DOCKET NO. 50-336

ATTACHMENT 1

MILLSTONE NUCLEAR POWER STATION, UNIT NO. 2

LARGE BREAK LOCA/ECCS PERFORMANCE RESULTS

JUNE, 1980

8006190610

LOSS OF COOLANT ACCIDENTS RESULTING FROM PIPING BREAKS WITHIN THE REACTOR COOLANT PRESSURE BOUNDARY

Introduction

The Acceptance Criteria for LOCA analysis is described in 10CFR50.46 [1] as follows:

1. The calculated fuel element peak clad temperature is below the requirement of 2200°F.

2. The amount of fuel element cladding that reacts chemically with water or steam does not exceed 1 percent of the total amount of Zircaloy in the reactor.

3. The clad temperature transient is terminated at a time when the core geometry is still amenable to cooling. The localized cladding oxidation limits of 17 percent are not exceeded during or after quenching.

4. The core remains amenable to cooling during and after the break.

5. The core temperature is reduced and decay heat is removed for an extended period of time, as required by the long lived radioactivity remaining in the core.

These criteria were established to provide significant margin in Emergency Core Cooling System (ECCS) performance following a LOCA.

Mathematical Model

The requirements of an acceptable ECCS evaluation model are presented in Appendix K of 10CFR50 [1].

Large Break LOCA Evaluation Model

The analysis of a large break LOCA Transient is divided into three phases: 1) blowdown, 2) refill, and 3) reflood. There are three distinct transients analyzed in each phase, namely the thermal-hydraulic transient in the RCS, the pressure and temperature transient within the Containment, and the pellet and clad temperature transient of the hottest fuel rod in the core. Based on these considerations, a system of interrelated computer codes has been developed for the analysis of the LOCA.

The description of the various aspects of the Westinghouse LOCA analysis methodology is given in Reference [2]. This document describes the major phenomena modeled, the interfaces among the computer codes, and the features of the codes which ensure compliance with the Acceptance Criteria. The SATAN-VI, WREFLOOD, COCO, and LOCTA-IV codes which are used in the LOCA analysis are described in detail in References [3] through [6]; code modifications are specified in References [7] through [11]. These codes are used to assess the core heat transfer geometry and to determine if the core remains amenable to cooling throughout and subsequent to the blowdown, refill, and reflood phases of the LOCA. The SATAN-VI computer code analyzes the thermal-hydraulic transient in the RCS during blowdown, and the WREFLOOD computer code is used to calculate this transient during the refill and reflood phases of the accident. The COCO computer code is used to calculate the Containment pressure transient throughout the LOCA analysis. Similarly, the LOCTA-IV computer code is used to compute the thermal transient of the hottest fuel rod during the entire analysis.

SATAN-VI is used to calculate the RCS pressure, enthalpy, density, and the mass and energy flow rates in the RCS, as well as steam generator energy transfer between the primary and secondary systems as a function of time during the blowdown phase of the LOCA. SATAN-VI also calculates the accumulator water flow rates and internal pressure and the pipe break mass and energy flow rates that are assumed to be vented to the Containment during blowdown. At the end of the blowdown phase, these data are transferred to the WREFLOOD code. The mass and energy release rates during blowdown are utilized in the COCO code for use in the determination of the Containment pressure response during this first phase of the LOCA. Additional SATAN-VI output data including the core flow rates and enthalpy, the core pressure, and the core power decay transient, are transferred to the LOCTA-IV code.

With initial information from the SATAN-VI code, WREFLOOD uses a system thermal-hydraulic model to determine the core flooding rate (i.e., the rate at which coolant enters the bottom of the core), the coolant pressure and temperature, and the core water level during the refill and reflood phases of the LOCA. WREFLOOD also calculates the mass and energy flow addition to the Containment through the break. Since the mass flow rate to the Containment depends upon the core flooding rate and the local core pressure, which is a function of the Containment backpressure, the WREFLOOD and COCO codes are interactively linked. WREFLOOD is also linked to the LOCTA-IV code in that thermal-hydraulic parameters from WREFLOOD are used by LOCTA-IV in its calculation of the fuel temperature. LOCTA-IV is used throughout the analysis of the LOCA transient to calculate the fuel clad temperature and metal-water reaction of the hottest rod in the core.

The large break analysis was performed with the Westinghouse evaluation model which includes modifications delineated in References [7, 8, 10 and 12]. Reactor Coolant pumps are assumed to continue to run during blowdown unless otherwise noted.

Results

Large Break Results

Based on the results of the LOCA sensitivity studies, (References [7] and [13]) the limiting large break will be the double ended cold leg guillotine (DECLG). This conclusion is confirmed for the Millstone 2 plant specifically by docketed analyses (Reference 14). Therefore, only the DECLG break need be considered in the large break ECCS performance analysis. Calculations were performed for a range of Moody break discharge coefficients. The results of these calculations are summarized in Tables 1 and 2. Containment parameters utilized in the analyses are provided in Table 3.

The maximum clad temperature calculated for a large break is 2111°F which is less than the Acceptance Criteria limit of 2200°F of 10CFR50.46. Maximum local metal-water reaction is 5.5 percent which is well below the embrittlement limit of 17 percent as required by 10CFR50.46. Total core metal-water reaction is less than 0.3 percent for all breaks, as compared with the 1 percent criterion of 10CFR50.46, and the clad temperature transient is terminated at a time when the core geometry is still amenable to cooling. As a result, the core temperature will continue to drop and the ability to remove decay heat generated in the fuel for an extended period of time will be maintained.

Figures 1 through 26 present the parameters of principal interest from the large break ECCS analyses. For all cases analyzed transients of the following parameters are presented:

1. Hot spot clad temperature.

2. Coolant pressure in the reactor core.

3. Water level in the core and downcomer during reflood.

4. Containment pressure transient

For the limiting break analyzed, the following additional transient parameters are presented in the figures:

1. Core flow during blowdown (inlet and outlet).

2. Fuel rod heat transfer coefficients.

3. Hot spot fluid temperature.

4. Mass released to Containment during blowdown.

5. Energy released to containment during blowdown.

6. Fluid quality in the hot assembly during blowdown.

7. Mass velocity during blowdown.

8. Safety injection tank water flow rate into RCS during blowdown (per tank).

9. Pumped safety injection water flow rate during reflood.

10. Core reflooding rate.

REFERENCES

1. "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Cooled Nuclear Power Reactors," 10CFR50.46 and Appendix K of 10CFR50. Federal Register, Volume 39, Number 3, January 4, 1974.

2. Bordelon, F. M., Massie, H. W. and Zordan T. A., "Westinghouse ECCS Evaluation Model - Summary," WCAP-8339, July 1974.

3. Bordelon, F. M., et al., "SATAN-VI Program: Comprehensive Space-Time Dependent Analysis of Loss of Coolant," WCAP-8302 (Proprietary) and WCAP-8306 (Non-Proprietary), June 1974.

4. Kelly, R. D., et al., "Calculational Model for Core Reflooding After a Loss of Coolant Accident (WREFLOOD Code)," WCAP-8170 (Proprietary) and WCAP-8171 (Non-Proprietary), June 1974.

5. Bordelon, F. M. and Murphy, E. T., "Containment Pressure Analysis Code (COCO)," WCAP-8327 (Proprietary) and WCAP-8326 (Non-Proprietary), June 1974.

6. Bordelon, F. M., et al., "LOCTA-IV Program: Loss of Coolant Transient Analysis," WCAP-8301 (Proprietary) and WCAP-8305 (Non-Proprietary), June 1974.

7. Ferguson, K. L., and Kemper, R. M., ECCS Evaluation Model for Westinghouse Fuel Reloads of Combustion Engineering NSSS, WCAP-9528 (Proprietary) and WCAP-9529 (Non-Proprietary), June 1979.

8. Ferguson, K. L., and Kemper, R. M., Addendum to ECCS Evaluation Model for Westinghouse Fuel Reloads of Combustion Engineering NSSS, October 1979.

9. Bordelon, F. M., et al., "Westinghouse ECCS Evaluation Model - Supplementary Information," WCAP-8471 (Proprietary) and WCAP-8472 (Non-Proprietary), April 1975.

10. "Westinghouse ECCS Evaluation Model - October 1975 Version," WCAP-8622 (Proprietary) and WCAP-8623 (Non-Proprietary), November 1975.

11. Letter NS-CE-924, dated January 23, 1976, C. Eicheldinger (Westinghouse) to D. B. Vassallo (NRC).

12. Eicheldinger, C., "Westinghouse ECCS Evaluation Model,, February 1978 Version," WCAP-9220-P-A (Proprietary Version), WCAP-9221-P-A (Non-Proprietary Version), February 1978.

13. Salvatori, R., "Westinghouse ECCS - Plant Sensitivity Studies, WCAP-8340 (Proprietary) and WCAP-8356 (Non-Proprietary), July 1974.

14. W. G. Counsil to R. Reid, Docket No. 50-336, March 30, 1979.

TABLE 1

LARGE BREAK

TIME SEQUENCE OF EVENTS

	C_D=0.8 DECLG (Sec)	C_D=0.6 DECLG (Sec)	C_D=0.4 DECLG (Sec)	C_D=0.6 DECLG RC Pumps Tripped (Sec)
START	0.0	0.0	0.0	0.0
S. I. Signal*	0.6	0.69	0.85	0.68
S. I. Tank Injection	13.3	15.7	21.6	16.4
End of Blowdown	20.19	21.65	29.07	22.43
Bottom of Core Recovery	33.2	34.6	43.0	36.4
S. I. Tank Empty	64.2	66.8	73.2	67.5
End of Bypass	20.18	21.65	29.07	22.43

*from containment pressure sensor

TABLE 2

LARGE BREAK

Results	C_D=0.8 DECLG	C_D=0.6 DECLG	C_D=0.4 DECLG	C_D=0.6 RC Pumps Tripped
Peak Clad Temp. °F	1985	2111	2000	1976
Peak Clad Location, Ft.	7.0	7.5	7.0	7.0
Local Zr/H_2O Rxn(max)%	3.7	5.5	3.9	3.6
Local Zr/H_2O Location, Ft.	7.5	7.5	7.0	7.0
Total Zr/H_2O Rxn %	<0.3	<0.3	<0.3	<0.3
Hot Rod Burst Time, sec	36.9	31.6	53.2	41.2
Hot Rod Burst Location, Ft.	5.70	5.70	6.25	5.70

Calculation Assumptions

NSSS Power, Mwt, 102% of	2700
Peak Core Linear Power, kw/ft	15.6
S.I. Tank Actuation Pressure, psia	215
S.I. Tank Water Volume, ft^3 per tank	1107

TABLE 3

Millstone Unit 2
Containment Physical Parameters

Net Free Volume	1.938×10^6 ft^3
Containment Initial Conditions:	
Humidity	99 %
Containment Temperature	60°F
Enclosure Building Temperature	60°F
Ground Temperature	40°F
Initial Pressure	14.7 psia
Initial Time for:	
Spray Flow	26 seconds
Fans (3)	0.0 seconds
Additional Fan	14.0 seconds
Containment Spray Water:	
Temperature	50°F
Flow Rate (Total, 2 pumps)	3300 gpm

Fan Cooling Capacity (Per Fan)

Vapor Temperature (°F)	Capacity (BTU/Sec)
60	0.0
145	3360.0
165	5280.0
300	28800.0
350	32400.0

Containment Heat Absorbing Surfaces

1. Surface Areas and Thicknesses
   a. Shell and dome - 71,870 Ft^2
      (1) Paint - 0.003 In. (one side exposed to containment atmosphere)
      (2) Carbon steel - 0.25 In.
      (3) Concrete - 3.0 Ft. (one side exposed to enclosure building atmosphere)

   b. Unlined Concrete - 62,800 Ft^2
      (1) Concrete - 2.0 Ft. (one side exposed to containment atmosphere, one side insulated)

   c. Galvanized Steel - 120,000 Ft^2
      (1) Zinc - 0.0036 In. (one side exposed to containment atmosphere)
      (2) Carbon steel - 0.20 In. (one side insulated)

TABLE 3 (Cont'd.)

