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R.E. GINNA REVISED LOCA ECCS ANALYSES FOR NOMINAL AND REDUCED TEMPERATURE AND PRESSURE OPERATION

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1.0 INTRODUCTION AND SUMMARY

This document presents ECCS analysis results for the R.E. Ginna reactor evaluating the effects of increased containment fan cooler capacity on peak clad temperature (PCT). Calculations were performed for nominal primary coolant system temperature and pressure conditions (573.5°F T_{AVG} and 2250 psia) and for previously analyzed reduced temperature and pressure conditions 527.5°F T_{AVG} and 2000 psia). The analysis results show that R.E. Ginna plant operation at primary coolant system temperature and pressure conditions at or between the nominal and reduced temperature and pressure conditions analyzed will conform to NRC 10 CFR 50.46 criteria.

The Rochester Gas & Electric Company (RG&E) Staff discovered that the fan cooler heat removal capacity versus containment atmospheric temperature curve supplied to ENC was applicable for one fan cooler rather than a total of four as was assumed in previous analyses[1,3]. ENC has reanalyzed the segment of the limiting large break (0.4 DECLG) calculation which is affected by the fan cooler capacity change for the two previously analyzed operating conditions[2,3]. A description of the reanalyzed segment of the transient and the codes used is provided in Section 2.0.

The PCT's for the two cases analyzed are shown in Table 1.1. The calculated PCT for nominal primary coolant temperature and pressure operating conditions is 1928°F, and the calculated maximum local Zr/H_2O reaction is less than 3 percent. The PCT calculated for the reduced temperature and pressure operating conditions is 2129°F, and the calculated maximum local Zr/H_2O reaction is less than 8 percent. These PCT results include the delta PCT calculation for upper plenum injection of low pressure safety injection (LPSI) flow. These ECCS calculations were performed with ENC WREM IIA PWR ECCS evaluation model[5,6,7,8,9,10] for a core composed of ENC fuel at Beginning-of-Life (BOL) conditions. The results show that the criteria specified by 10 CFR 50.46 are satisfied, with this analysis which was performed in conformance with Appendix K of 10 CFR 50[4]. This analysis supports operation of the R.E. Ginna plant with a peak Linear Heat Generation Rate (LHGR) of 13.76 kw/ft at a total peaking factor (F_Q^T) of 2.32 and at a rated power of 1520 MWt, over the range of primary coolant system fluid conditions of 2000 to 2250 psia and 527.5°F to 573.5°F T_{AVG}.

Table 1.1 Peak Cladding Temperature Results
R.E. Ginna Reactor with ENC Fuel

$F_Q^T = 2.32$

Nominal Temperature and Pressure Conditions

	DECLG $C_D = 0.4$
PCT, °F	1928*
Time of PCT (sec)	106.0
ΔPCT due to UPI, °F	-10.
% Local metal-water reaction	<3%

Reduced Tempereature and Pressure Conditions

	0.4 DECLG $C_D = 0.4$
PCT, °F	2129*
Time of PCT (sec)	50.6
ΔPCT due to UPI, °F	-5.
% Local metal-water reaction	<8%

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* Includes ΔPCT calculation for UPI effects

2.0 ANALYSIS METHODS

The discovery by RG&E that the containment fan coolers had been underestimated in the ENC LOCA-ECCS analysis[1,2,3] required that revised analyses be performed. RG&E's desire to operate the R.E. Ginna reactor at reduced temperature and pressure led to a revised analysis at the reduced temperature and pressure conditions previously analyzed[3].

The effect of the increased fan cooler capacity on LOCA ECCS results for both nominal temperature and pressure conditions (573.5°F T_{AVG} and 2250 psia) and reduced temperature and pressure conditions (527.5°F T_{AVG} and 2000 psia) has been evaluated by recalculating the segment of the LOCA ECCS transients when the fan coolers are in operation. In the ENC LOCA ECCS analysis, the R.E. Ginna plant fan coolers begin to remove heat from the containment approximately 26 seconds after the beginning of the LOCA transient. Since fan cooler operation begins after end-of-bypass time, reanalysis of the blowdown and hot channel calculations is not required. Previously calculated blowdown and hot channel results reported in XN-NF-77-58[2] and XN-NF-80-44[3] remain applicable. The same WREM IIA PWR evaluation model used for the reduced temperature and pressure analysis as reported in XN-NF-80-44, was used to evaluate this fan cooler capacity change.

The ENC WREM-IIA calculations required for evaluation of fan cooler capacity change are:

- Containment pressure response with appropriate blowdown mass and energy input using CONTEMPT-LT/22.
- Accumulator and safety injection system (SIS) response with appropriate containment pressure using RELAP4-EM/ENC28FC.
- Refill with appropriate accumulator and SIS flows.

- Reflood with appropriate containment pressure, accumulator and SIS flows using REFLEX.
- Hot rod heatup with appropriate reflood rates using TOODEE2/MAY79.
- Delta PCT with appropriate reflood rates to account for upper plenum injection.

The key variables in this Ginna ECCS analysis are containment pressure, fan cooler activation time and the time at which the peak clad temperature (PCT) occurs. Fan coolers remove energy from the containment atmosphere and reduce the containment pressure during a LOCA event. During the Ginna limiting break LOCA transient at nominal temperature and pressure conditions, the fan coolers are active for approximately 80 seconds before the PCT occurs. At reduced temperature and pressure conditions, the fan coolers are active for only approximately 30 seconds before PCT occurs. Within 80 seconds, at nominal temperature and pressure conditions and 30 seconds at reduced temperature and pressure conditions, a small but not significant decrease in containment pressure occurs due to the factor of four increase in fan cooler capacity. This small pressure reduction results in only a small increase in PCT for the Ginna plant for both nominal and reduced temperature and pressure conditions.

The results in the next section show the effect of fan cooler capacity on calculated containment pressure, reflood rate and PCT.

3.0 RESULTS FOR INCREASED FAN COOLER CAPACITY

Using the ENC WREM IIA codes discussed in Section 2.0, the containment pressure transient, reactor vessel lower plenum refill, reflood rates and PCT's have been calculated for the 0.4 DECLG case for nominal and reduced temperature and pressure conditions. The event times for the increased fan cooler capacity analyses are shown in Table 3.1. The blowdown calculation is unaffected by fan cooler operation, because fan cooler operation begins after the blowdown process has been completed. Therefore, blowdown event times remain as reported in earlier formal documentation[2,3], and they are not shown in Table 3.1. Peak clad temperature and metal-water reaction results are shown in Table 3.2.

The revised limiting break calculation for nominal temperature and pressure conditions produced a calculated PCT of 1938°F and a maximum metal-water reaction of less than 3% at 180 seconds. For reduced temperature and pressure conditions, the revised limiting break calculation produced a maximum PCT of 2134°F and a maximum metal-water reaction of less than 8% at 180 seconds. The interim upper plenum injection (UPI) model yielded calculated results of -10°F and -5°F for the nominal and reduced temperature and pressure cases, respectively. When the UPI results are added to the ENC WREM-IIA calculated PCT results, the final calculated PCT results become 1928°F and 2129°F for the nominal and reduced temperature and pressure cases, respectively. These calculations were performed at a peak linear heat generation rate of 14.03 kw/ft (F_Q^T=2.32) for ENC fuel (102% of 13.76 kw/ft).

Figures 3.1 through 3.13 show the calculated containment pressure, reflood and hot rod heatup parameters of interest. Figure 3.1 shows four plots of calculated containment pressure versus time for nominal conditions and reduced temperature and pressure with both one and four fan coolers. The lower energy state corresponding to reduced primary coolant system temperature and pressure conditions is apparent in the magnitude of the peak containment pressure and the pressure decay shown in Figure 3.1. The fan cooler actuation time and the time of maximum PCT for both nominal and reduced temperature and pressure conditions are also shown as vertical lines on Figure 3.1. Since the PCT's for both the nominal and reduced temperature and pressure conditions occur early in the containment pressure transient before the effect of increased fan cooler capacity on containment pressure becomes significant, the increased fan cooler capacity shown in Table 3.4 has only a small effect on PCT and does not require a change of the R.E. Ginna ECCS allowed operating limits.

