Reflood Upper Plenum Pressure

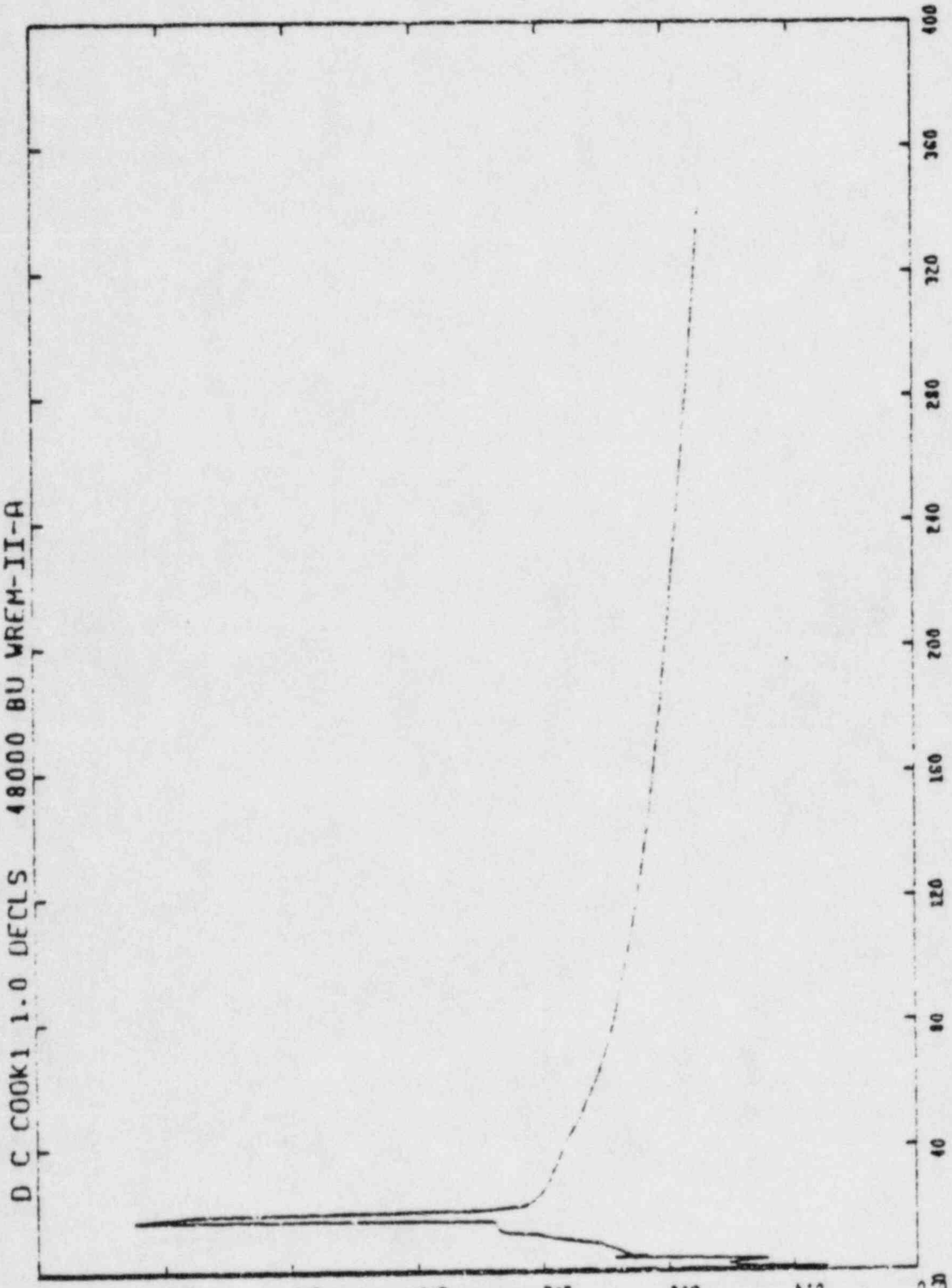

Figure 3.16 Core Reflooding Rate

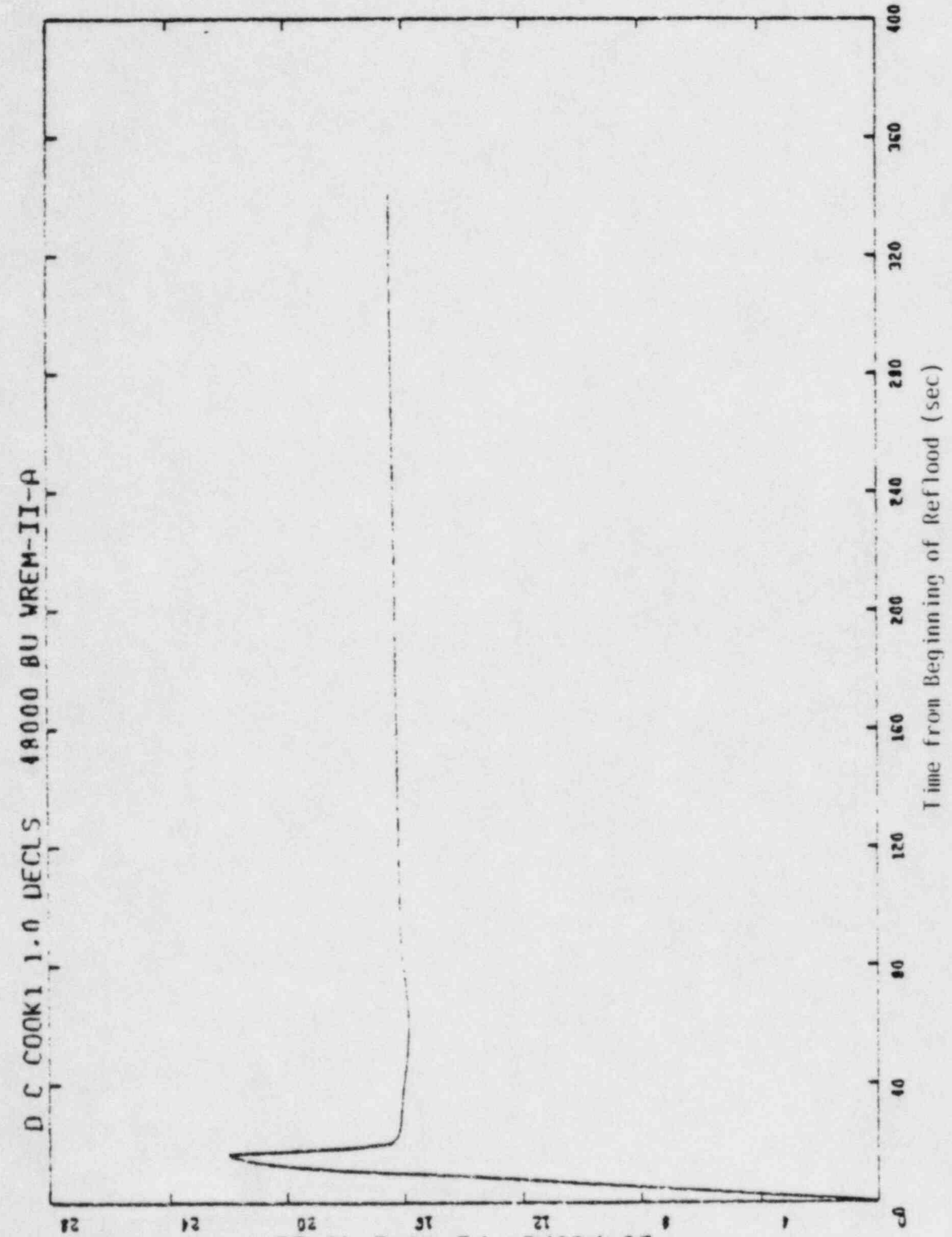

Figure 3.17 Reflood Downcomer Mixture Level

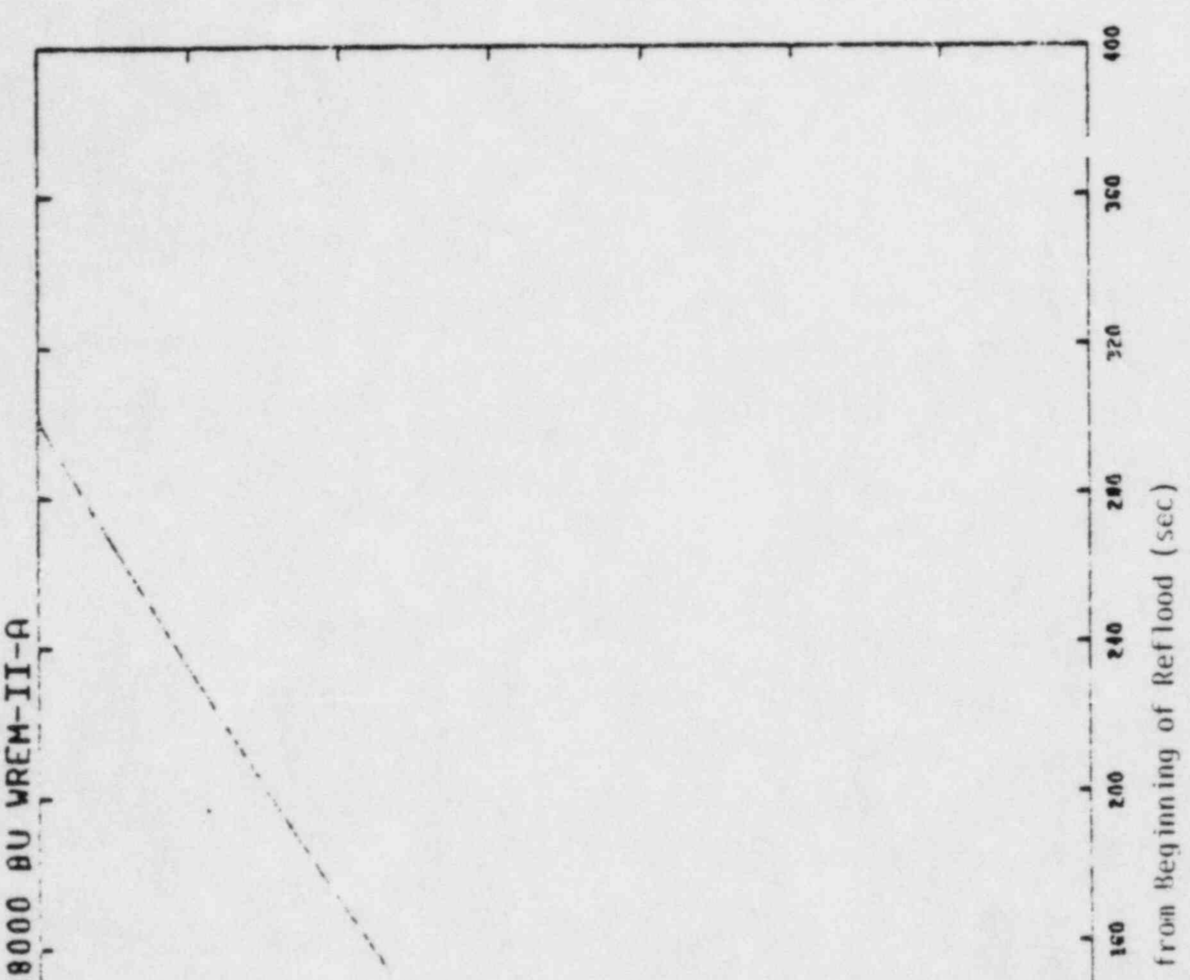

Figure 3.18 Reflood Core Mixture Level

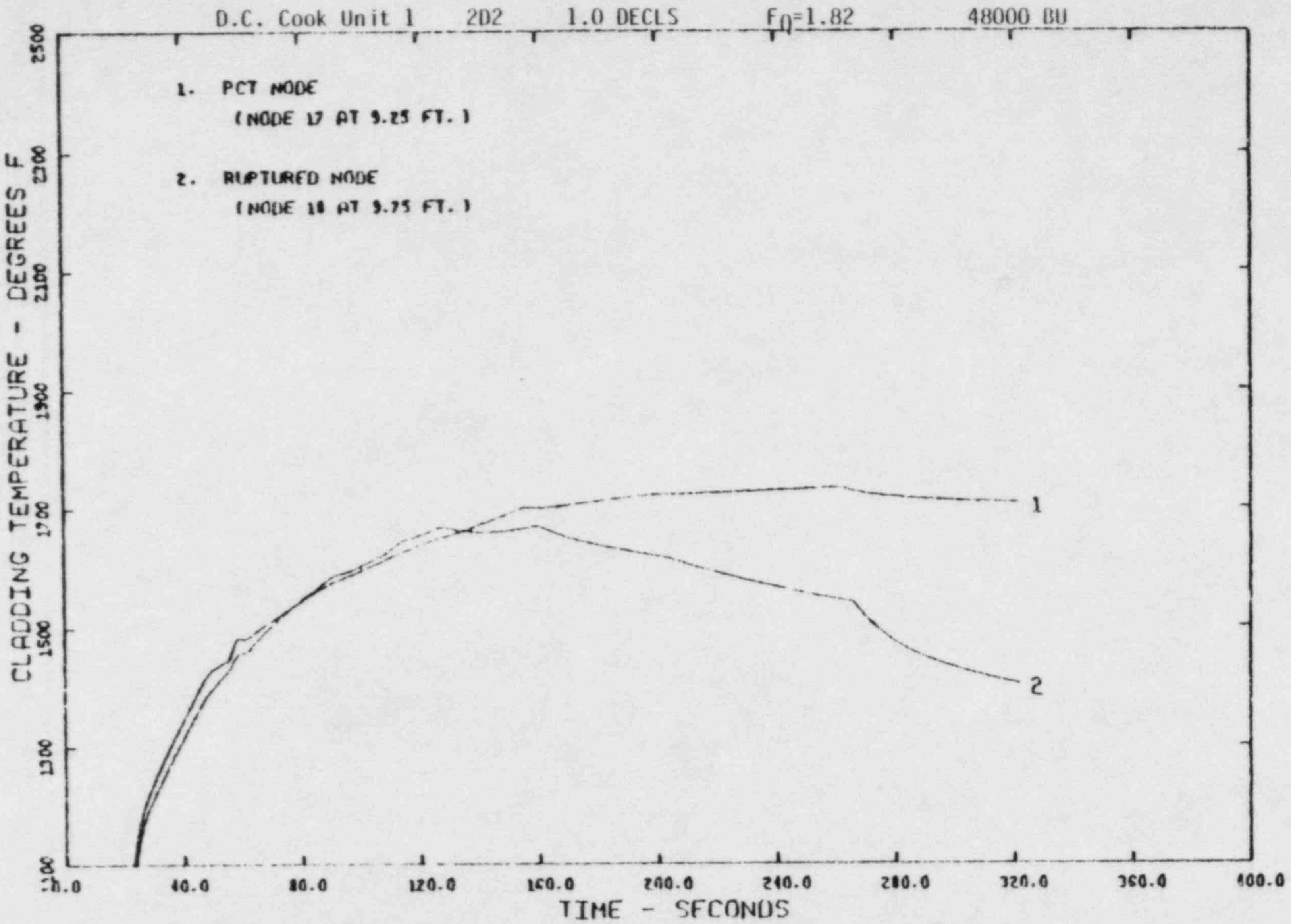

Figure 3.19 Cladding Surface Temperature During Heatup for ENC Fuel at 48 GWD/MTM Peak Pellet Burnup

4.0 CONCLUSIONS

The analysis of the limiting break (1.0 DECLS) for the D.C. Cook Unit 1 reactor with the ENC WREM-IIA and selected