Millstone Unit 2
Containment Physical Parameters

d. Painted Thin Steel - 56,850 Ft^2
   (1) Paint - 0.003 In. (one side exposed to containment atmosphere)
   (2) Carbon steel - 0.2 In. (one side insulated)

e. Painted Steel - 32,600 Ft^2
   (1) Paint - 0.003 In. (one side exposed to containment atmopshere)
   (2) Carbon steel - 0.26 In. (one side insulated)

f. Painted Steel - 22,425 Ft^2
   (1) Paint - 0.003 In. (one side exposed to containment atmosphere)
   (2) Carbon steel - 0.86 In. (one side insulated)

g. Painted Thick Steel - 4,230 Ft^2
   (1) Paint - 0.003 In. (one side exposed to containment atmosphere)
   (2) Carbon steel - 2.94 In. (one side insulated)

h. Containment Penetration Area - 3,000 Ft^2
   (1) Paint - 0.003 In. (one side exposed to containment atmosphere)
   (2) Carbon steel - 0.75 In.
   (3) Concrete - 3.75 Ft. (one side exposed to enclosure building atmosphere)

i. Stainless Steel Line Concrete - 8,340 Ft^2
   (1) Stainless steel - 0.25 In. (one side exposed to containment atmosphere)
   (2) Concrete - 2.0 Ft. (one side insulated)

j. Base Slab - 11,130 Ft^2
   (1) Concrete - 8.0 Ft. (one side exposed to containment sump, one side exposed to ground)

k. Neutron Shield - 1400 Ft^2
   (1) Stainless steel - 0.024 Ft. (both sides exposed to containment atmosphere)

2. Thermal Properties

Material	Conductivity (BTU/hr-ft-°F)	Heat Capacity (BTU/ft³-°F)
a. Concrete	2.0	36
b. Carbon Steel	35.0	55
c. Stainless Steel	10.0	62
d. Paint	1.5	32
e. Zinc	70.0	45

