ATTACHMENT 1

DC POWER SOURCE FAILURE FOR BWR 3 AND 4

7812040139

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION

The purpose of this study was to investigate in a generic manner the implications of a direct current (DC) power source failure for the BWR 3 and 4 operating plants. In addition, this study provides bounding peak cladding temperatures (PCT) as a function of break area for small breaks which can be applied generically to operating BWR 3's and 4's.

For purposes of this study, it was determined that the plants could be divided into two categories: (1) those plants which have modified the low pressure coolant injection (LPCI) system (LPCI mod plants), and (2) those plants which have retained LPCI loop selection logic (Non-LPCI mod plants). From each of these categories, a worst-case plant was determined such that each category could be represented by a bounding analysis. Details of how the worst-case plants were selected and justification for the bounding assumptions are presented in the following text.

This study covers both the small break and large break regions for each of the above two categories. The analyses were performed with the 1977 approved model and input changes using bounding assumptions for the emergency core cooling systems (ECCS) remaining operable after a DC power source failure. The codes used in these calculations were the SAFE/REFLOOD models (details of these models may be found in NEDO-20566).

The effect of reduced ADS capacity (for use in ADS out-of-service situations) and the effect of increased relief valve setpoint (SRSV simmering analysis) may be superimposed on these new break spectra.

2. CONCLUSIONS

The overall conclusions reached are:

a. For small break LOCAs, there is an increase in the maximum peak cladding temperature (PCT) beyond the previously calculated single failure [i.e., the failure of high pressure coolant injection (HPCI) pump]. However, the increase in PCT did not exceed 200°F for any of the operating BWR 3 and 4 plants, nor did any PCTs exceed 2200°F.

b. The limiting break which is the basis for the maximum average planar linear heat generation rate (MAPLHGR) did not change.

c. For large break LOCAs, the maximum PCT for any plant is not affected by a DC power source failure.

d. The MAPLHGR for any plant is not affected by a DC power source failure.

3. SMALL BREAK ACCIDENT ANALYSIS

For the small break LOCA transient, the Automatic Depressurization System (ADS) capacity of a plant relative to vessel size is an important characteristic affecting calculated PCT. In general, plants without the low pressure coolant injection modification (non-LPCI mod plants) have lower ADS capacities than plants with the low pressure coolant injection modification (LPCI mod plants). Also, the minimum number of emergency core cooling systems remaining operable after a DC power source failure are generally the same for "non-LPCI mod" plants, while more variation in design exists among "LPCI mod" plants. Therefore, the operating BWRs were initially developed into two categories; namely,

a. Non-LPCI mod plants*

b. LPCI mod plants

*One BWR 4 is an exception because it has larger ADS capacity relative to vessel size than other non-LPCI mod plants and is included in the LPCI mod plant category for the small break analysis.

From each category a worst-case plant (i.e., the plant expected to result in the highest small break PCT) was determined. The procedure for determining the worst-case plant is outlined below. For a small break LOCA, the principal factors contributing to calculated PCT are:

a. The number and kind of emergency core cooling systems (ECCS) operating;

b. The rate of depressurization of the reactor; and

c. The maximum average planar linear heat generation rate (MAPLHGR) of the fuel.

It should be noted that the time to uncover the fuel was also considered but does not vary significantly within each category.

Item a., above is a function of plant design and break location. The combination of ECC systems that would give the highest PCT (i.e., the minimum possible combination of ECC systems remaining after DC power failure), for each of the two categories mentioned above, are tabulated in Table 1. A conservative assumption was made that the minimum possible combination of ECC systems remaining operable for any one plant was applicable to all the plants in that category. For the non-mod plants, there was no ambiguity as to what systems would give the highest PCT. For the modified plants, some doubt existed as to which of the five combinations of systems mentioned in Table 1 might give the highest PCT. Test calculations were made using all the systems' combinations, and it was determined that the combination of 1 CS + 1 LPCI + ADS gave the highest PCT; hence, this combination was chosen for the analysis.

In all calculations, for BWR/4 plants where only one core spray loop was operable, a 50% reduction in the convective heat transfer coefficient was used for all uncovered rods after the core spray had attained rated conditions. This occurrence will be termed "½h" in the following text.