Table 3.1 R.E. Ginna Nominal and Reduced Temperature and Pressure Limiting Break (0.4 DECLG) Event Times

Event	Time (seconds)	
	Reduced T & P Four Fan Coolers	Nominal T & P Four Fan Coolers
Start	0.0	0.0
Initiate Break	0.05	0.05
End-of-Bypass	19.94	20.22
Safety Injection Flow, SIS	25.75	25.74
Start of Reflood	39.84	39.89
Accumulator Empty, Intact Loop	46.73	48.30
Peak Clad Temperature Reached	50.6	106.0

Table 3.2 R.E. Ginna Nominal and Reduced Temperature and Pressure Limiting Break (0.4 DECLG) Results

Parameter	Results	
	Reduced T & P Four Fan Coolers	Nominal T & P Four Fan Coolers
Peak Cladding Temperature, ^{o}F	2129	1928
ΔPCT for Upper Plenum Injection, ^{o}F	-5	-10
Calculated PCT, ^{o}F	2134	1938
Peak Temperature Location, ft.	5.92	7.17
Local Zr/H_2O Reaction, (Max.) %	<8% at 180 sec.	<3% at 180 sec.
Local Zr/H_2O Location, ft.	5.92	5.92
Total H_2 Generation, % of total Zr reacted	<1%	<1%
Hot Rod Burst Time, sec	32.04	36.42
Hot Rod Burst Location, ft.	5.92	5.92

Table 3.3 R.E. Ginna 2-Loop PWR Data

	Nominal Temp & Pressure	Reduced Temp & Pressure
Primary Heat Output, MWt	1520*	1520*
Primary Coolant Flow, lbm/hr	6.8×10^7	7.16×10^7
Primary Coolant Volume, ft^3	9457**	9457**
Operating Pressure, psia	2250.	2000.
Inlet Coolant Temperature, ^oF	545.	497.
Reactor Vessel Volume, ft^3	2396.	2396.
Pressurizer Volume, Total, ft^3	800.	800.
Pressurizer Volume, Liquid, ft^3	480.	480.
Accumulator Volume, Total, ft^3 (each of two)	1750.	1750.
Accumulator Volume, Liquid, ft^3	1100.	1100.
Accumulator Trip Point Pressure, psia	700.	775.***
Steam Generator Heat Transfer Area, ft^2	39,987.	39,987.
Steam Generator Secondary Flow, lbm/hr	3.13×10^6	3.13×10^6
Steam Generator Secondary Pressure, psia	778.7	490.
Reactor Coolant Pump Head, ft	252.	252.
Reactor Coolant Pump Speed, rpm	1189.	1189.
Moment of Inertia, lbm-ft^2/rad	80,000.	80,000.
Steam Generator Tube Plugging (assumed uniform)	10%	10%

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* Primary heat output used in RELAP4-EM Model = 1.02 x 1520 = 1550.4 MWt

** Includes total accumulator and pressurizer volumes.

*** This pressure represents the nominal accumulator pressure setting rather than the minimum. The nominal pressure gives in a slightly more conservative ECCS analysis result.

Table 3.4 R.E. Ginna Dry Containment Data - Containment Physical Parameters

Net Free Volume	$1.066 \times 10^6 ft^3$
Outside Air Temperature	-10^oF
Initiation Time for:	
Spray Flow	2.0 sec
Fan Coolers	20.0 sec
Containment Initial Conditions:	
Temperature	90^oF
Pressure	14.7 psia
Relative Humidity	100%
Containment Spray Water:	
Temperature	37^oF
Flow Rate (Total, 2 pumps)	3600 gpm

Fan Air Cooler Capacity
(total 4 coolers)

Vapor Temperature (^oF)	Capacity (Btu/hr)
165	8.00×10^6
210	1.14×10^8
230	1.60×10^8
260	2.36×10^8
295	3.20×10^8

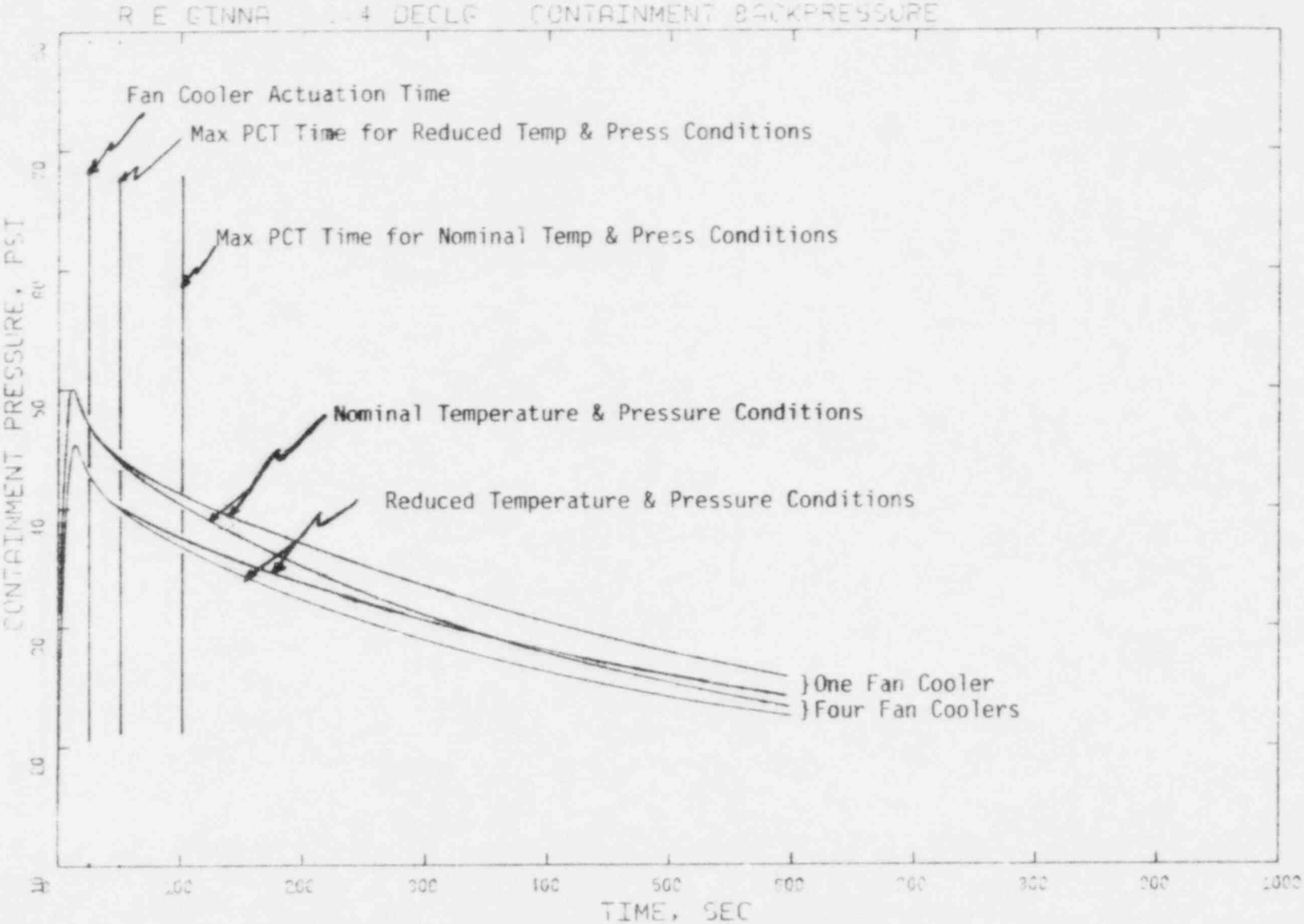

Figure 3.1 Containment Pressure versus Time for Nominal and Reduced Temperature and Pressure Conditions with Both One and Four Fan Coolers