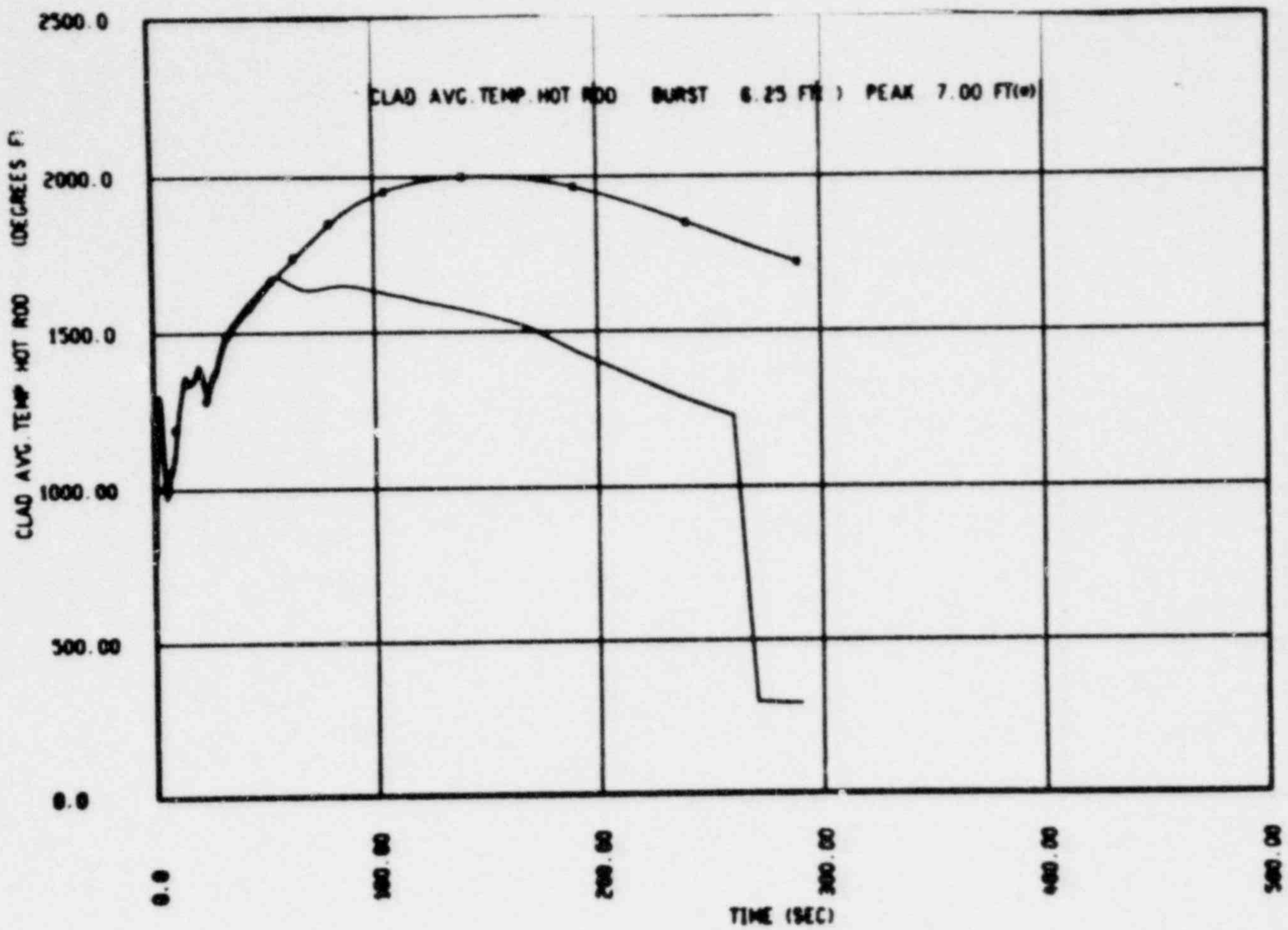

FIGURE 1 - HOT SPOT CLAD TEMPERATURE, 0.4 DECLG

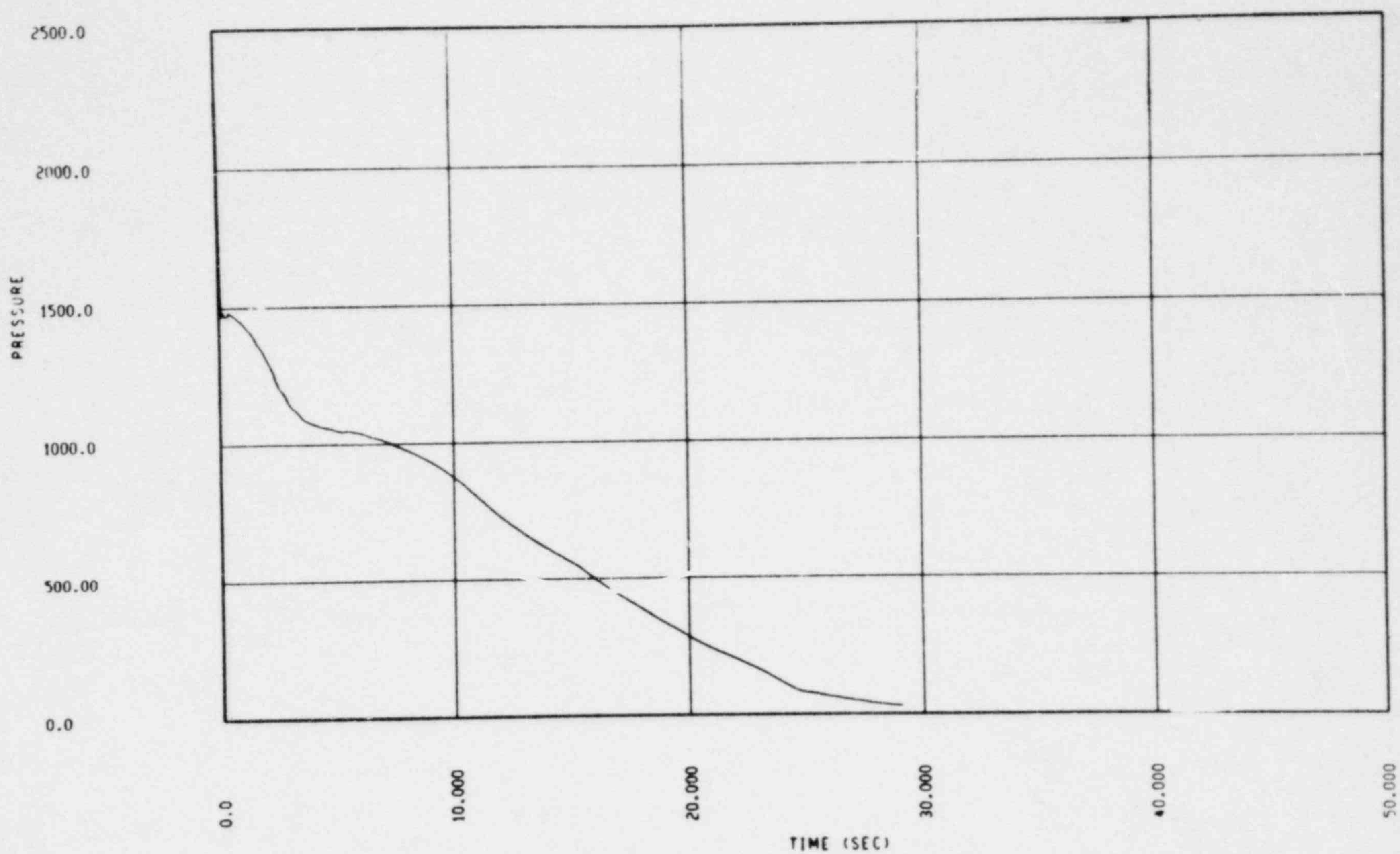

FIGURE 2 - REACTOR COOLANT PRESSURE, 0.4 DECLG

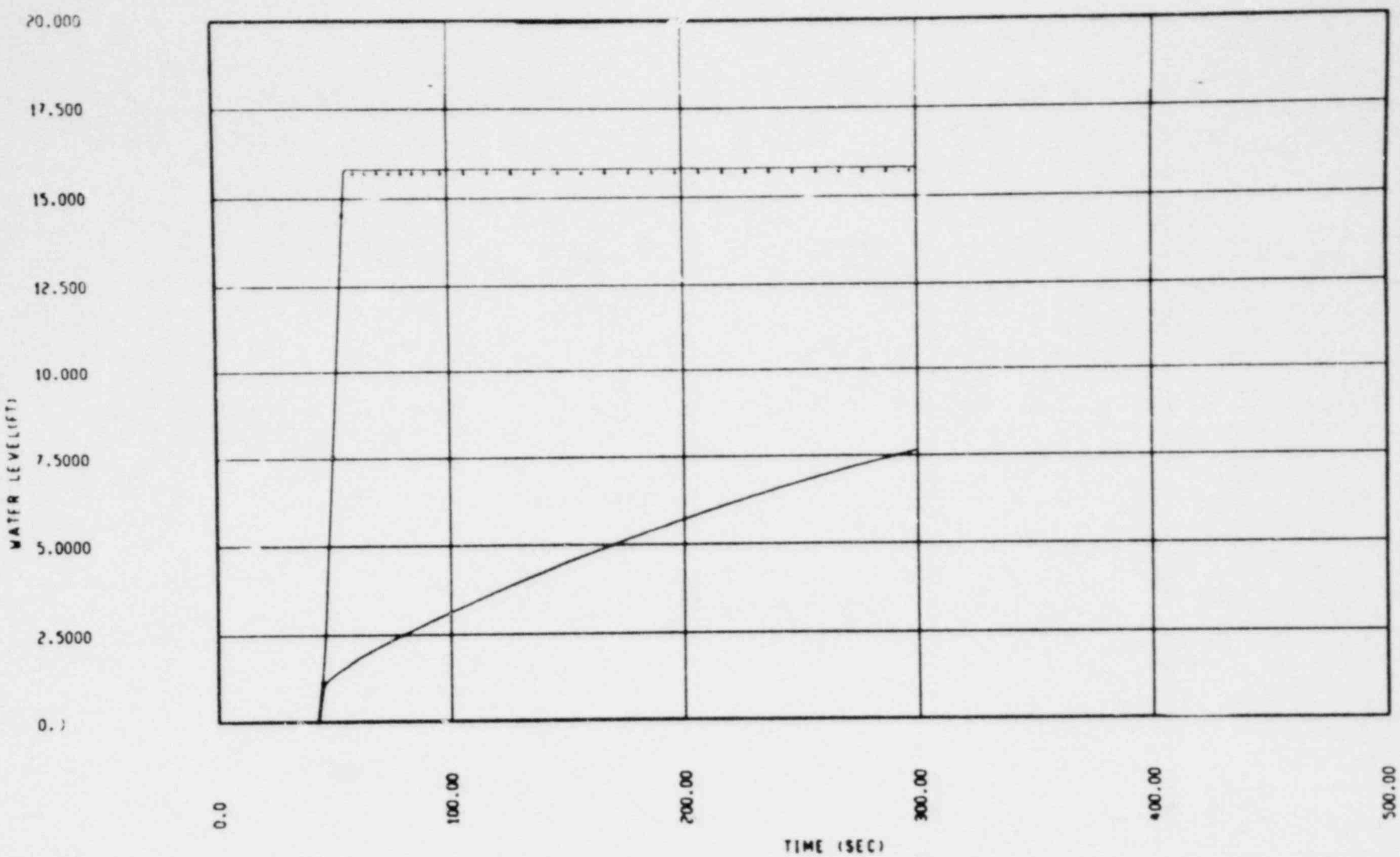

FIGURE 3 - WATER LEVEL, 0.4 DECLG

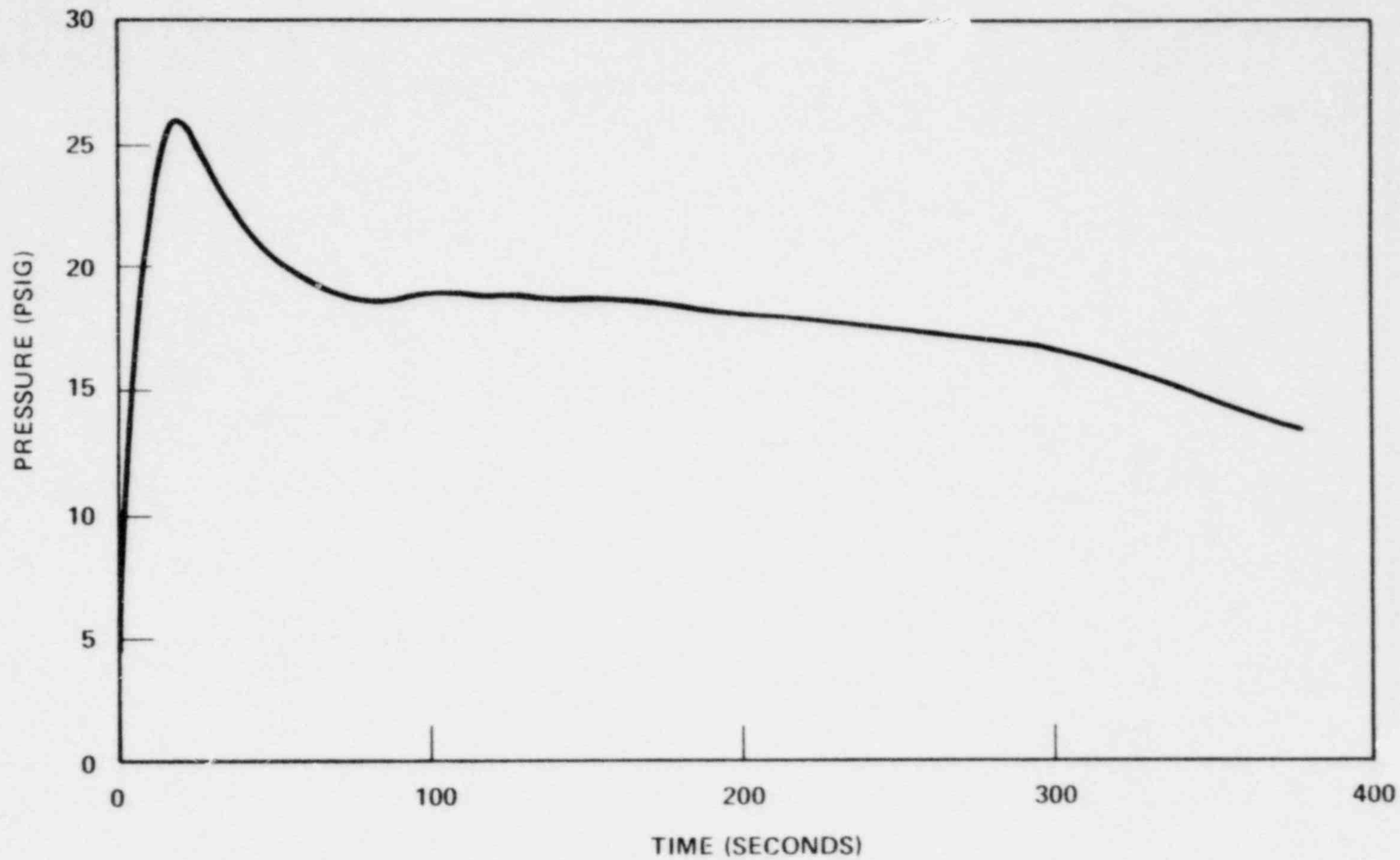

Figure 4 Containment Pressure, C_D = 0.4 DECLG

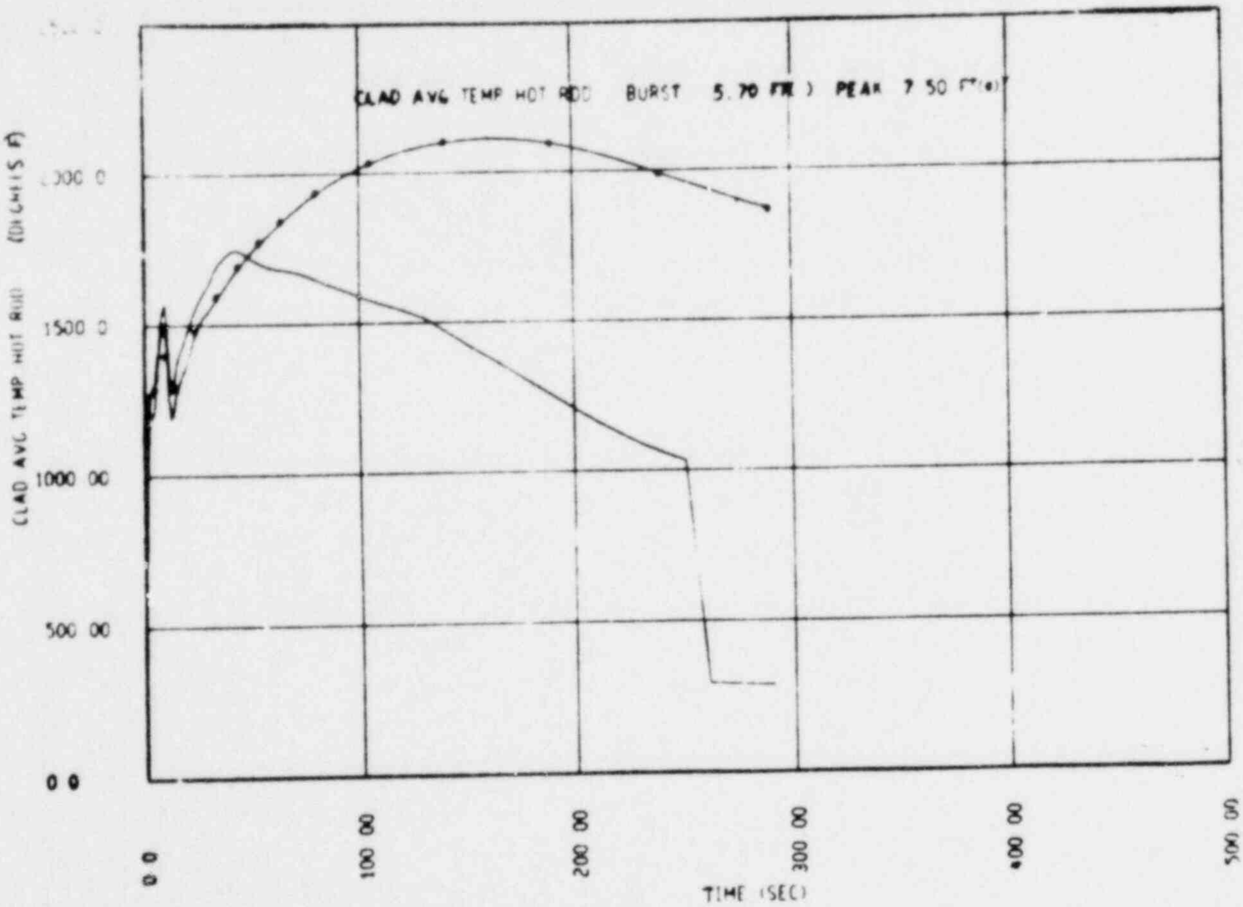