The characteristics determining how the reactor depressurizes for a given break are the vessel volume and the ADS capacity. Values were tabulated for these two variables and for the vessel volume to ADS valve capacity ratio for all the plants. This value and the MAPLHGR were used as measures to select the plant that would yield the highest PCT in each category. That is, the plant with the largest MAPLHGR and vessel volume per ADS valve capacity should be the plant that results in the highest small break PCT. This method of determining the worst-case plant was found to be creditable, since the plant selected in each category was also found to be the plant with the highest PCT for the previous calculations with a postulated HPCI failure. The limiting systems combination and the break spectrum to be analyzed are tabulated in Table 2. The resulting PCT as a function of break size are shown in Figures 1 and 2. The analysis was then repeated for the "worst" small break changing only the single failure assumption to an HPCI failure. Comparisons of the maximum PCT with the two failures are tabulated in Table 3. Hence, for the non-LPCI mod plants, a difference in PCT between a DC power source failure and an HPCI failure was 161°F; for the LPCI mod plants, the above difference in PCT was 150°F.

Plots of water level, vessel pressure, and peak cladding temperature as a function of time for the worst small break, are provided in Figures 3 through 6.

4. LARGE BREAK ACCIDENT ANALYSIS

The plants were again divided into two categories, as for the small break analysis, as follows:

a. Non-LPCI mod plants

b. LPCI mod plants.

The worst-case plant for a small break standpoint is not necessarily the "worst case" for a large break because of rapid blowdown conditions during large breaks. The criterion used in determining if a DC power source failure on the previously assumed low pressure coolant injection system injection valve (LPCI-IV) failure is more limiting for a DBA was to compare the remaining ECC systems operable for the two failures. Table 4 below shows the minimum systems remaining operable for the two categories given above. For large breaks, the HPCI and ADS systems are ineffective because of the rapid blowdown. Hence, the decision to be made for non-LPCI mod plants is whether 2 CS or 1 CS + 2 LPCI is more limiting. Appendix K analysis with this combination of systems operable have been conducted and have shown that 1 CS + 2 LPCI is less limiting for large breaks. For the LPCI mod plants with a discharge break in the recirculation line, studies have been performed assuming a diesel-generator failure which yields the following operable systems: 1 CS + 1 LCPI + HPCI + ADS, which is effectively the same as a DC power source failure with 1 CS + 1 LPCI + ADS operable, since the HPCI system is ineffective for large breaks. This study showed that the resulting PCT was substantially less than the PCT for a LPCI-IV failure. An analysis was performed on the LPCI mod plant to verify the above conclusion. Results of the analysis are given in Table 5. The PCT for the DC power source failure was estimated to be 2073°F, approximately 120°F less than the PCT for a LPCI-IV failure. The DC power source failure for LPCI mod plants that are suction break limited leaves ICS + 3 LPCI systems operable. This is less limiting than the 2 CS + 2 LPCI + HPCI + ADS system combination derived from the LPCI-IV failure reported in the Appendix K analysis. Therefore, it is assured that both suction and discharge breaks have been properly considered in this evaluation.

5. LOSS OF ADS CAPACITY

Additional analyses were performed to determine the impact of a loss of ADS capacity on the PCT for small breaks assuming a DC power source failure. The analysis assumed a 20% loss of ADS capacity for the LPCI mod category of plants. Results and conditions of this analysis are shown in Table 6. The column labeled $\Delta T_{(N-1)}$ is the difference in PCT between the case with 20% reduction in ADS capacity and the case with all the ADS valves operating. This difference was found to be a 155°F increase (1924°F versus 1769°F).

Table 1

ECC SYSTEMS CATEGORY DESIGNATION

Category	ECC Systems	Break Location
Non-LPCI Mod Plants	1 CS + 2 LPCI + ADS	Suction
LPCI Mod Plants	2 CS + ADS	Discharge
	1 CS + 1 LPCI + ADS	Discharge
	1 CS + 2 LPCI + ADS	Discharge
	1 CS + 3 LPI2* + ADS	Suction
	1 CS + 2 LPI2* + ADS	Suction

*LPI2 means LPCI injection into 2 loops

Table 2

OPERABLE ECC SYSTEMS AND BREAK SPECTRUM USED FOR SMALL BREAK

Category	ECC Systems	Break Location	Break Size (ft^2)
Non-LPCI-Mod Plants	1 CS + 2 LPCI + ADS	Suction	0.005, 0.03, 0.04, 0.05, 0.07, 0.1, 0.2, 0.5
LPCI Mod Plants	1 CS** + 1 LPCI + ADS	Discharge	0.005, 0.03, 0.06, 0.07, 0.08, 0.09, 0.1, 0.2, 0.5