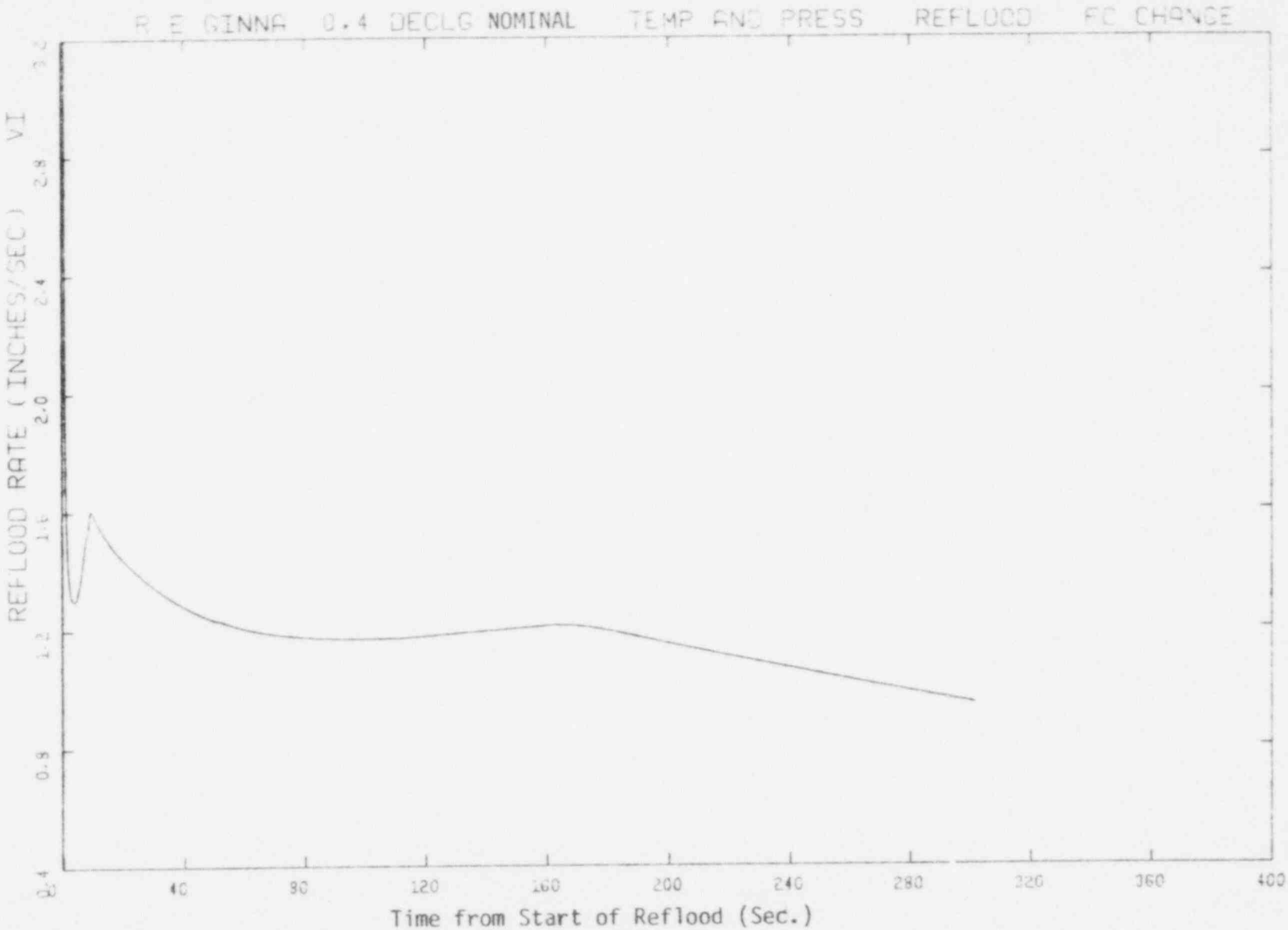

Figure 3.2 Reflood Core Flooding Rate, Nominal Temperature and Pressure Initial Conditions, 0.4 DECLG Break

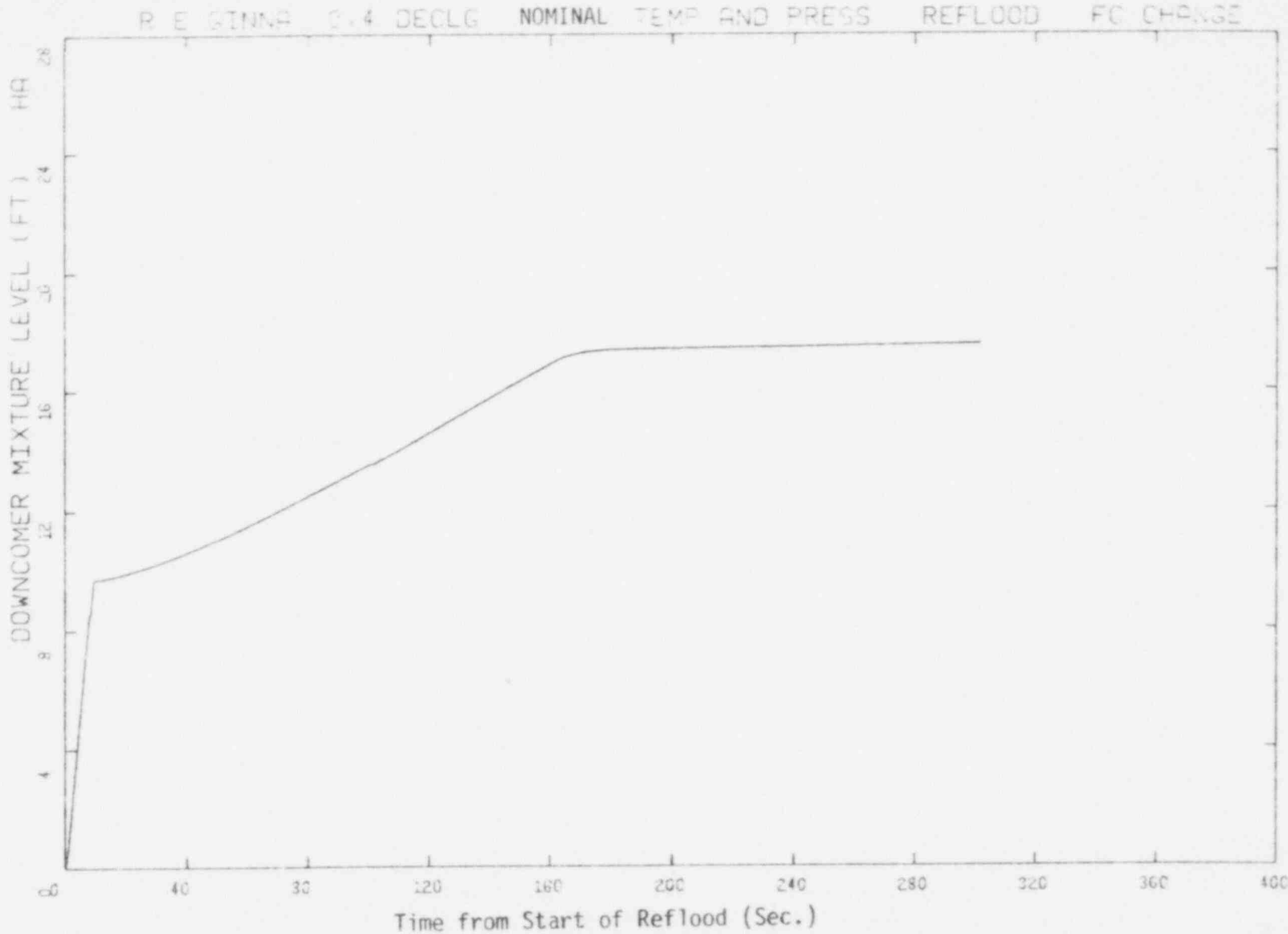

Figure 3.3 Reflood Downcomer Mixture Level, Nominal Temperature and Pressure Initial Conditions, 0.4 DECLG Break