FIGURE 5 - HOT SPOT CLAD TEMPERATURE, 0.6 DECLG

FIGURF 6 - REACTOR COOLANT PRESSURE, 0.6 DECLG

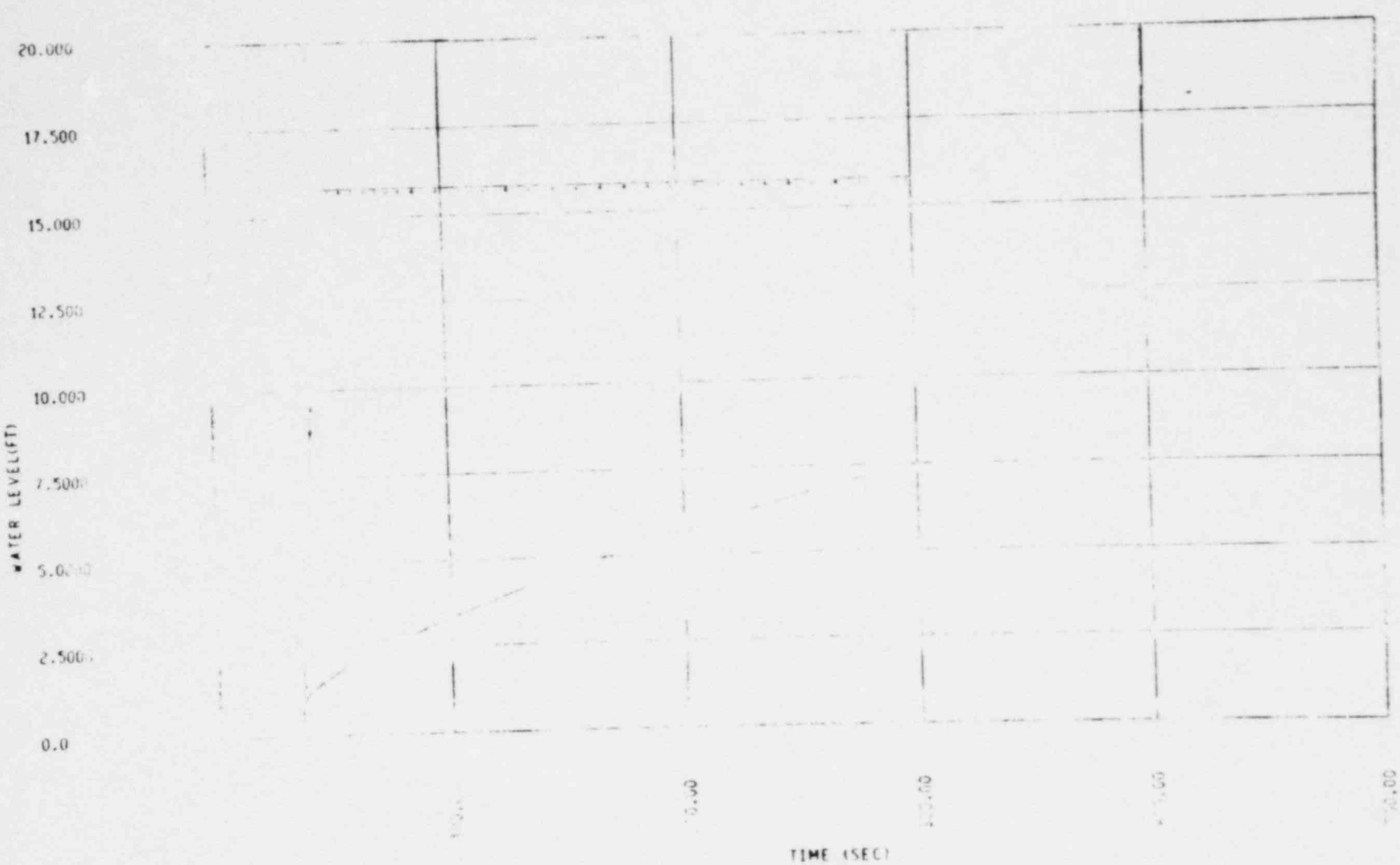

FIGURE 7 - WATER LEVEL, 0.6 DECLG

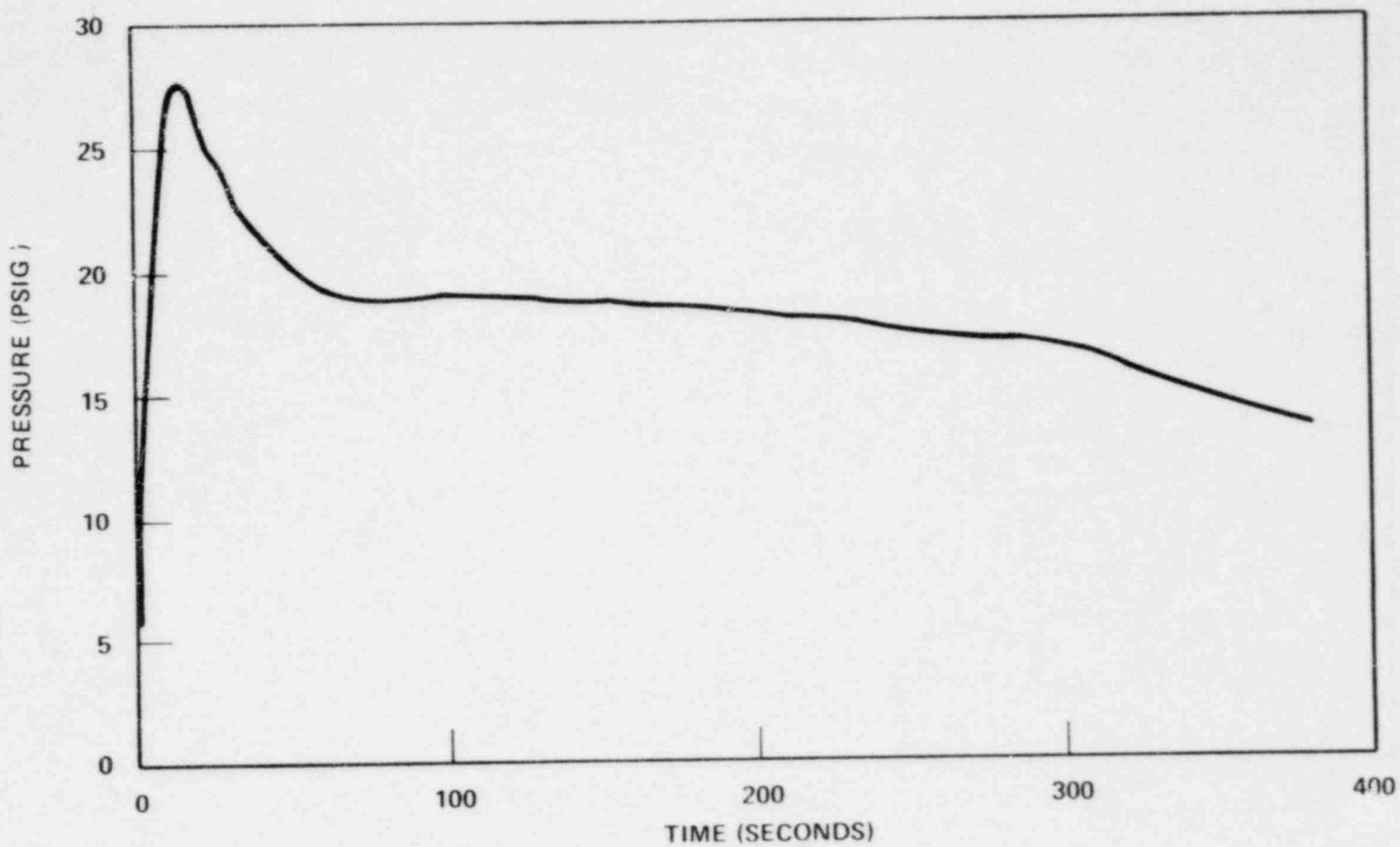

Figure 8 Containment Pressure, C_D = 0.6 DECLG

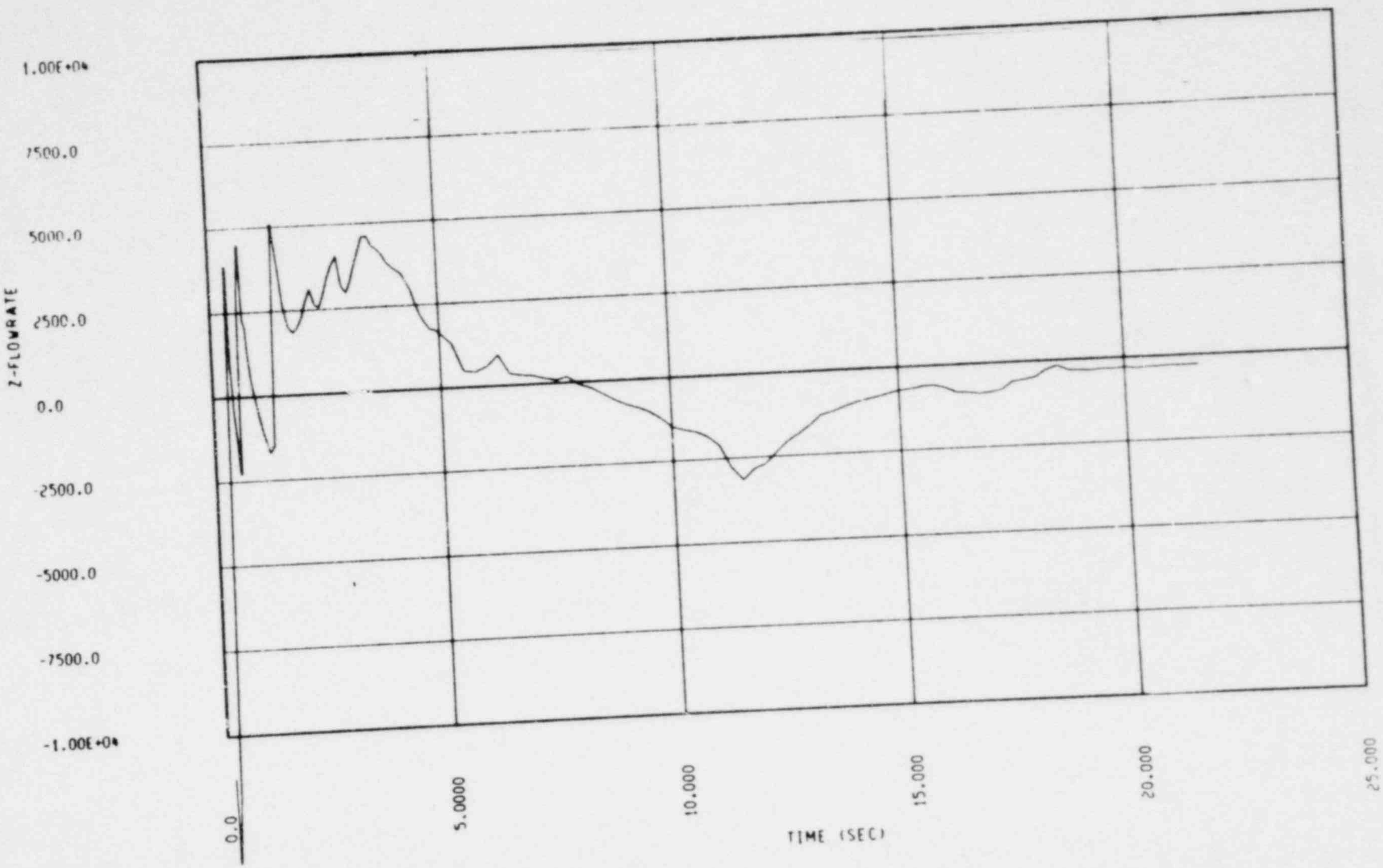

FIGURE 9 - CORE FLOW DURING BLOWDOWN, 0.6 DECLG

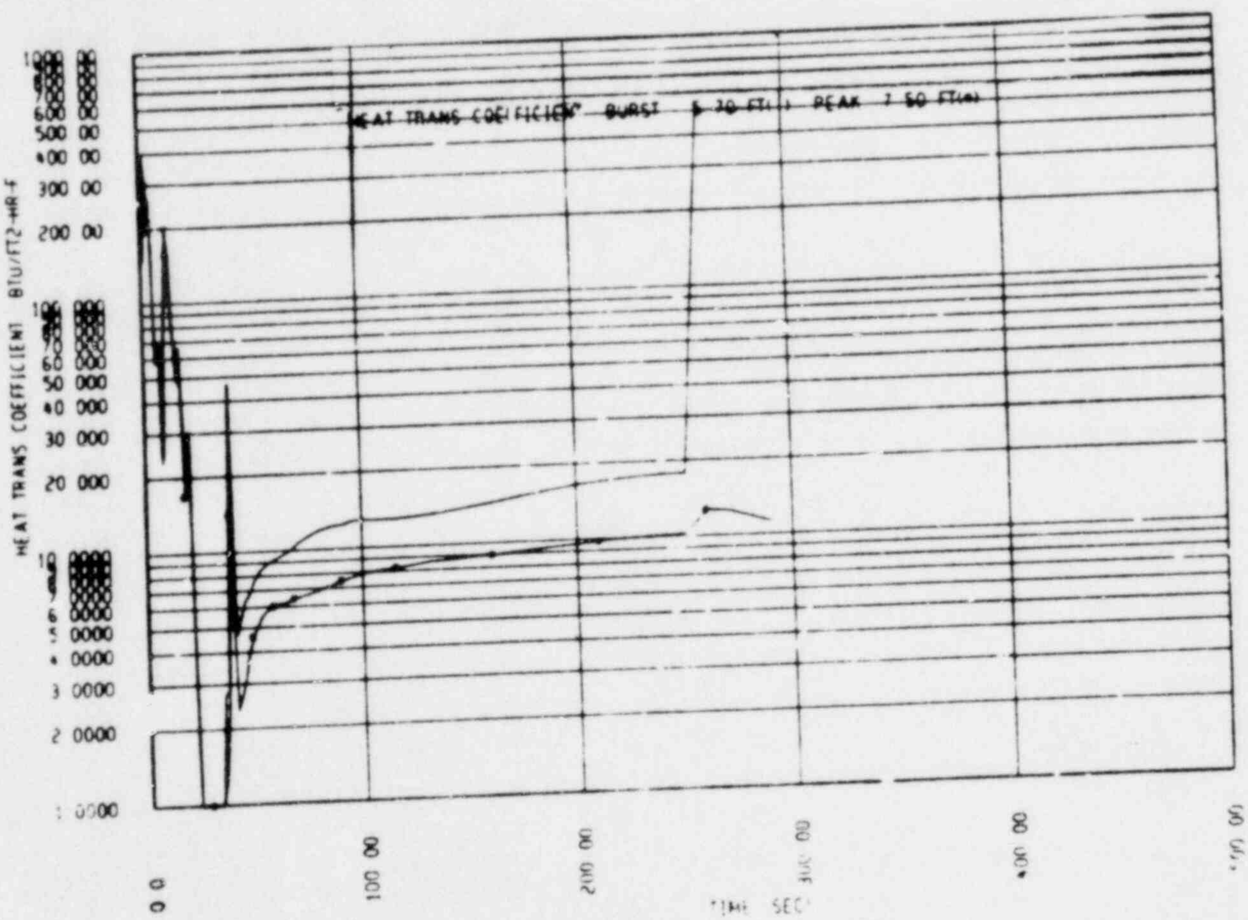