**Used "½h" (see text for explanation)

Table 3

DC POWER SOURCE/HPCI FAILURE COMPARISONS FOR SMALL BREAK

Category	Failure	Break Location	Break Size (ft^2)	PCT (°F)	ΔPCT (°F) (DC-HPCI)
Non-LPCI Mod Plants	DC Power Source	Suction	0.05	1931	161
	HPCI	Suction	0.05	1770	
LPCI Mod Plants	DC Power Source	Discharge	0.08	1769	150
	HPCI	Discharge	0.08	1619	

Table 4

SYSTEMS OPERABLE FOR LARGE BREAK

Category	Failure	Break Location	Systems Operable
Non-LPCI Mod Plants	LPCI-IV	Suction	2 CS + HPCI + ADS
	DC Power Source	Suction	1 CS + 2 LPCI + ADS
LPCI Mod Plants	LPCI-IV	Discharge	2 CS + HPCI + ADS
	LPCI-IV	Suction	2 CS + 2 LPCI + HPCI + ADS
	DC Power Source	Suction	1 CS + 2 LPCI + ADS
	DC Power Source	Suction	1 CS + 3 LPI2* + ADS
	DC Power Source	Discharge	2 CS + ADS
	DC Power Source	Discharge	1 CS + 1 LPCI + ADS

*LPI2 means LPCI injection into 2 loops

Table 5

DC POWER SOURCE/LPCI-IV FAILURE COMPARISONS FOR LARGE BREAK

Systems Operable	Failure	Break Location	Break Size	First Uncovery (sec)	Recovery (sec)	PCT (°F)
2 CS + HPCI + ADS	LPCI-IV	Discharge	100% DBA	44.73	175.42	2195
1 CS* + 1 LPCI + ADS	DC Power Source	Discharge	100% DBA	46.25	138.76	2073

*Used "½h" (see text for explanation)

Table 6

RESULTS FOR 20% REDUCTION IN ADS CAPACITY

Failure	ECC Systems	Number of ADS Valves	PCT (°F)	$\Delta T_{(N-1)}$ (°F)
DC Power Source	1 CS** + 1 LPCI + ADS	5	1769	155
DC Power Source	1 CS** + 1 LPCI + ADS	4	1924	

