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DENTON,H.R. Office of Nuclear Reactor Regulation, Director

SUBJECT: Forwards addl info re hydrogen mitigation & control at facilities.Util continues to work w/TVA & Duke Power Co toward completion of executive summary rept on ice condenser hydrogen R & D program. *See repts*

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September 30, 1982
AEP:NRC:0500H

Donald C. Cook Nuclear Plant Unit Nos. 1 and 2
Docket Nos. 50-315 and 50-316
License Nos. DPR-58 and DPR-74
HYDROGEN MITIGATION AND CONTROL STUDIES

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Denton:

This letter and its Attachments provide additional information related to Hydrogen Mitigation and Control at the Donald C. Cook Nuclear Plant Unit Nos. 1 and 2. Attachment No. 1 contains a summary of the results of Cook Plant specific analyses. The CLASIX analyses included in Attachment No. 1 supplement the analysis contained in Attachment No. 2 to our AEP:NRC:00500E letter dated July 2, 1981. Attachment No. 2 to this letter contains a summary of a Core Recovery Analysis performed by Westinghouse using the LOCTA and WFLASH computer codes. Attachment No. 3 to this letter contains a summary of an evaluation of igniter separation in the ice condenser upper plenum.

American Electric Power continues to work with the Tennessee Valley Authority and Duke Power Company toward compilation of an Executive Summary Report on the ice condenser utilities' hydrogen research and development program, as requested in Mr. S. A. Varga's letter of April 29, 1982.

This document has been prepared following Corporate Procedures which incorporate a reasonable set of controls to insure its accuracy and completeness prior to signature by the undersigned.

Very truly yours,

A001

R. S. Hunter
Vice President

/os

cc:(attached)

cc: John E. Dolan - Columbus
M. P. Alexich
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W. G. Smith, Jr. - Bridgman
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G. Charnoff
Joe Williams, Jr.
NRC Resident Inspector at Cook Plant - Bridgman

ATTACHMENT NO. 1 TO AEP:NRC:00500H
DONALD C. COOK NUCLEAR PLANT UNIT NOS. 1 AND 2
HYDROGEN MITIGATION AND CONTROL STUDIES
CLASIX ANALYSES

1.0 Introduction

A series of five containment response analyses have been performed using the version of the CLASIX computer code described in Reference 1 (hereafter referred to as the "new" version of CLASIX). Theses analyses supplement the analysis detailed in Attachment No. 2 to Reference 2 and provide additional information requested in Mr. S. A. Varga's letter of July 15, 1981. The results of the containment analyses indicate that for all cases analyzed the containment pressure remains well within the structural capability of the Cook Plant containment. The basis for selection of base case accident conditions and a summary of the parametric analyses are given below.

2.0 Selection of 'Base Case Accident' Conditions

The selection of a 'base case accident' sequence to be used for evaluation of hydrogen control in general and use of the Distributed Ignition System (DIS) was made in consideration of the hydrogen generation during the TMI-2 accident, the relative probability of various hypothetical event sequences involving substantive hydrogen generation, and engineering judgment. The S_2D sequence was chosen as it is somewhat similar in nature to the TMI-2 accident and it represented one of the more probable event sequences for a Pressurized Water Reactor identified in the Reactor Safety Study, WASH-1400 (Reference 3). The selection of S_2D as the base case event sequence is further justified in light of the results of the Reactor Safety Study Methodology Applications Program (RSSMAP) analysis of the Sequoyah Ice Condenser Plant (Reference 4), the results of which indicate that small and intermediate break LOCAs are the dominant accident sequences. Hence, the S_2D event was chosen as the base case accident sequence and parametric variations on hydrogen and steam production rates evaluated in light of the remaining dominant hydrogen-related sequences identified in NUREG-1659. The base case hydrogen and steam production rates were generated by analysis of the S_2D event with the MARCH computer code. The containment response to the S_2D event, including hydrogen release and combustion, was analyzed with the CLASIX computer code. CLASIX is fully described in Westinghouse/Offshore Power Systems (W/OPS) document OPS-07A35 (Reference 1), previously transmited to the NRC by Tennessee Valley Authority (TVA) in Reference 5.

The percent hydrogen required for ignition in the base case analysis is eight volume percent (v/o). Use of the relatively high ignition limit in effect denies credit for the ability of the glow plug igniter to reliably initiate combustion of mixtures as lean as 5-6 v/o in hydrogen under adverse conditions, as shown in the results of the Fenwal (Reference 6 and 7), Whiteshell Nuclear Research (Reference 8), and Lawrence Livermore Laboratory (Reference 9) test programs. Furthermore, use of an 8 v/o ignition limit, coupled with the 85% burn completion fraction assumed in the base case analysis, results in conservatively high predictions for post-combustion containment temperature and pressure transients. Similarly, use of a six feet per second (fps) flame speed results in a conservative overestimation of the energy input rate into the containment which, in turn, results in conservatively high containment temperature and pressure transients.