FIGURE 10 - FUEL ROD HEAT TRANSFER COEFFICIENTS, 0.6 DECLG

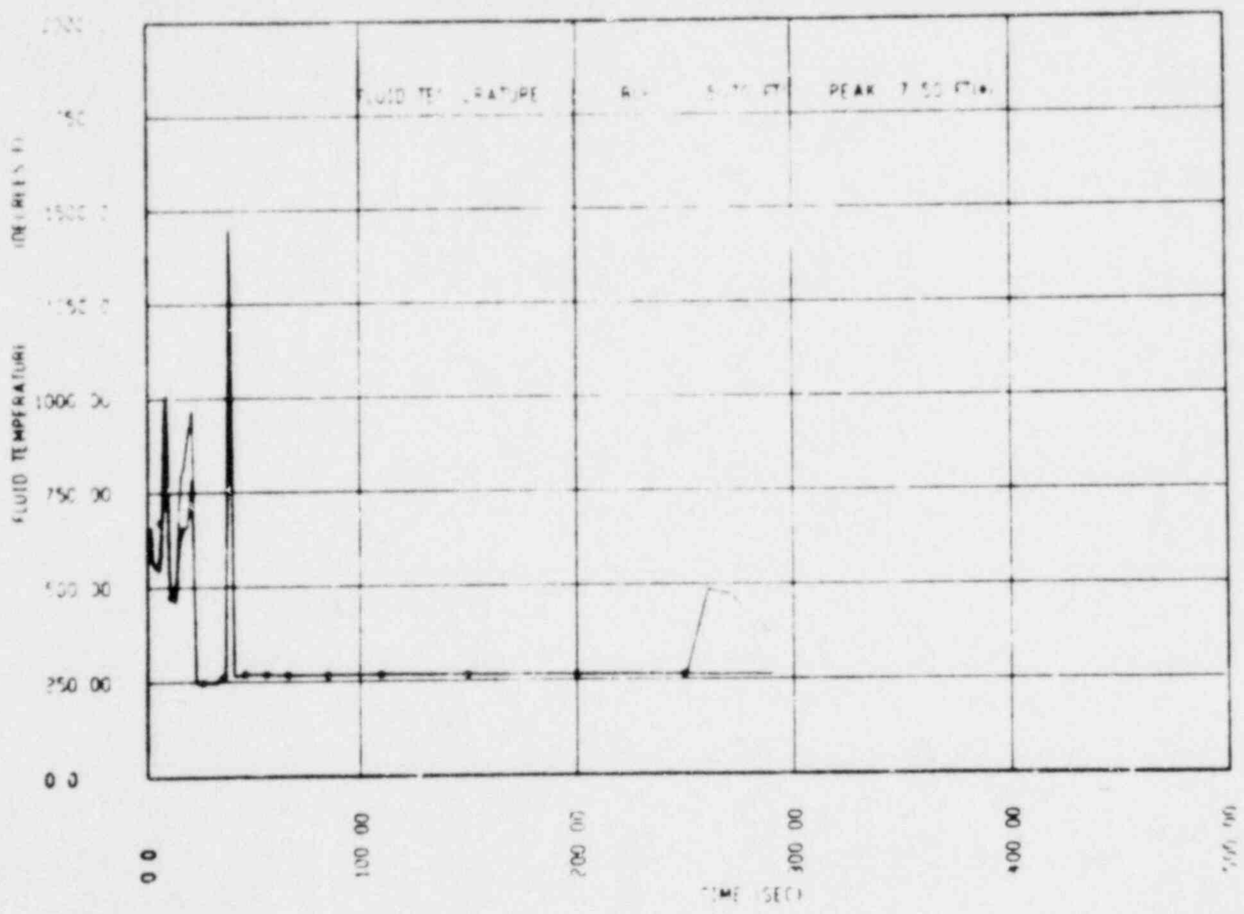

FIGURE 11 - HOT SPOT FLUID TEMPERATURE, 0.6 DECLG

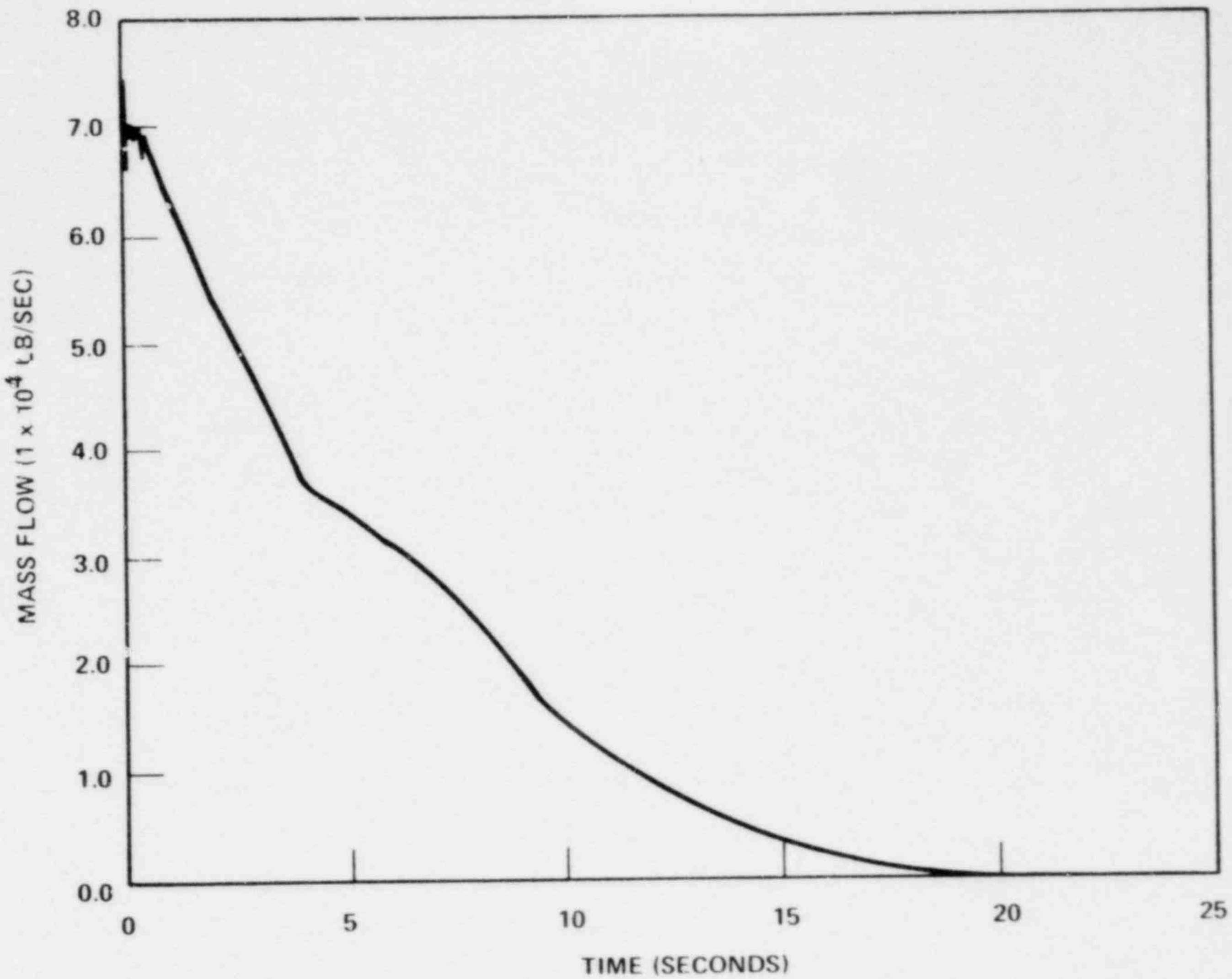

Figure 12 Mass Flow Rate Into Containment, C_D = 0.6 DECLG

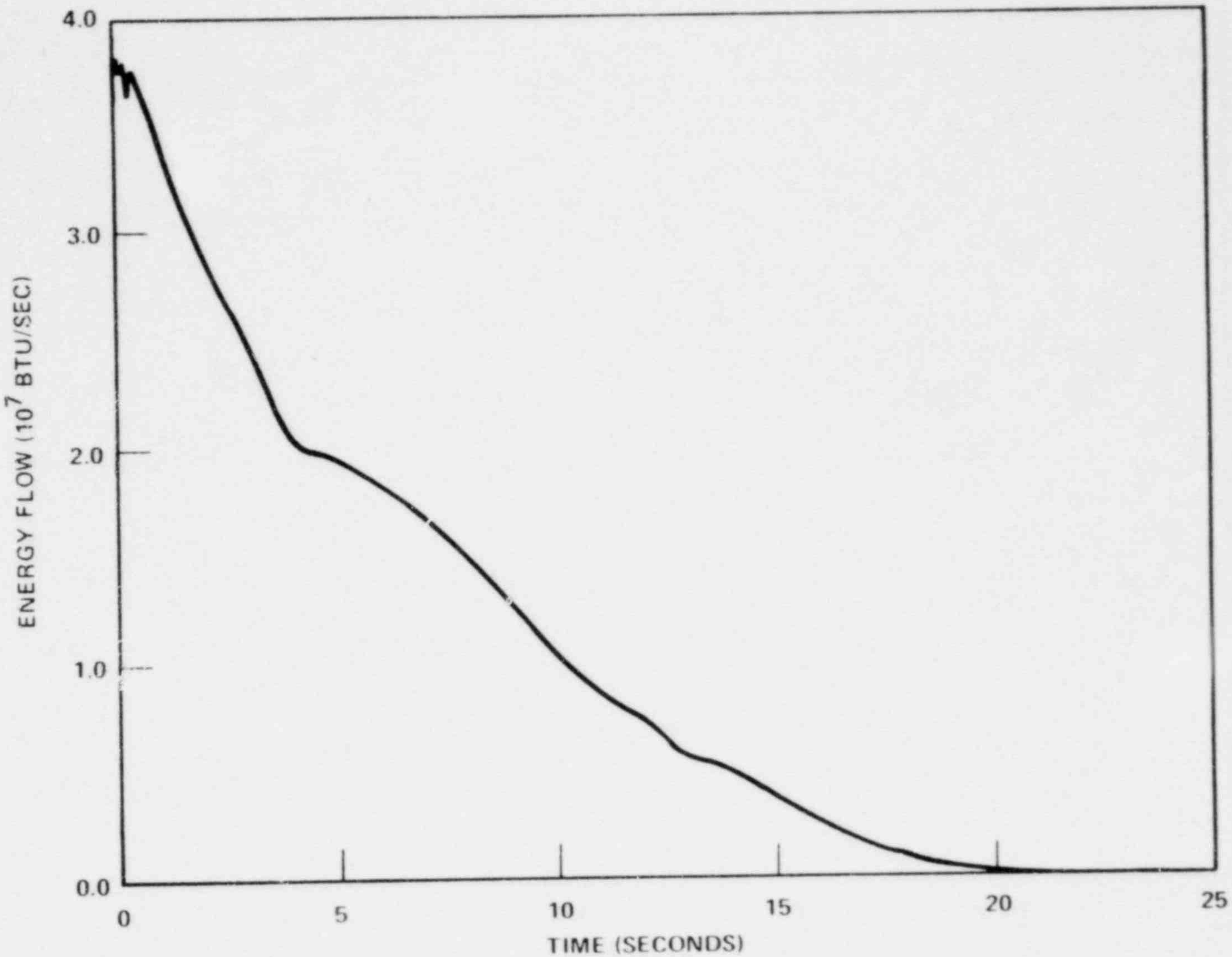

Figure 13 Energy Flow Rate into Containment, $C_D = 0.6$ DECLG