**Used "½h" (see text for explanation)

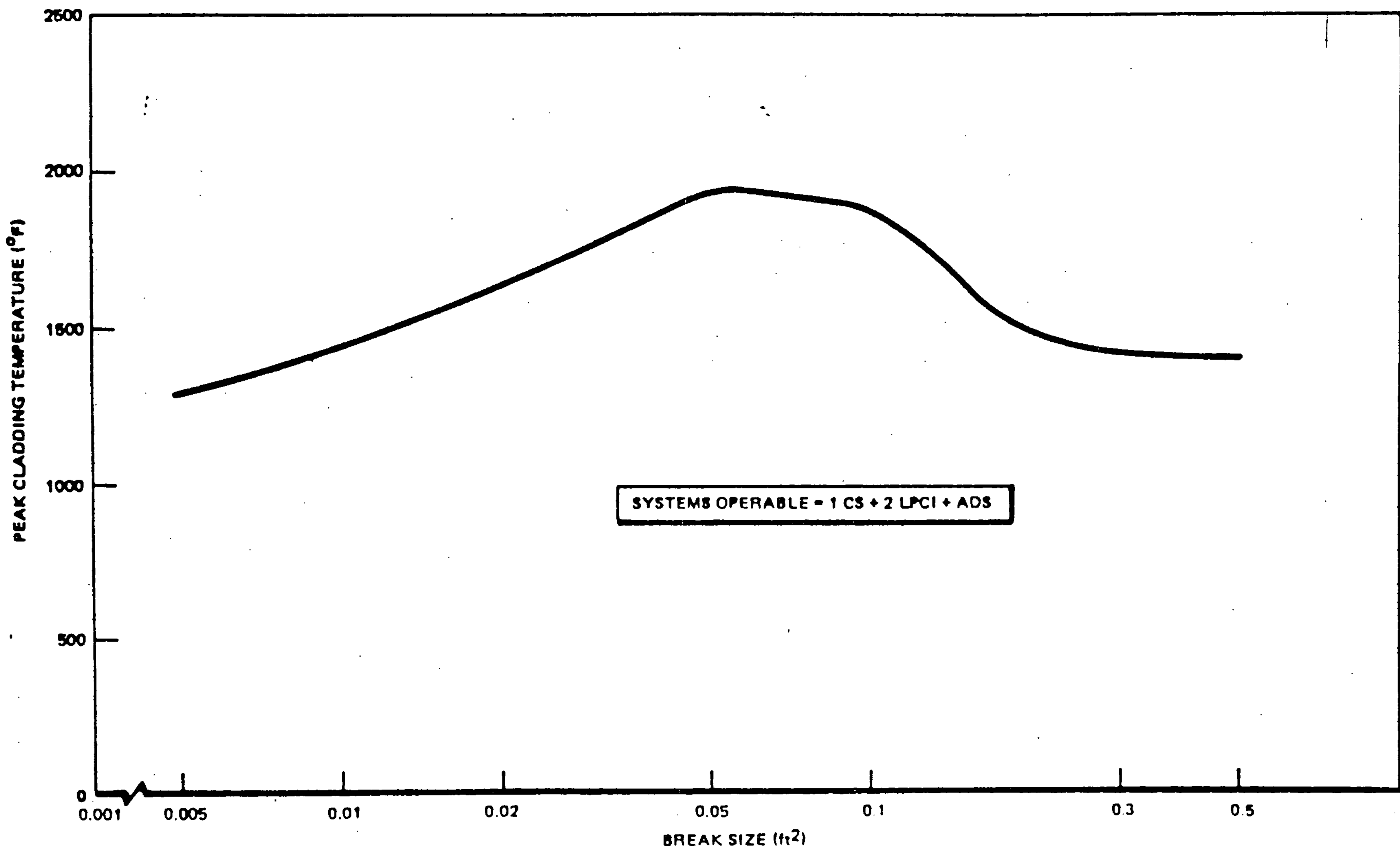

Figure 1. Non-LPCI Modified Plants Bounding Small Break Spectrum
Peak Cladding Temperature Versus Break Size