EXEM/PWR ECCS evaluation models shows that the reactor can operate at allowed total peaking F_Q^T of 1.82 and $F_{\Delta H}$ of 1.55 at a peak pellet burnup of 48 GWD/MTM and continue to meet the NRC 10 CFR 50.46 criteria with analyses performed in conformance to 10 CFR 50 Appendix K requirements. Operation within the ECCS allowed limits as defined in Figure 1.1 and Table 1.1 assures that the NRC acceptance criteria are met. That is:

(1) The calculated peak fuel cladding temperature does not exceed 2200°F.

(2) The calculated local cladding oxidation does not exceed 17% of the cladding thickness during or after quenching, and the temperature transient is terminated while the core geometry is amenable to cooling.

(3) The calculated core-wide reaction of cladding with water or steam does not exceed 1% of the total mass of zircaloy in the reactor.

(4) System long term cooling capabilities provided for previous cores will also cool ENC fueled cores.

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(2) U.S.N.R.C., "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Nuclear Power Reactors," 10 CFR 50.46 and Appendix K to 10 CFR 50. Federal Register, Volume 39, Number 3, January 4, 1974.

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(13) G.N. Lauben, "TOODEE2: A Two-Dimensional Time Dependent Fuel Element Thermal Analysis Program," NRC Report NUREG-75/057, May 1975.

(14) "Exxon Nuclear Company ECCS Cladding Swelling and Rupture Model," XN-NF-82-07(P), March 1982, Exxon Nuclear Company.

(15) Letter, H.G. Shaw (ENC) to H.L. Sobel (AEP), HGS:062:82, dated February 23, 1982.

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