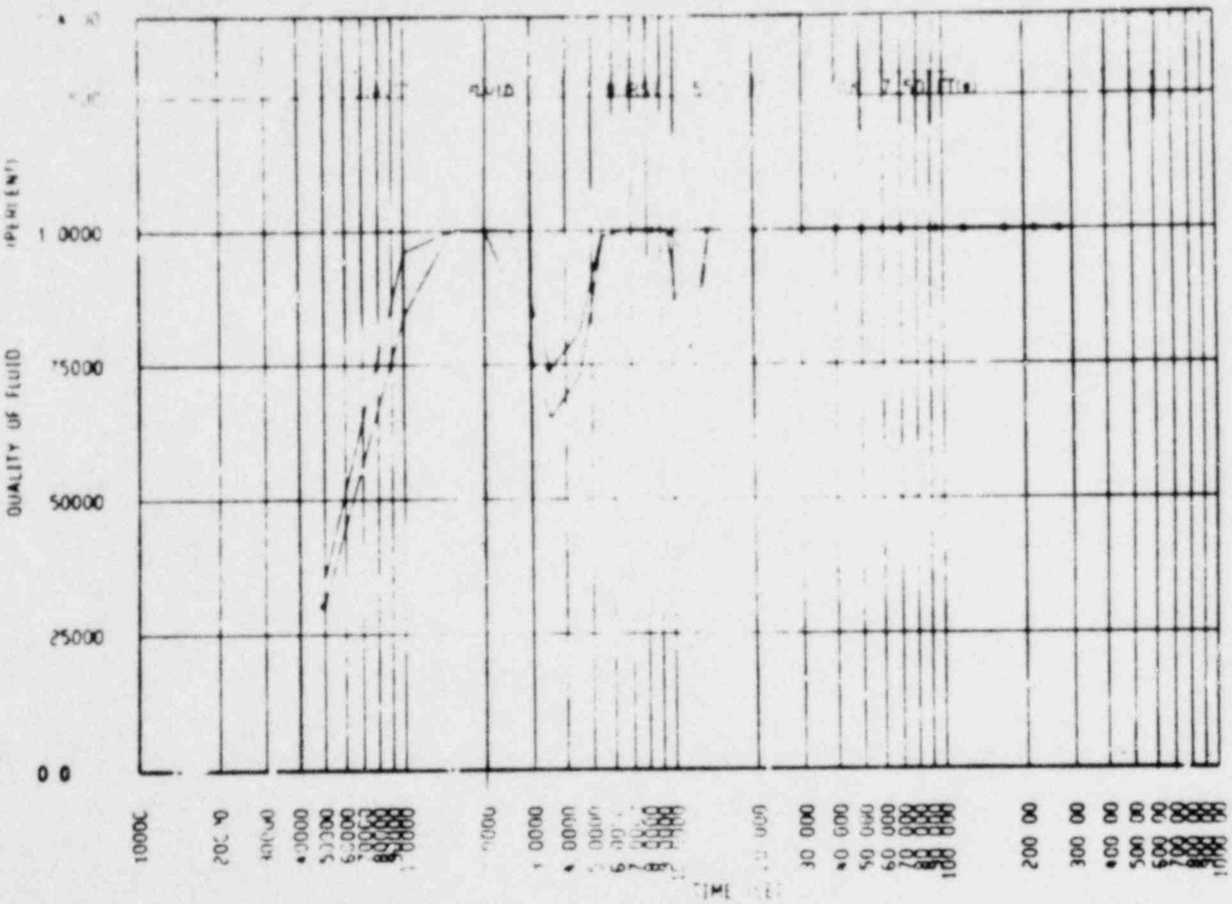

FIGURE 14 - FLUID QUALITY IN THE HOT ASSEMBLY, 0.6 DECLG

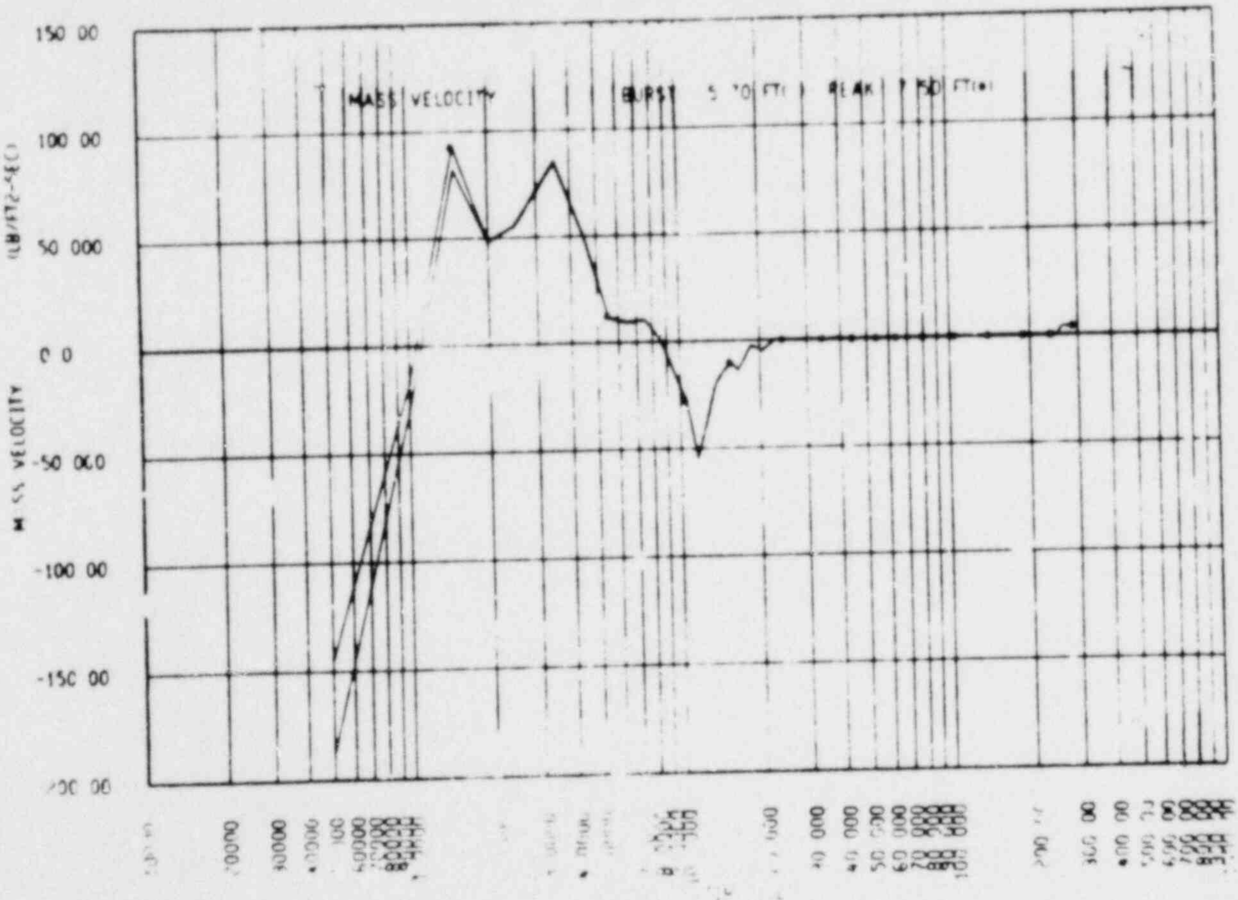

FIGURE 15 - MASS VELOCITY DURING BLOWDOWN, 0.6 DECLG

16

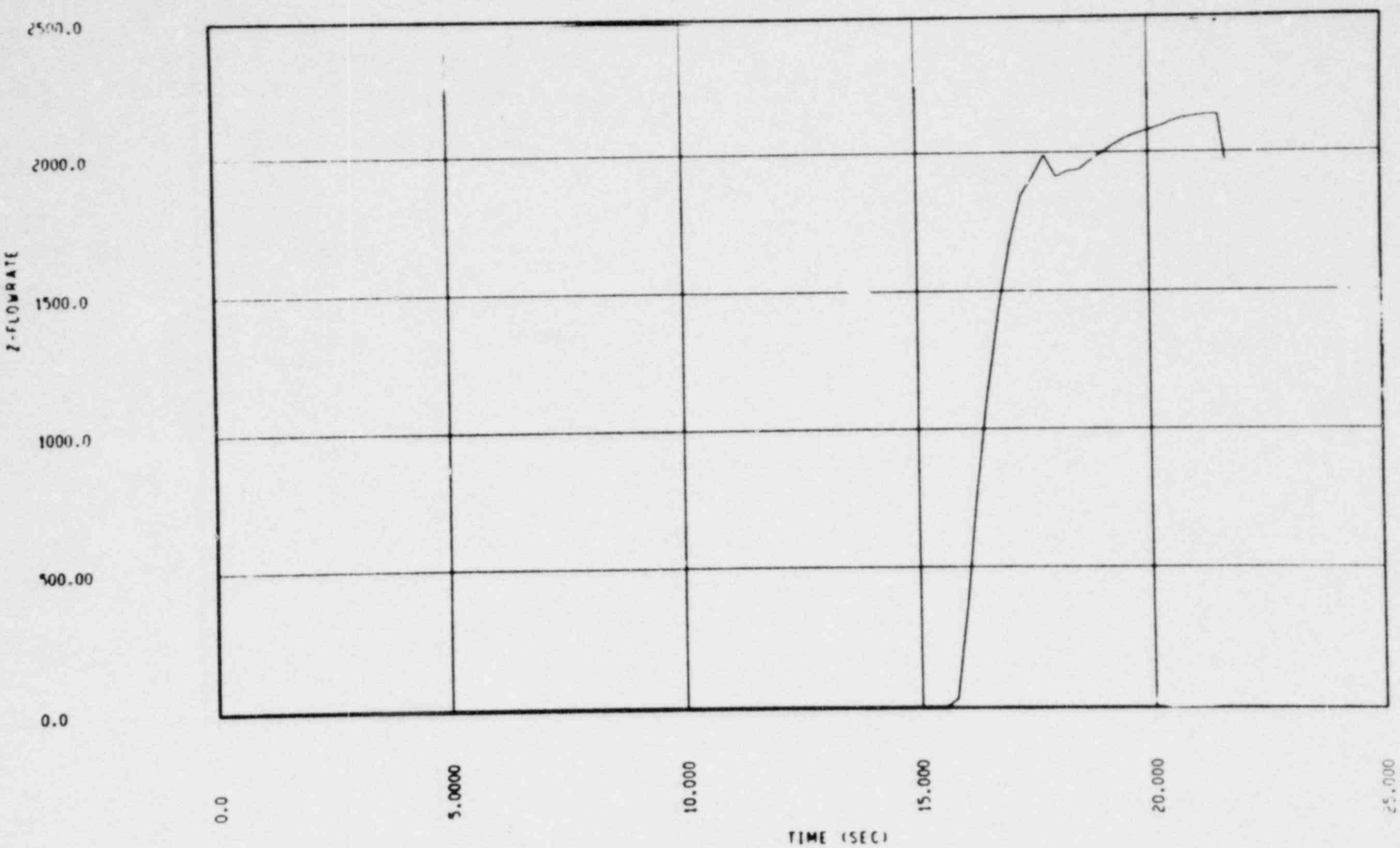

FIGURE 16 - SAFETY INJECTION TANK FLOW RATE, 0.6 DECLG

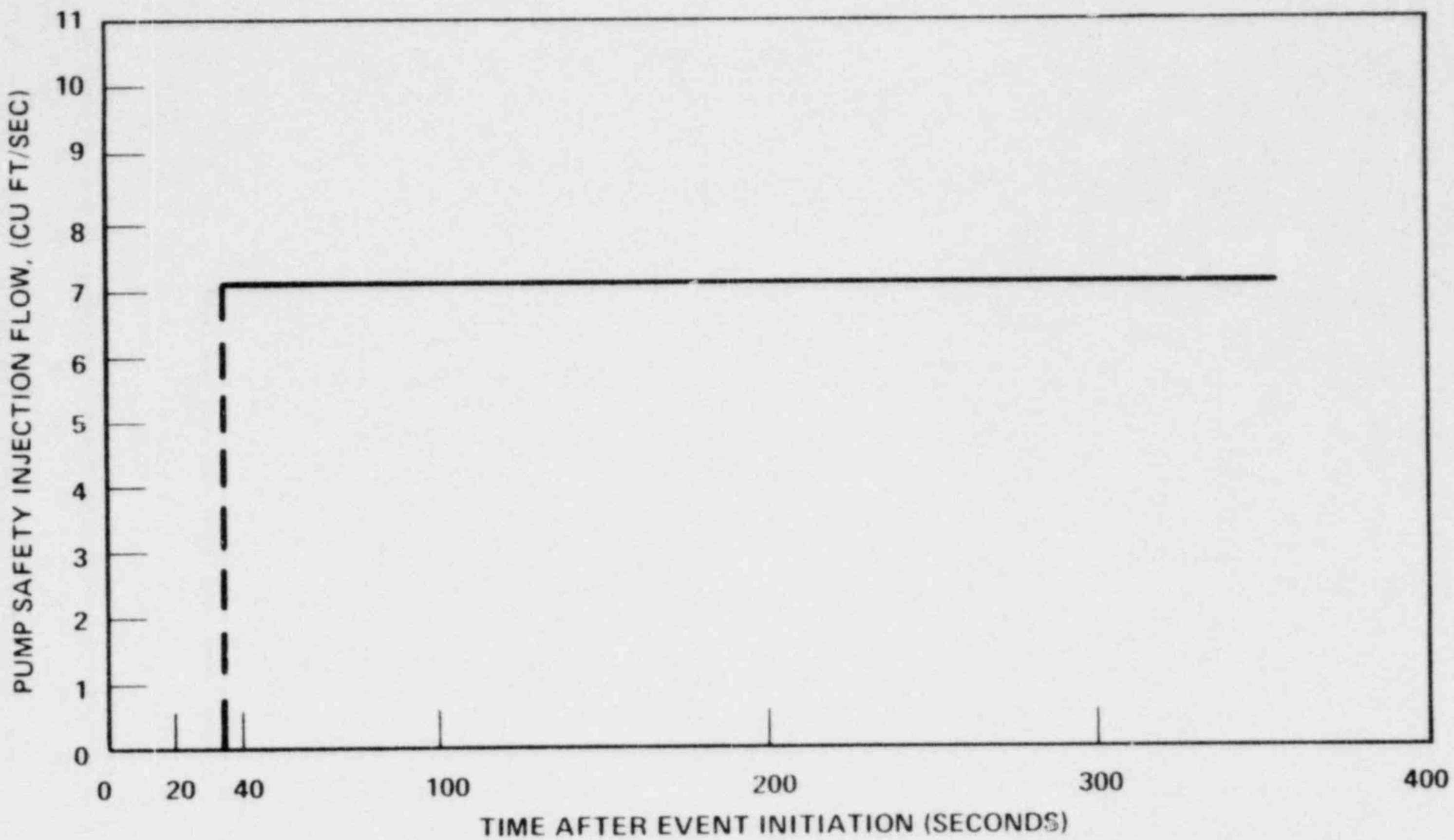

Figure 17 Pumped SI Flow During Reflood (C_D = 0.6 DECLG)