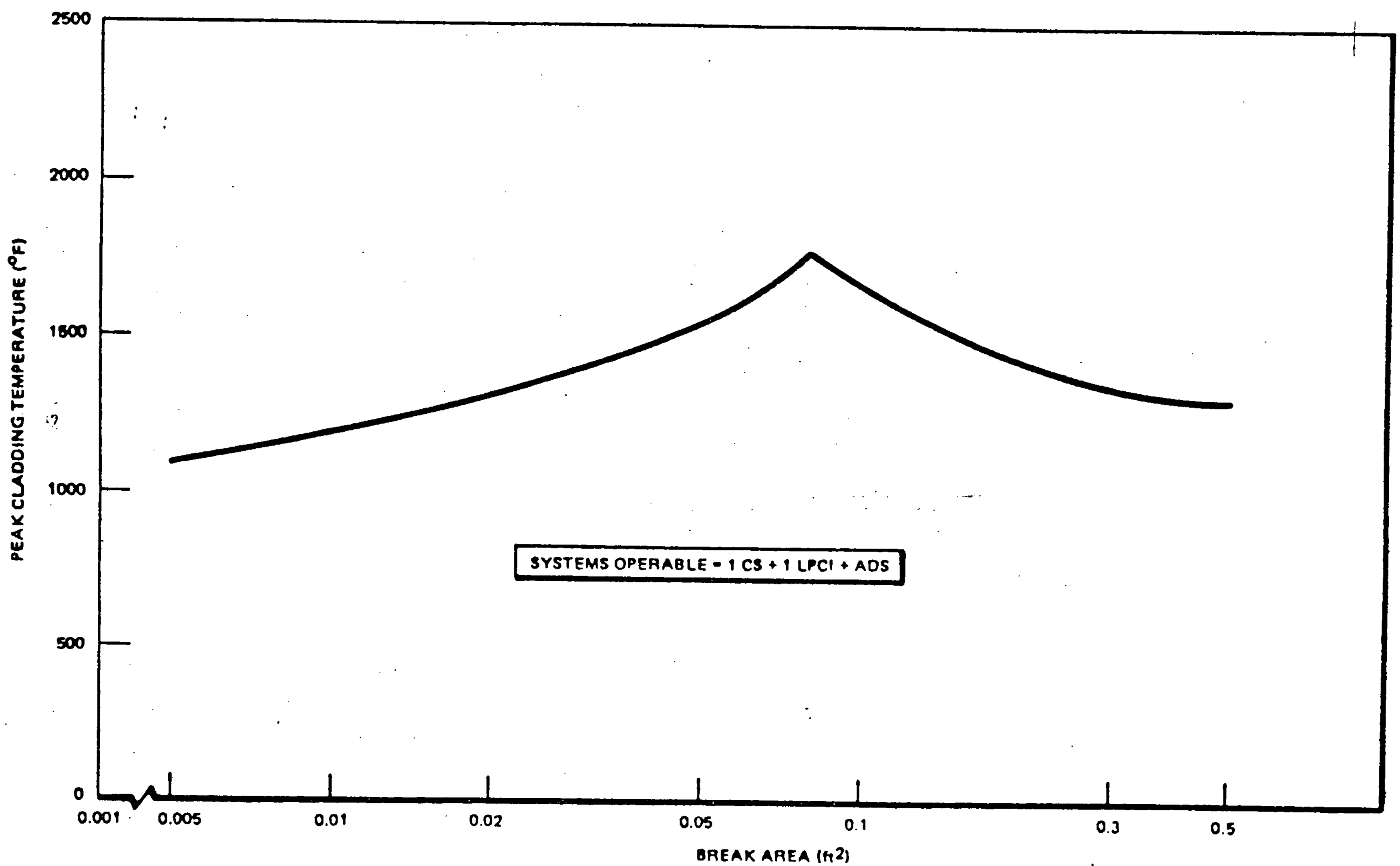

Figure 2. LPCI Modified Plants Bounding Small Break Spectrum Peak Cladding Temperature Versus Break Size