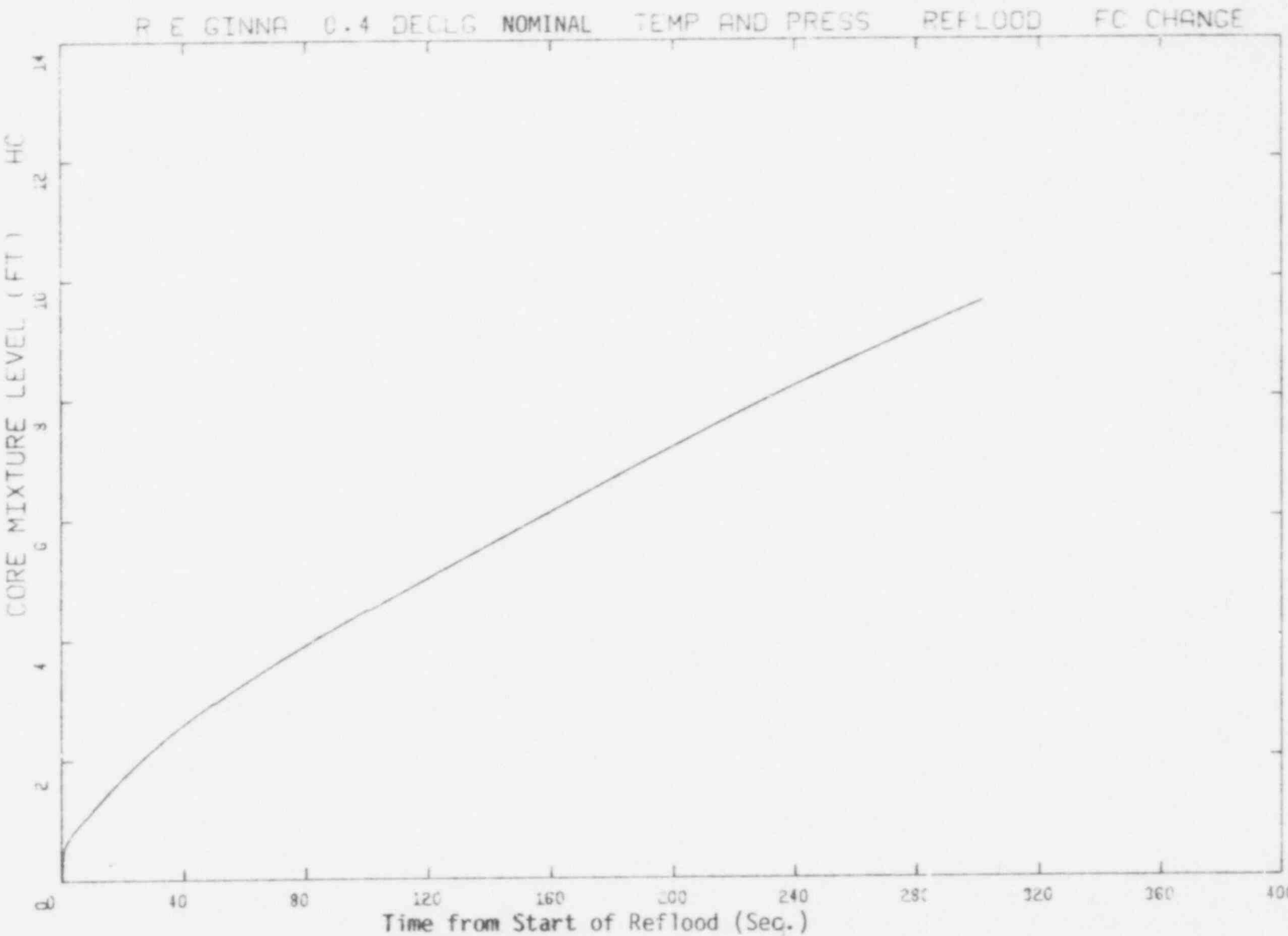

Figure 3.4 Reflood Core Mixture Level, Nominal Temperature and Pressure Initial Conditions, 0.4 DECLG Break

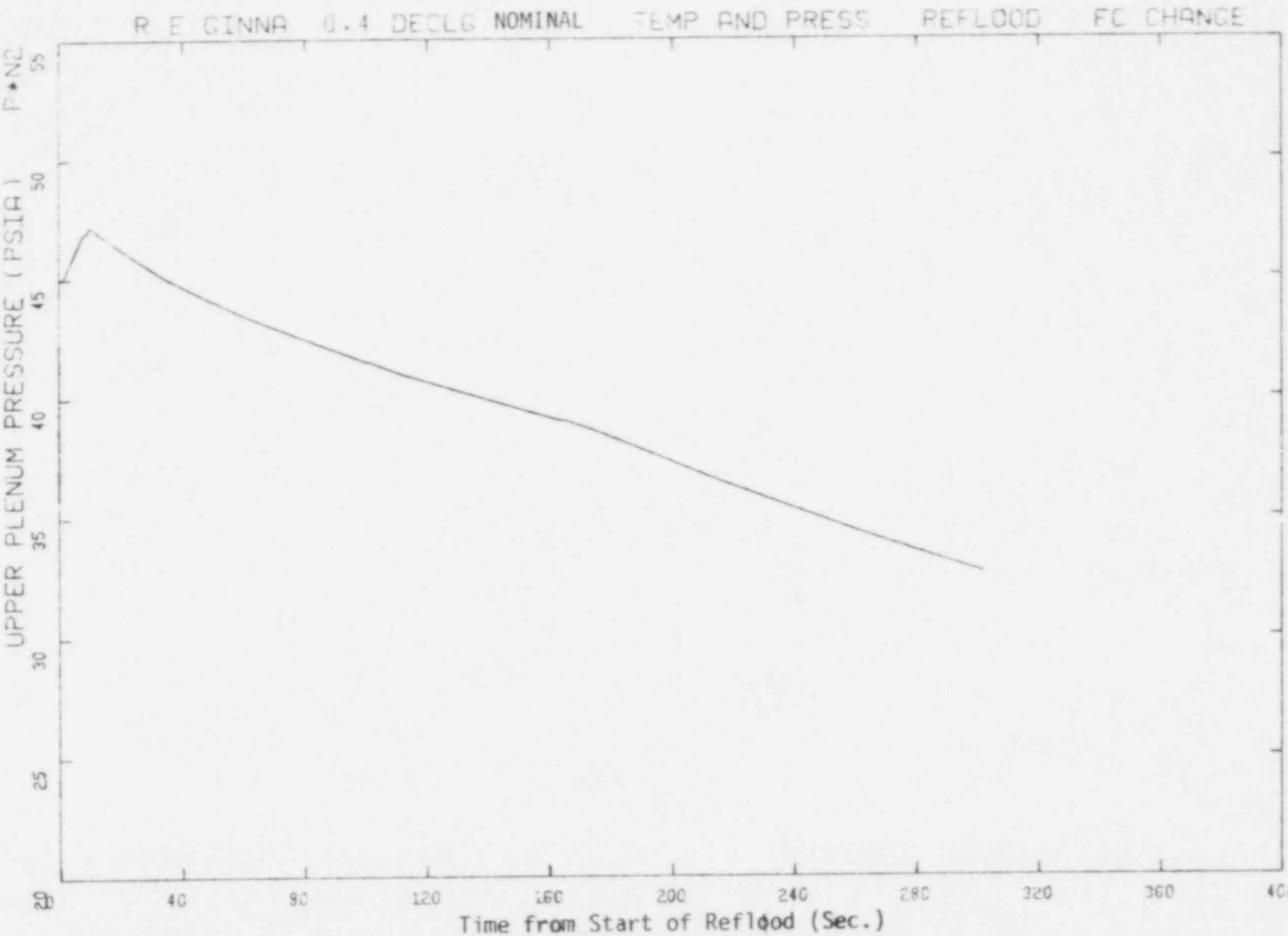

Figure 3.5 Reflood Upper Plenum Pressure, Nominal Temperature and Pressure Initial Conditions, 0.4 DECLG Break