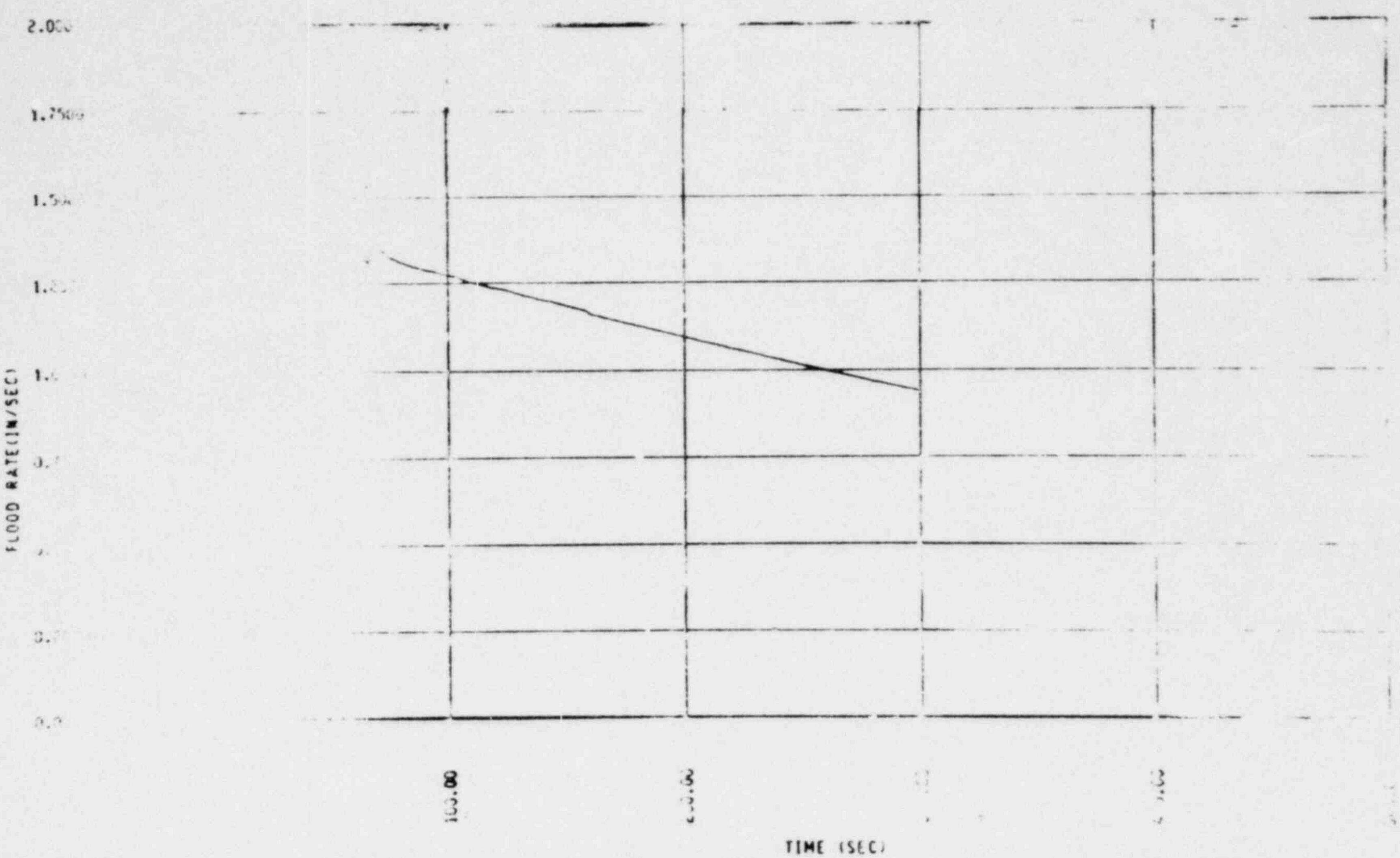

FIGURE 18 - CORE REFLOODING RATE, 0.6 DECLG

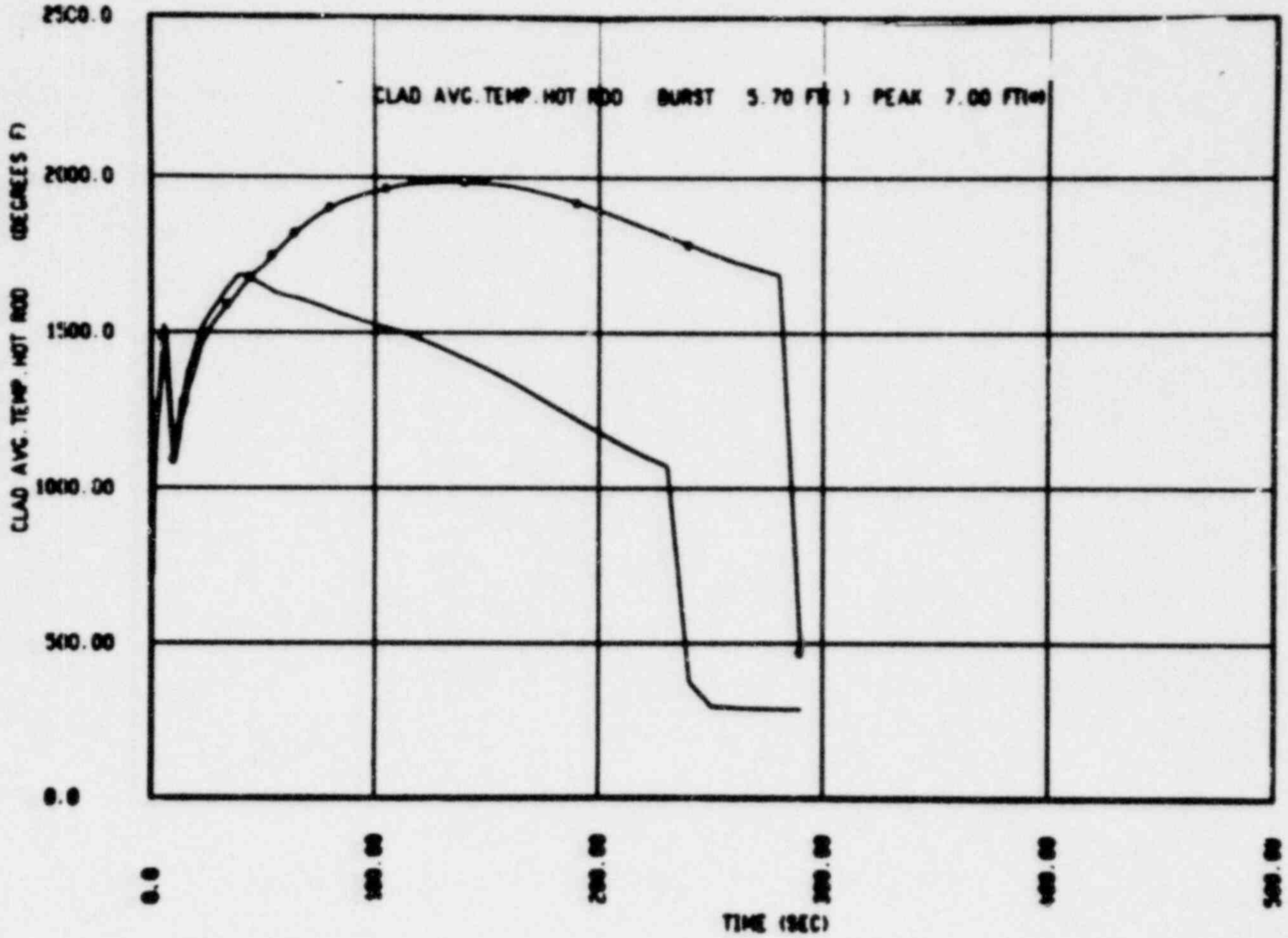

FIGURE 19 - HOT SPOT CLAD TEMPERATURE, 0.8 DECLG

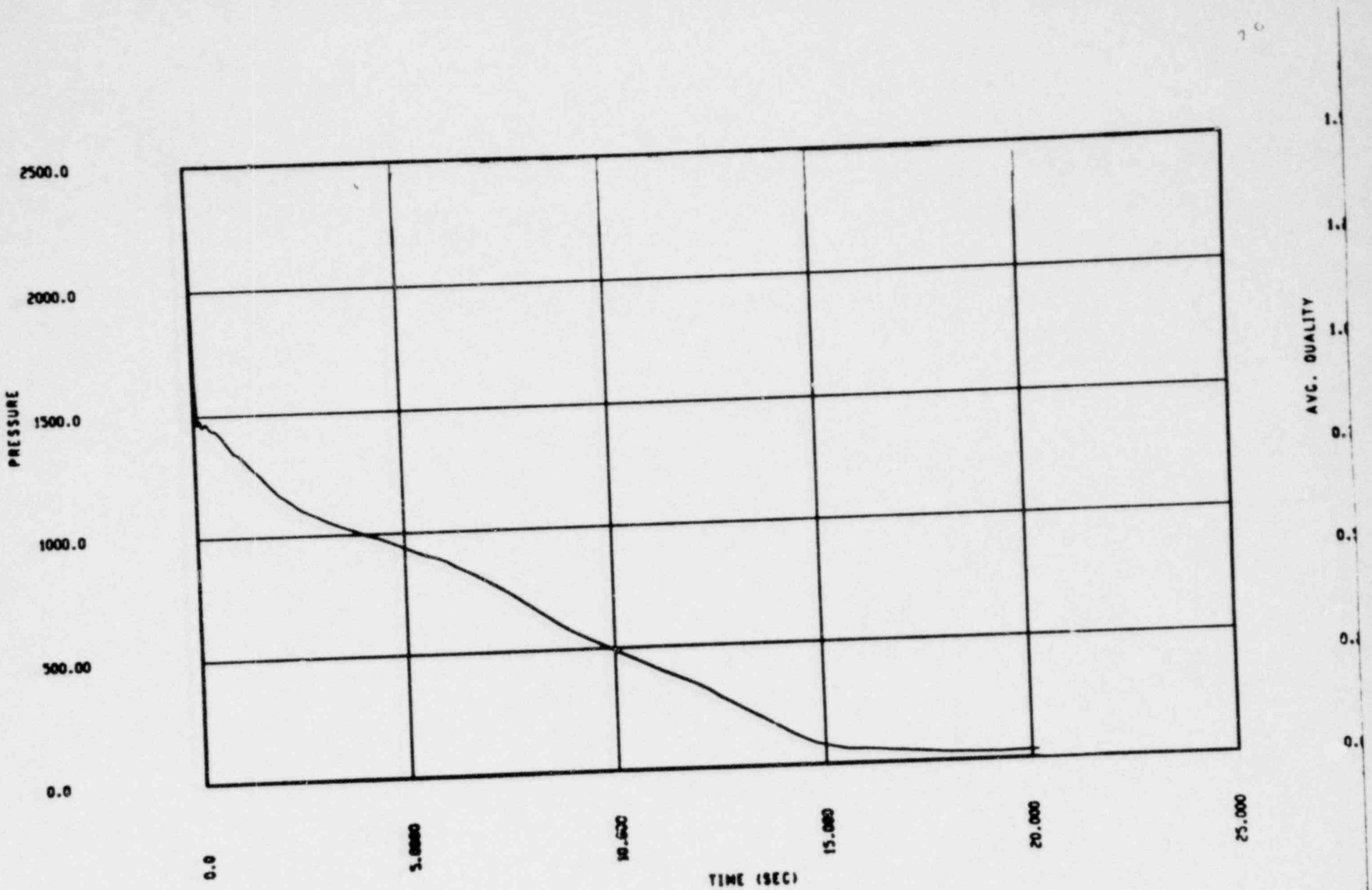

FIGURE 20 - REACTOR COOLANT PRESSURE, 0.8 DECLG

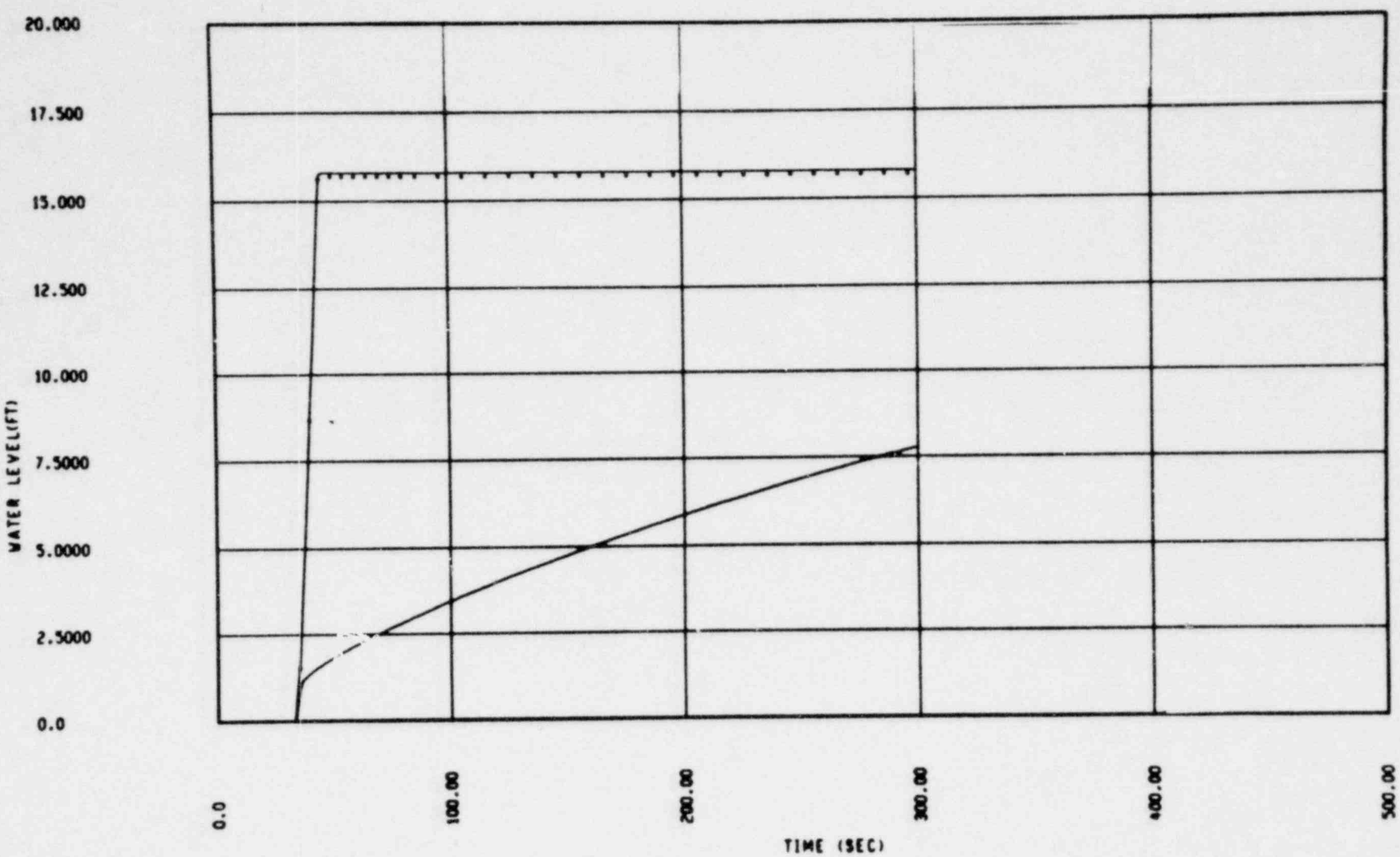

FIGURE 21 - WATER LEVEL, 0.8 DECLG

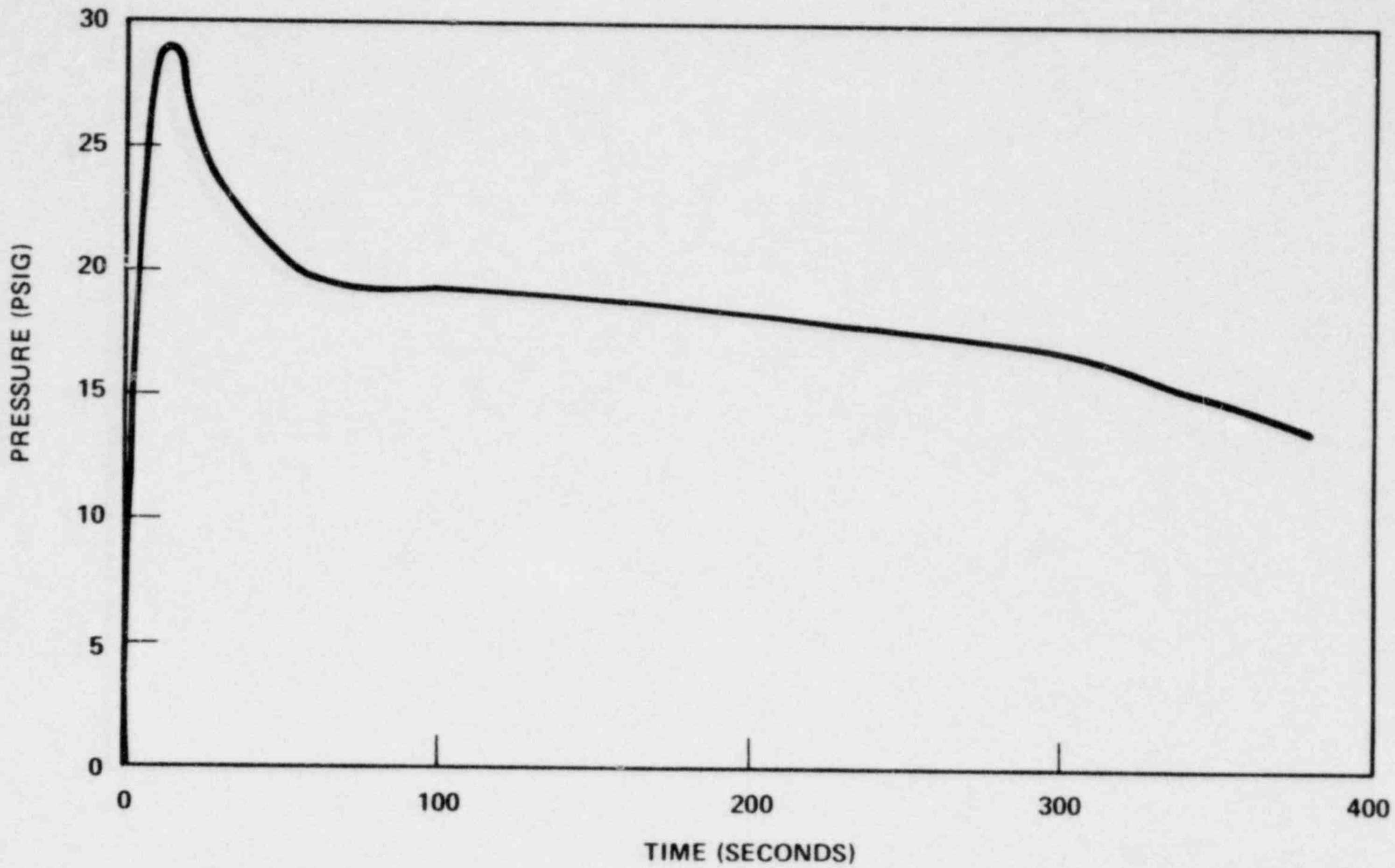