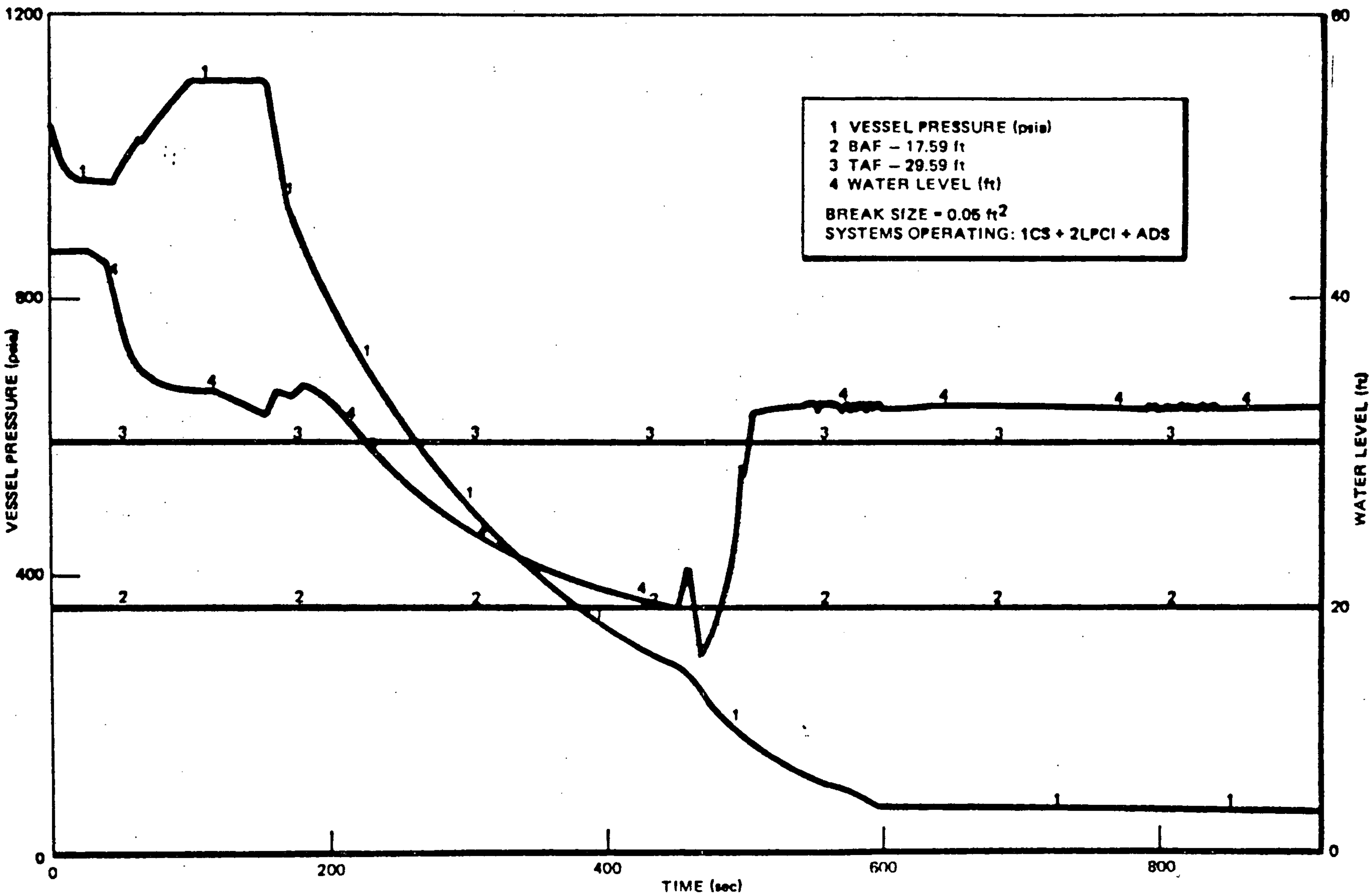

Figure 3. Non-LPCI Plants Vessel Pressure and Water Level Versus Time for a Small Break