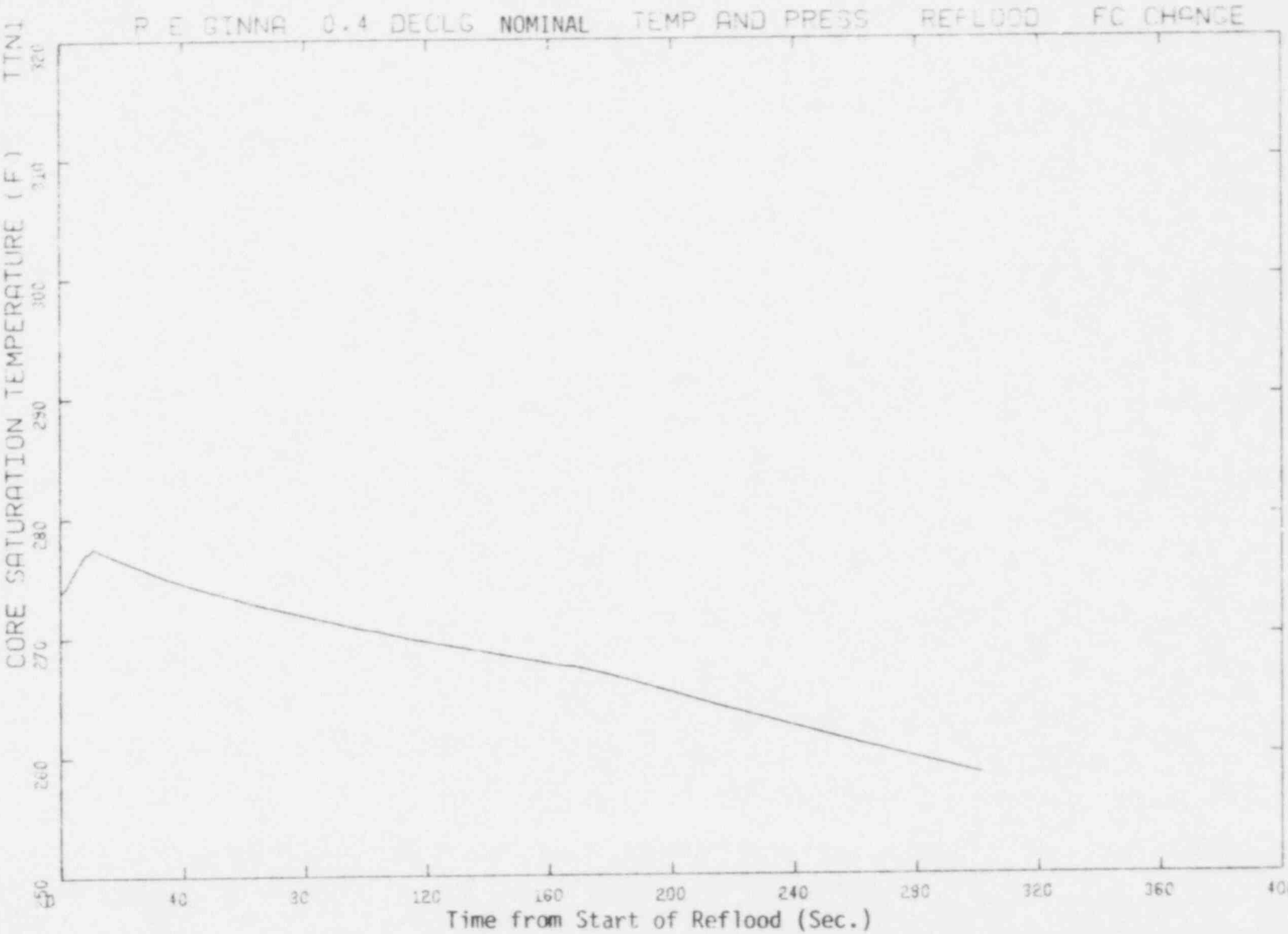

Figure 3.6 Reflood Core Saturation Temperature, Nominal Temperature Initial Conditions, 0.4 DECLG Break

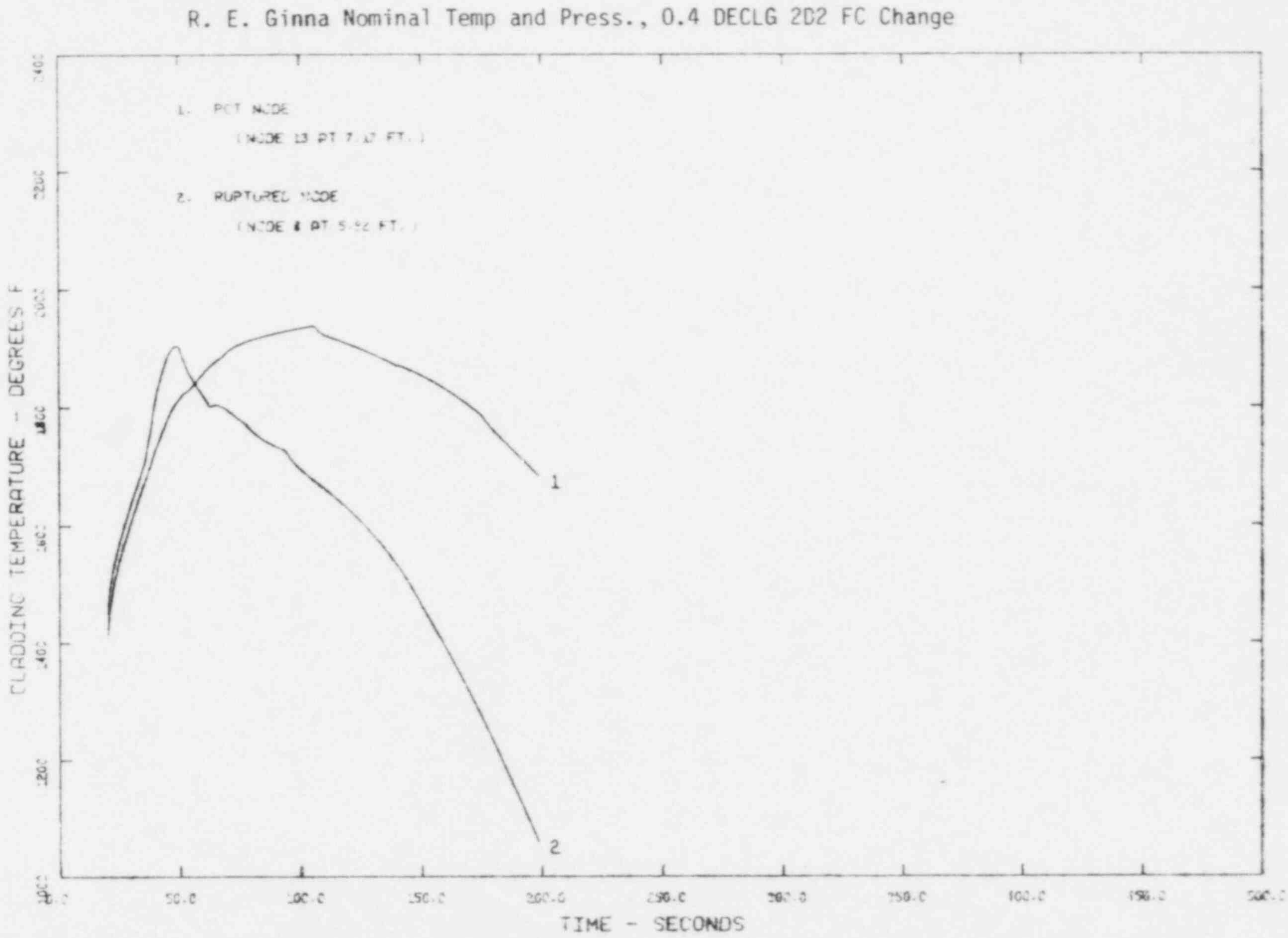

Figure 3.7 TOODEE2 Calculated Cladding Temperature, Nominal Temperature and Pressure Initial Conditions, 0.4 DECLG Break