Figure 22 Containment Pressure, C_D = 0.8 DECLG

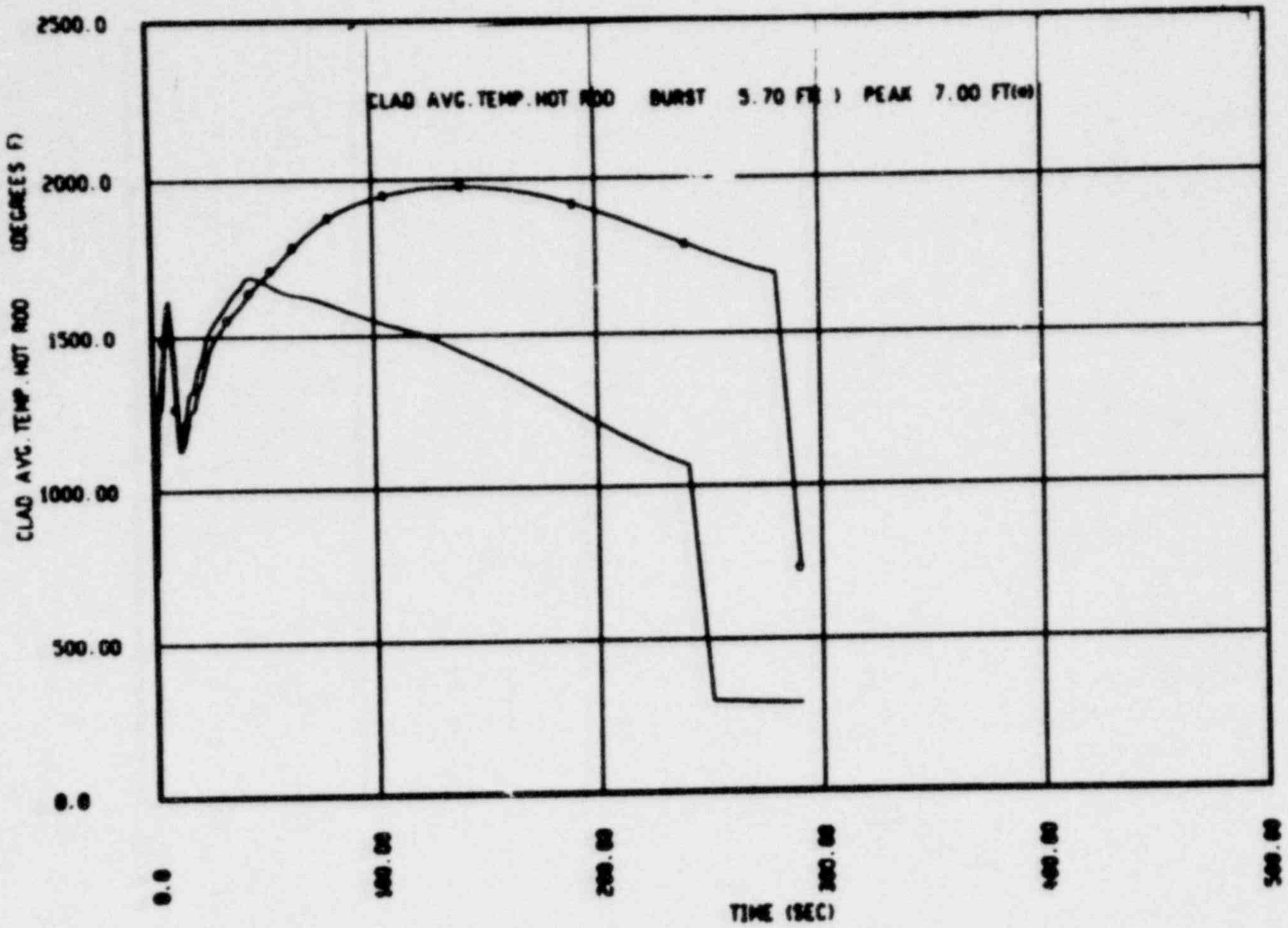

FIGURE 23 - HOT SPOT CLAD TEMPERATURE, 0.6 DECLG, TRP

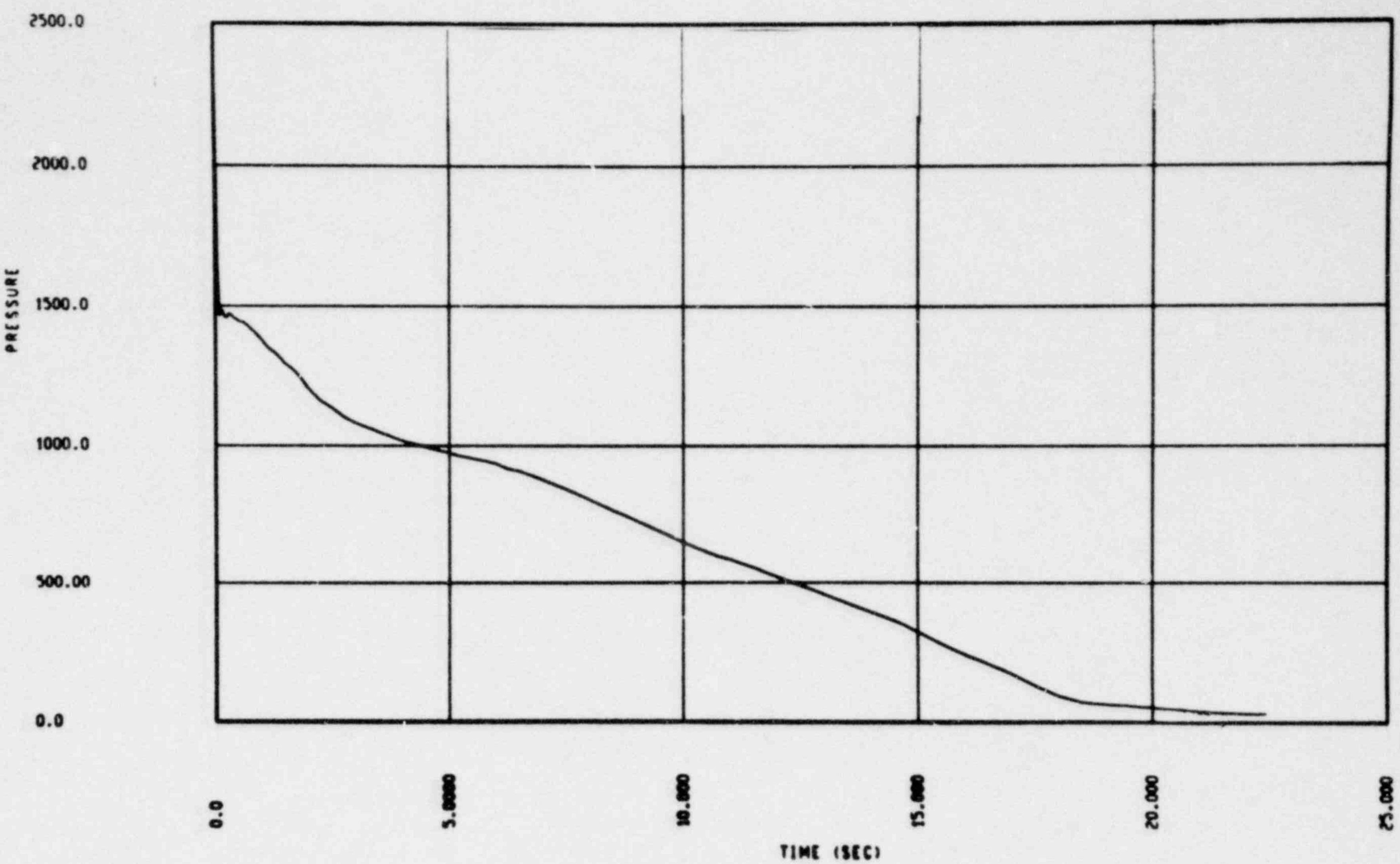

FIGURE 24 - REACTOR COOLANT PRESSURE, 0.6 DECLG, TRP

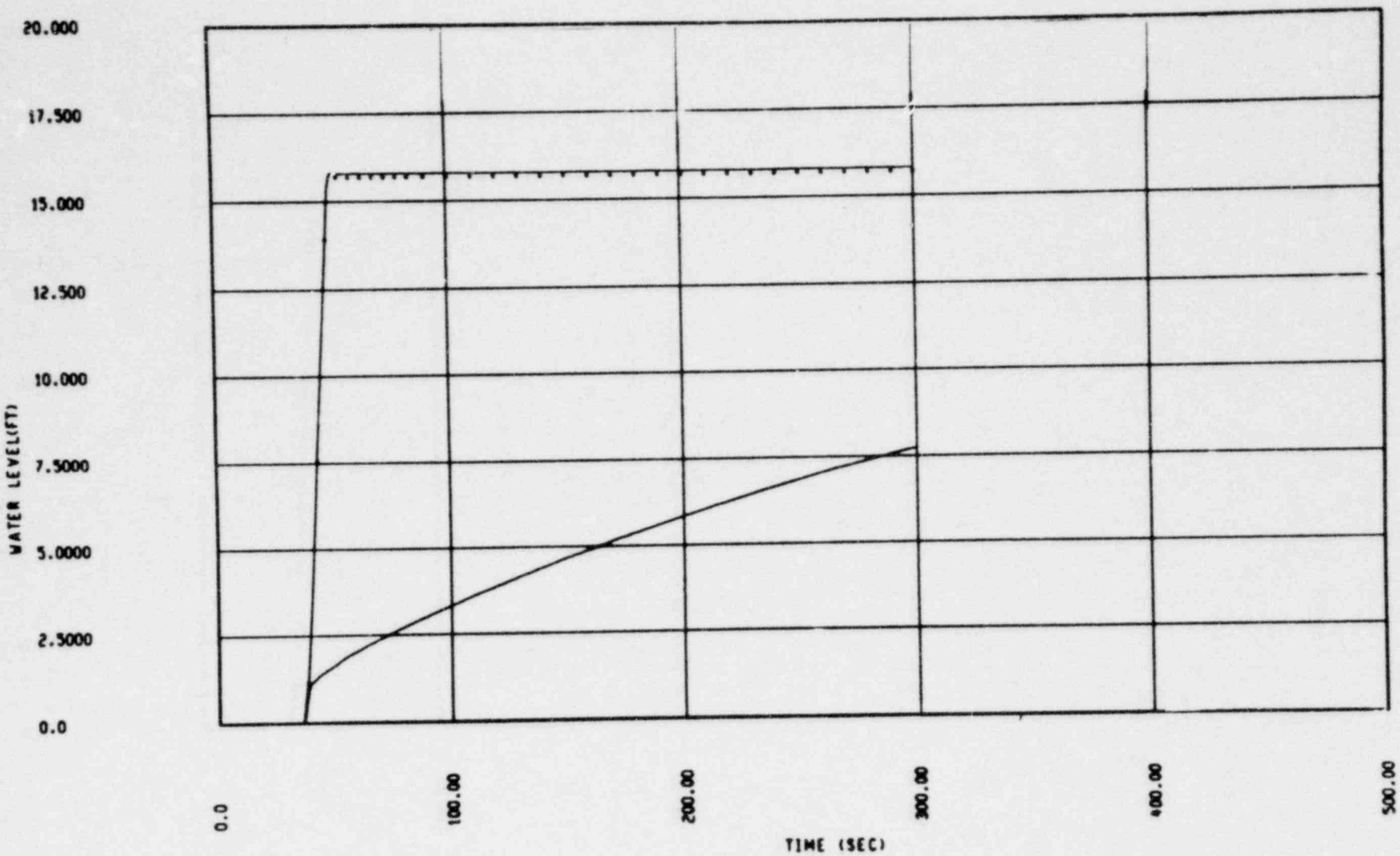

FIGURE 25 - WATER LEVEL, 0.6 DECLG, TRP

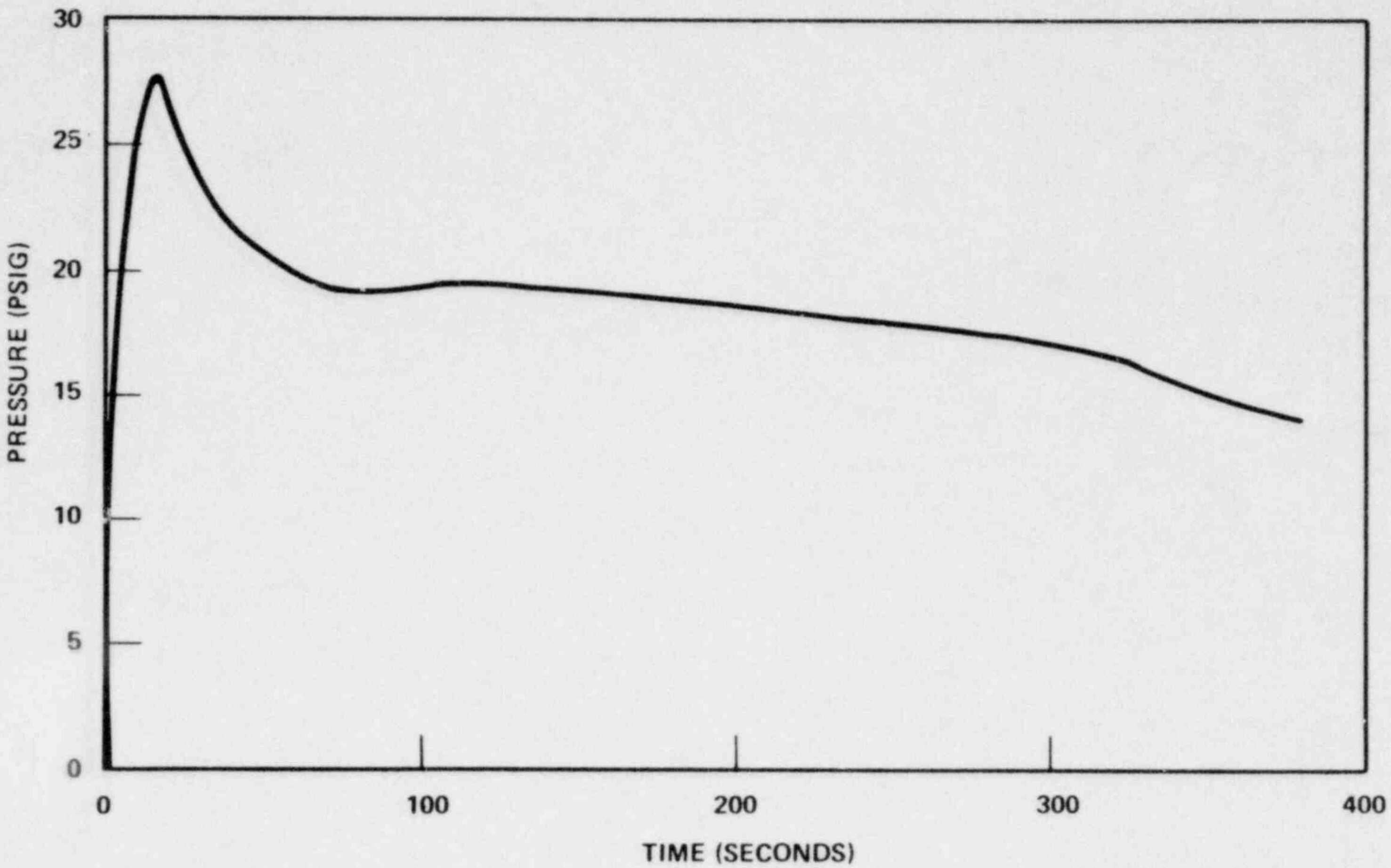

Figure 26 Con-tainment Pressure, C_D = 0.6 DECLG, Pumps Trip