3.0 The Base Case Analysis

Containment analyses have been performed using the version of the CLASIX computer code described in Reference No. 1. The analysis detailed in Attachment No. 2 to Reference 2 (Case A), originally performed with the 'old' version of CLASIX, has been repeated using the new version of the code. The results of the re-analysis (Case B) are shown in Figures 3.0-1 through 3.0-19. In these figures, Case B is described as the "Cook, Old Base Case" because the differences in results between this case and Case A are only due to coding changes in CLASIX, not to changes in the input parameters. Input parameters for both of these cases are given in Tables 1 through 18 of Attachment No. 2 to Reference 2. A comparison of the results of these two analyses, contained in Table 3.0-1, shows very small differences in the calculated results as a result of the coding modifications.

A third base case analysis, Case C, was performed using the same input parameters as were used for Case A and Case B except that:

(1) The burn time within a given compartment and the burn propagation delay time between compartments have been modified to reflect the number and location of igniters installed in the containment, and

(2) The air recirculation fan flow/head curve has been modified to account for increased air flow rates during periods when the upper compartment (fan suction) pressure exceeds the fan/accumulator room pressure.

Case C constitutes the best possible "Base Case" for the Cook Plant.

These changes in input values are summarized in Table 3.0-2 and a summary of the results is given in Table 3.0-3. The percent hydrogen for ignition and the burn completion fraction used in Case C are 8 v/o and 85%, respectively. The results of the analyses are shown in Figures 3.0-20 through 3.0-38.

TABLE 3.0 -1

COMPARISON OF CLASIX RESULTS *

	CASE A **	CASE B ***
NUMBERS OF BURNS PREDICTED		
LOWER COMPARTMENT	7	7
LOWER PLENUM	0	0
UPPER PLENUM	30	31
UPPER COMPARTMENT	0	0
DEAD-ENDED VOLUME	0	0
FAN/ACCUMULATOR ROOMS	0	0
PEAK ATMOSPHERIC TEMPERATURE (°F)		
LOWER COMPARTMENT	828	846
LOWER PLENUM	383	359
UPPER PLENUM	1155	1140
UPPER COMPARTMENT	168	160
DEAD-ENDED VOLUME	216	208
FAN/ACCUMULATOR ROOMS	205	185
PEAK PRESSURE (PSIG)		
LOWER COMPARTMENT	10.9	10.9
LOWER PLENUM	10.8	10.2
UPPER PLENUM	10.8	10.5
UPPER COMPARTMENT	10.5	10.0
DEAD-ENDED VOLUME	10.9	10.7
FAN/ACCUMULATOR ROOMS	10.8	10.7

NOTES FOR TABLE 3.0 -1

* Hydrogen concentration for ignition assumed to be 8 $^{v}/_{o}$ and the burn fraction assumed to be 85%. Remaining input parameters are given in Table Nos. 1 through 18 of Attachment No. 2 to Reference 2.

** Case A was performed using the 'old' version of CLASIX. The results of this analysis have been previously transmitted to the Commission via Reference 2.

*** Case B was performed using the 'new' version of CLASIX described in OPS Document No. OPS-07A 35 (Reference 1).

TABLE 3.0.-2
CLASIX INPUT PARAMETERS - CASE C
BURN PARAMETERS

(1)

COMPARTMENT	BURN TIME (SECONDS)
LOWER COMPARTMENT (LC)	3.80
LOWER PLENUM (LP)	4.36
UPPER PLENUM (UP)	1.80
UPPER COMPARTMENT (UC)	9.70
DEAD-ENDED VOLUME (D-E)	2.42
FAN/ACCUMULATOR ROOMS (F/A)	2.58

(2)

JUNCTION	PROPAGATION DELAY TIME (SECONDS)
LC-IP	3.80
IP-UP	5.48
UP-UC	1.10
UC-LC	9.70
DE-LC	3.80
F/A-LC	3.80

(3) FAN FLOW/HEAD PARAMETERS

HEAD (inches of H_2O)	FLOW (cfm)
- 1.40 E+2	1.672 E+5
- 1.20 E+2	1.547 E+5
- 8.00 E+1	1.264 E+5
- 4.00 E+1	8.939 E+4
- 2.00 E+1	6.321 E+4
0.00 E+0	5.300 E+4
1.00 E+0	5.050 E+4
2.00 E+0	4.750 E+4
3.00 E+0	4.450 E+4
4.00 E+0	4.150 E+4
4.50 E+0	3.970 E+4
5.00 E+0	3.800 E+4
6.00 E+0	3.420 E+4
6.50 E+0	3.100 E+4
6.80 E+0	2.500 E+4
6.90 E+0	1.600 E+4
6.90	0.00

Note: ALL OTHER INPUT PARAMETERS FOR CASE C ARE THE SAME AS THOSE GIVEN IN TABLE NO. 1 THROUGH 18 OF ATTACHMENT NO. 2 TO REFERENCE 2.