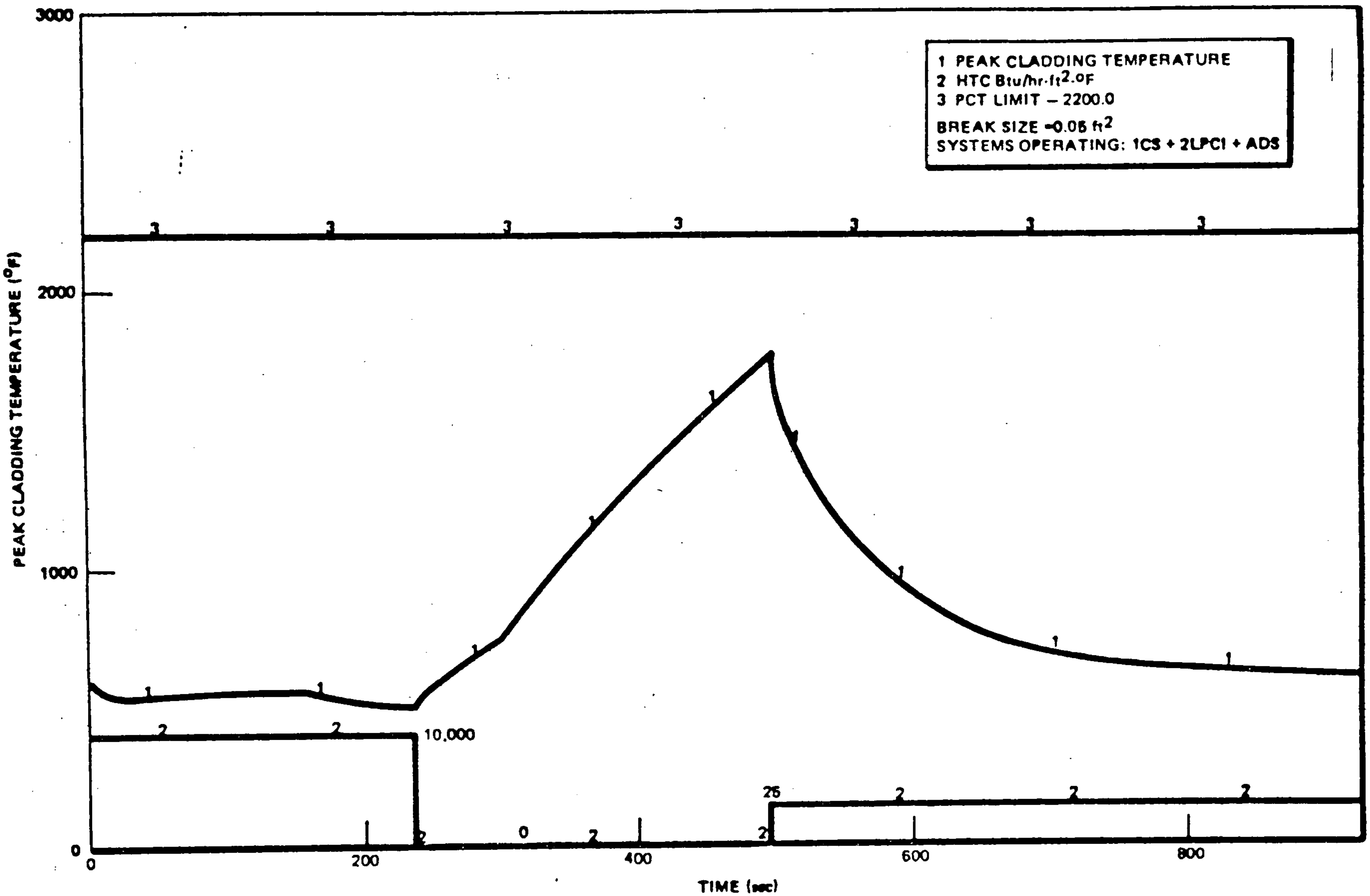

Figure 4. Non-LPCI Modified Plants Peak Cladding Temperature Versus Time for a Small Break

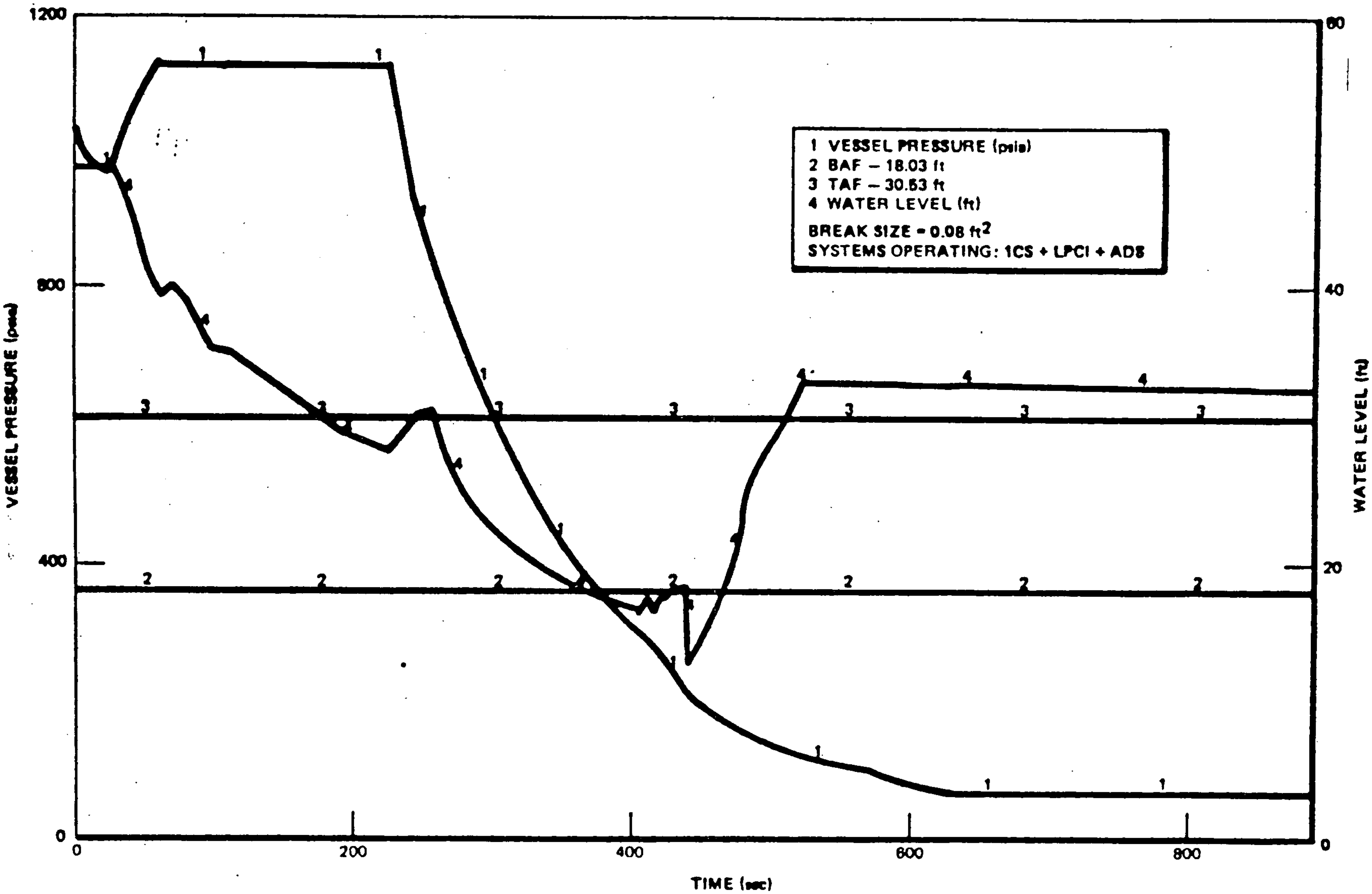

Figure 5. LPCI Modified Plants Vessel Pressure and Water Level Versus Time for a Small Break