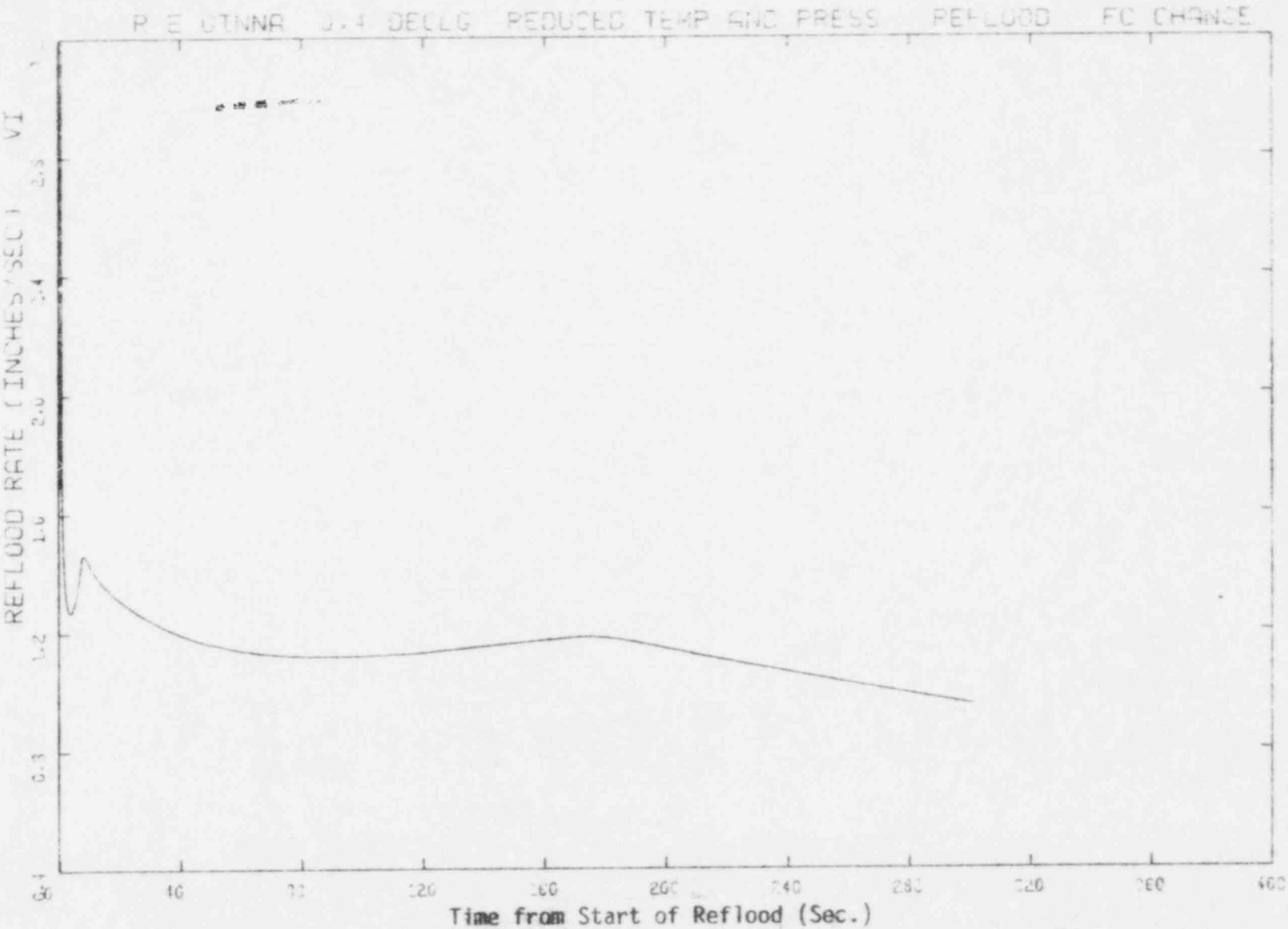

Figure 3.8 Reflood Core Flooding Rate, Reduced Temperature and Pressure Initial Conditions, 0.4 DECLG Break

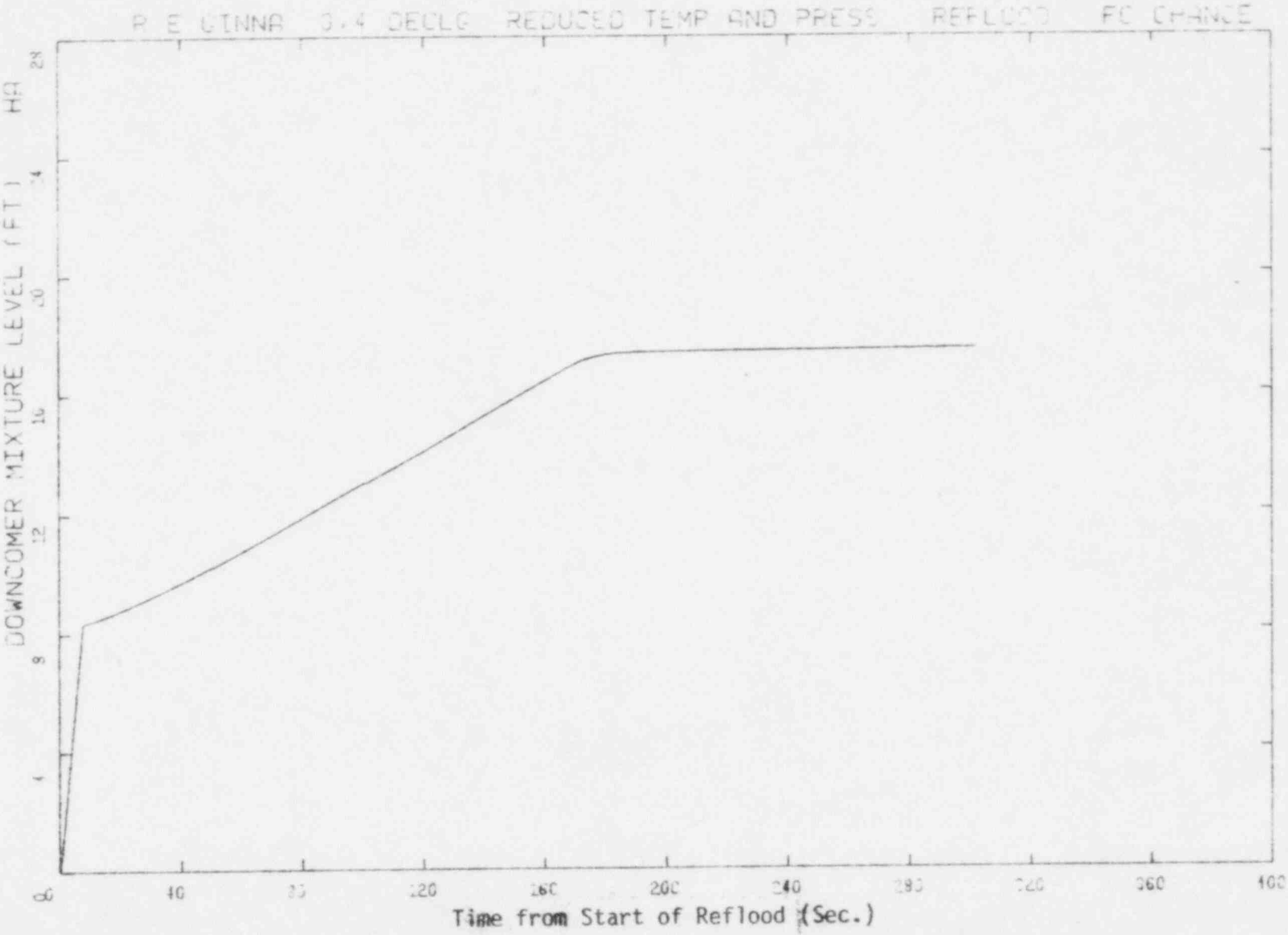

Figure 3.9 Reflood Downcomer Mixture Level, Reduced Temperature and Pressure Initial Conditions, 0.4 DECLG Break