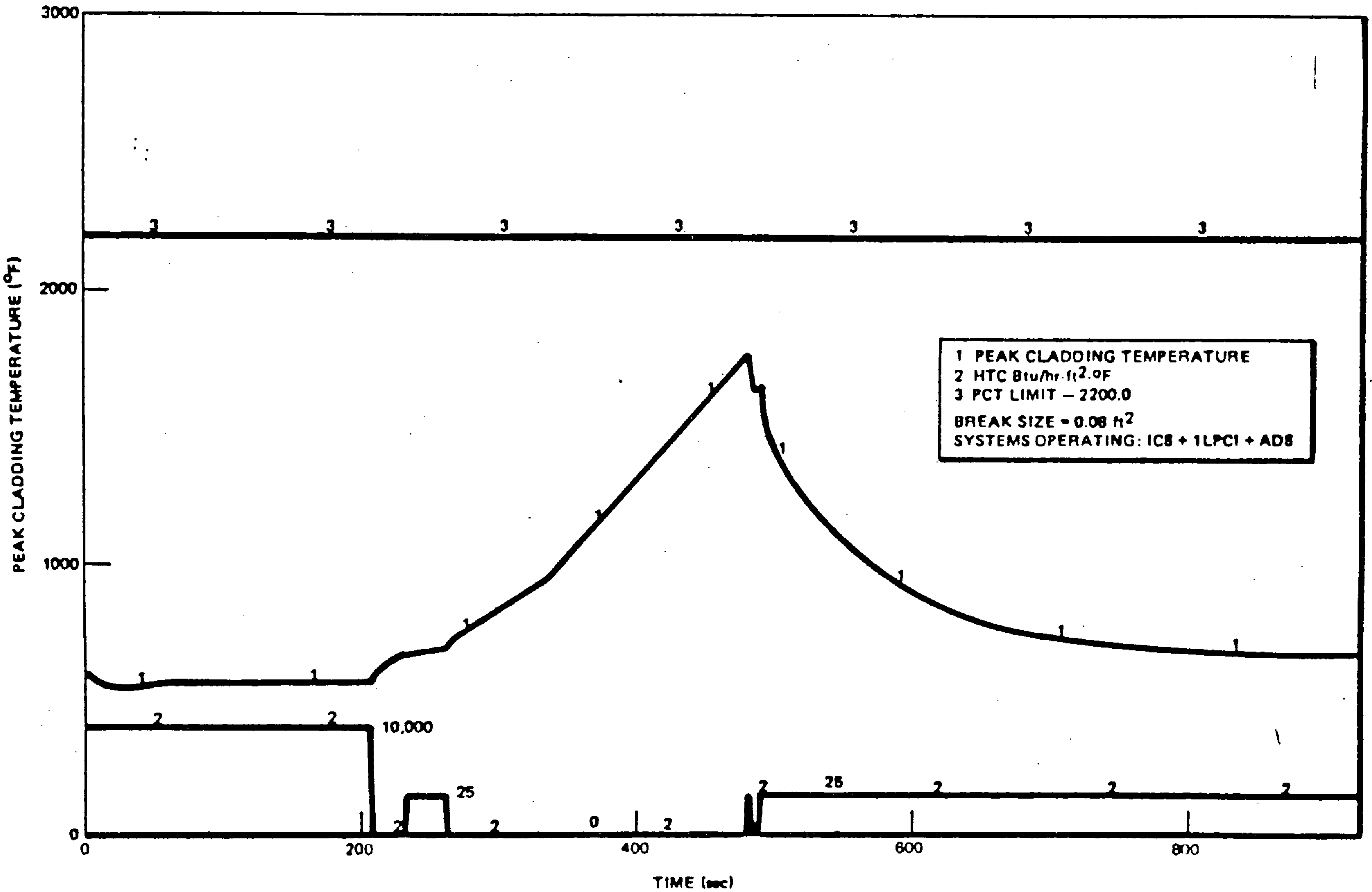

Figure 6. LPCI Modified Plants Peak Cladding Temperature Versus Time for a Small Break