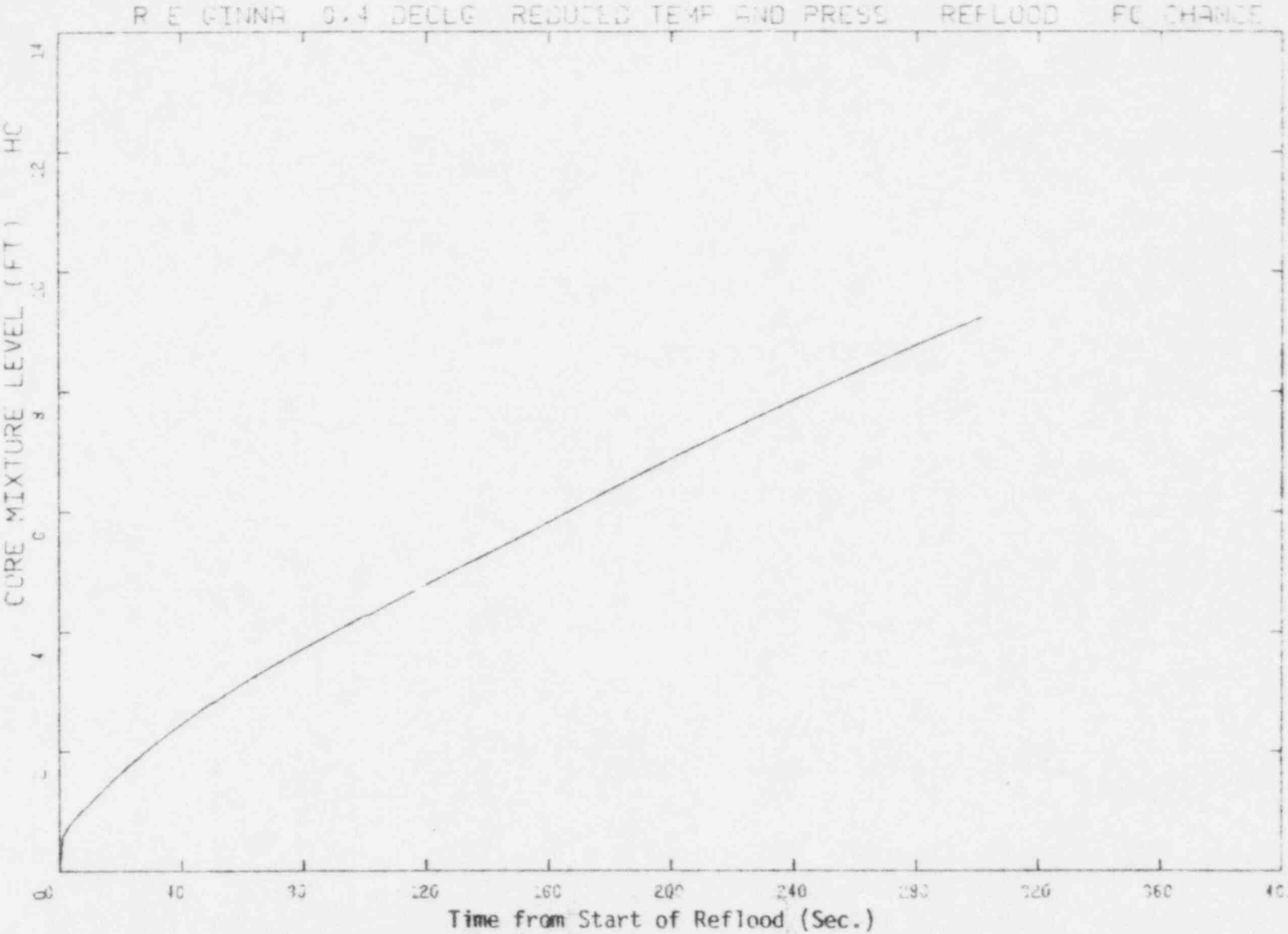

Figure 3.10 Reflood Core Mixture Level, Reduced Temperature and Pressure Initial Conditions, 0.4 DECLG Break

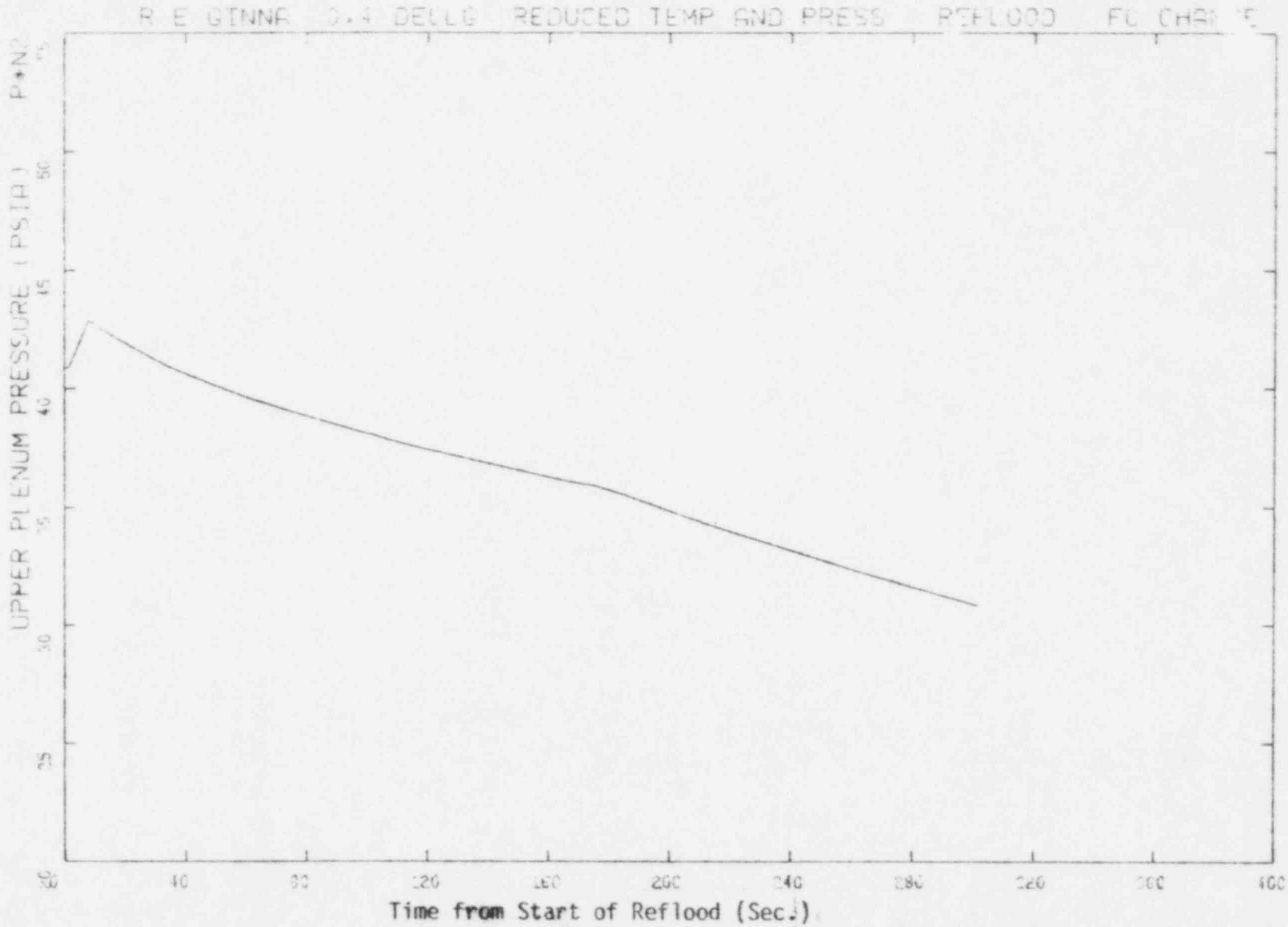

Figure 3.11 Reflood Upper Plenum Pressure, Reduced Temperature and Pressure Initial Conditions, 0.4 DECLG Break

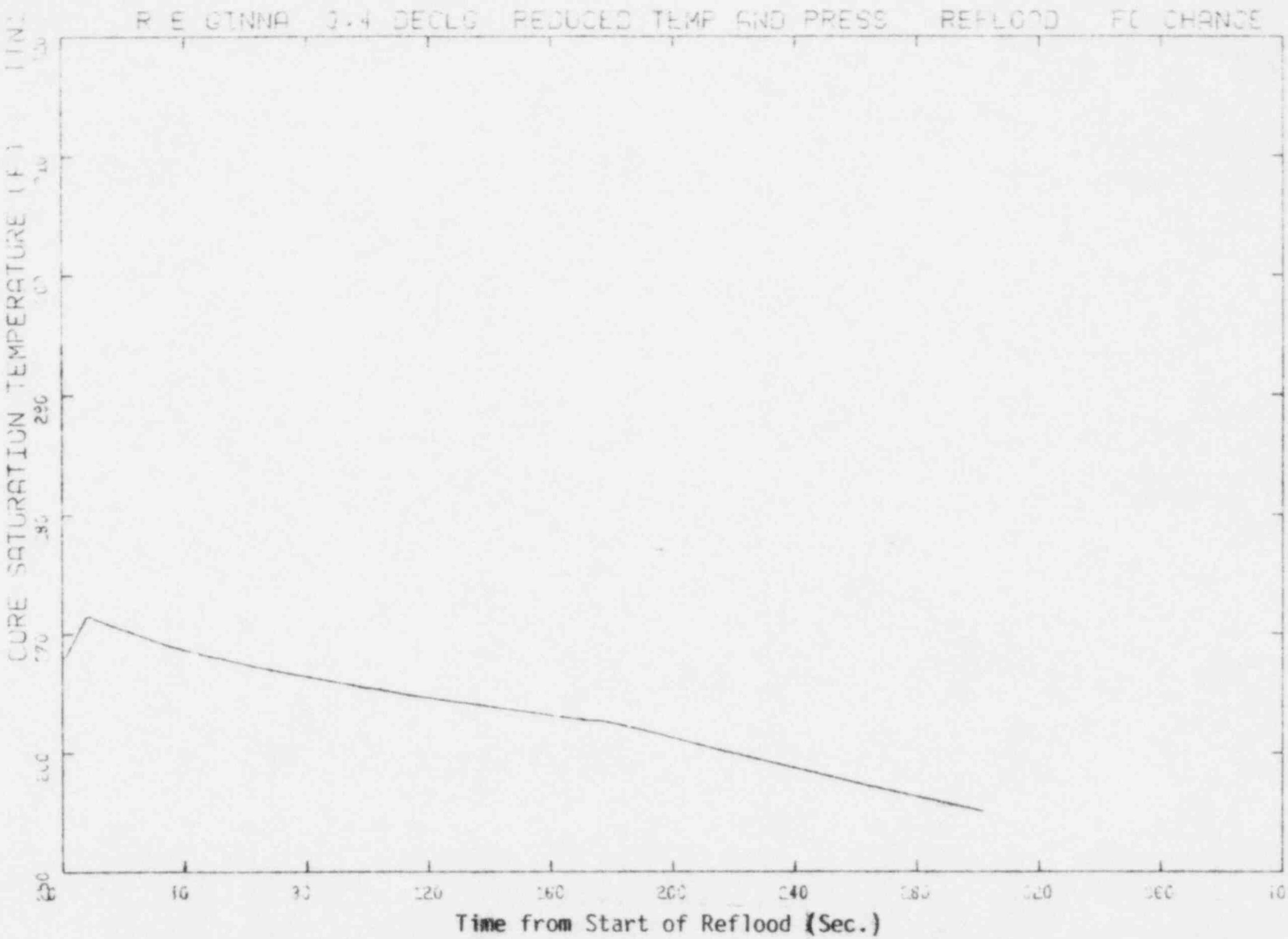

Figure 3.12 Reflood Core Saturation Temperature, Reduced Temperature and Pressure Initial Conditions, 0.4 DECLG Break

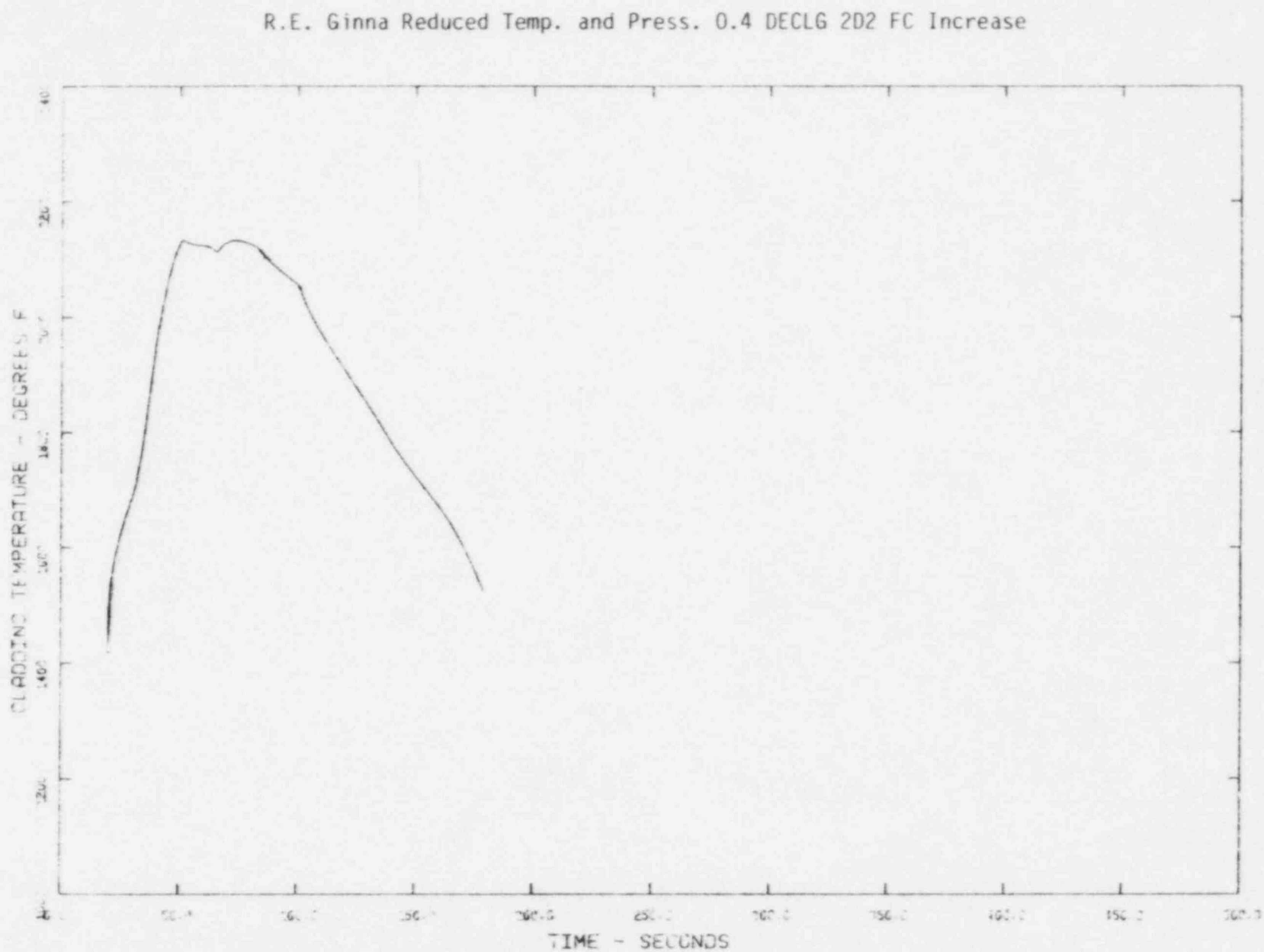

Figure 3.13 TOODEE2 Calculated Cladding Temperature, Reduced Temperature and Pressure Initial Conditions, 0.4 DECLG Break

4.0 ECCS OPERATING LIMITS

The ECCS analysis for the R.E. Ginna plant at nominal primary coolant system temperature and pressure conditions and reduced temperature and pressure conditions was performed in conformance with Appendix K of 10 CFR 50, and the requirements specified by 10 CFR 50.46 are satisfied. This analysis supports plant operation at a total peaking factor (F_Q^T) of 2.32 with a total linear heat generation rate of 13.76 kw/ft for rated power over a range of coolant system operating conditions bounded by the two analyses. There is a reduction in PCT margin associated with plant operation below the nominal primary coolant system temperature and pressure which can be explained in terms of the calculated phenomena and Appendix K ECCS models.

The reduction in PCT margin associated with the change from nominal to reduced primary coolant system temperature and pressure conditions is due to the following factors:

- The intact loop accumulator has less water to fill the downcomer during the reflood transient, because the accumulator started to flow earlier in the blowdown transient and exhausted more water during blowdown as a result of decreased system pressure and temperature conditions. Appendix K requires that this water be assumed lost in the ECCS analysis.
- The containment pressure has been reduced by approximately ten percent due to the smaller blowdown energy release associated with reduced primary coolant temperature conditions.
- Blowdown core heat transfer has been reduced as a result of generally reduced calculated core flow.

The controlling phenomena are the LOCA blowdown pressure transient (determined by saturation conditions) and the initial primary fluid energy content. From the steam tables[11] it can be seen that these quantities vary smoothly and continuously between the two operating conditions analyzed. Therefore, the two cases analyzed will bound calculated results for operating conditions between the two cases calculated.

As long as plant operation is maintained at or between the operating conditions assumed for these analyses, the calculated PCT of 2129°F is an upper bound to calculated ECCS results. This result provides 71°F of PCT margin with respect to the 2200°F ECCS limit.

5.0 CONCLUSIONS

For breaks up to and including the double-ended severance of a reactor coolant pipe, the R.E. Ginna Emergency Core Cooling System will meet the Acceptance Criteria as presented in 10 CFR 50.46 for the ENC reload fuel in accordance with the LHGR limits and operating conditions noted in Section 1.0. That is:

1. The calculated peak fuel element clad temperature does not exceed the 2200°F limit.
2. The amount of fuel element cladding that reacts chemically with water or steam does not exceed 1% of the total zircaloy associated with the active fuel length in the reactor.
3. The cladding temperature transient is terminated at a time when the core geometry is still amenable to cooling. The hot fuel rod cladding oxidation limits of 17% are not exceeded during or after quenching.
4. The plant can be operated at or between the primary coolant system temperature and pressure conditions specified in this document.
5. The system long-term cooling capabilities provided for previous cores remain applicable for ENC fuel.

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