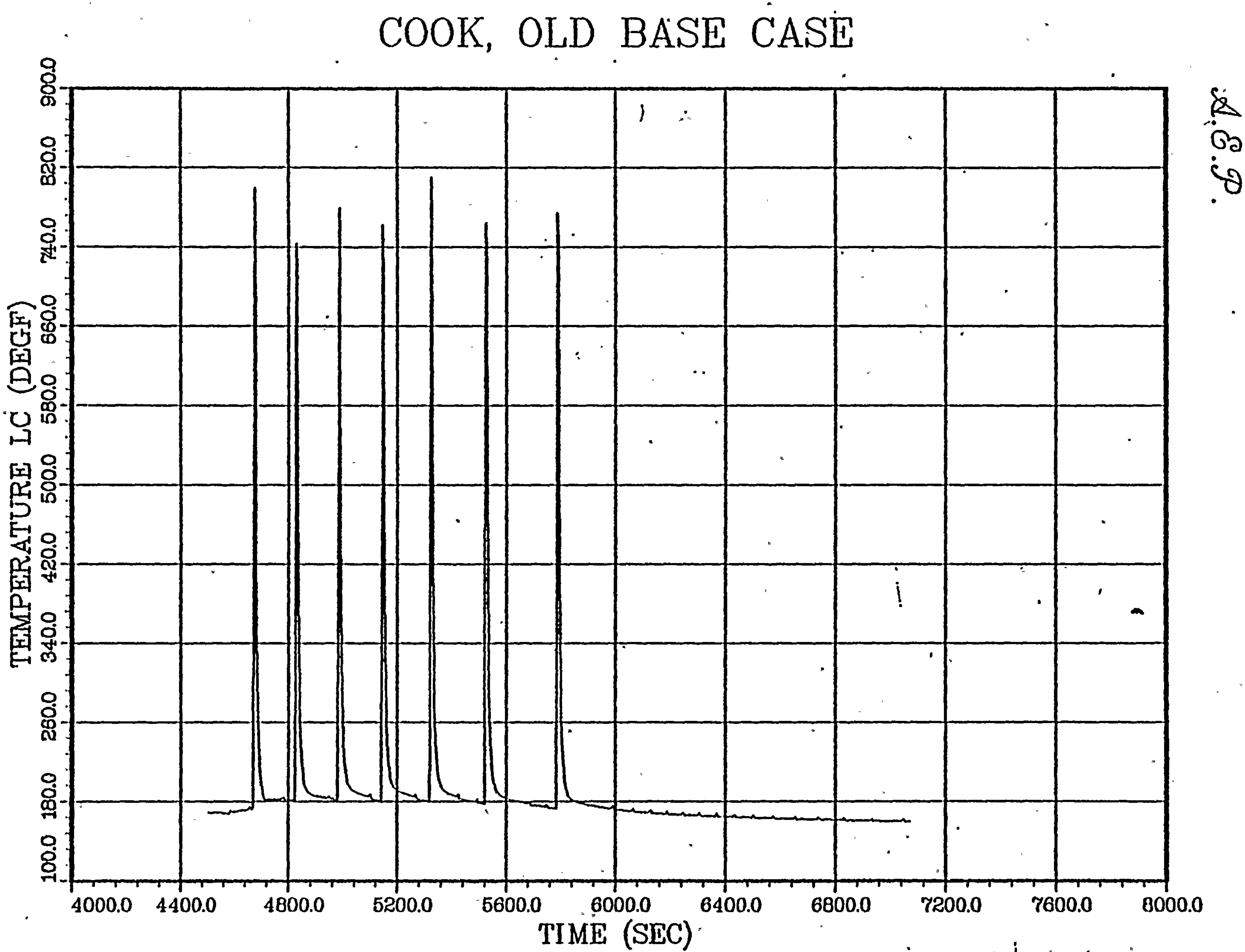
TABLE 3.0 -3

SUMMARY OF RESULTS - CASE C

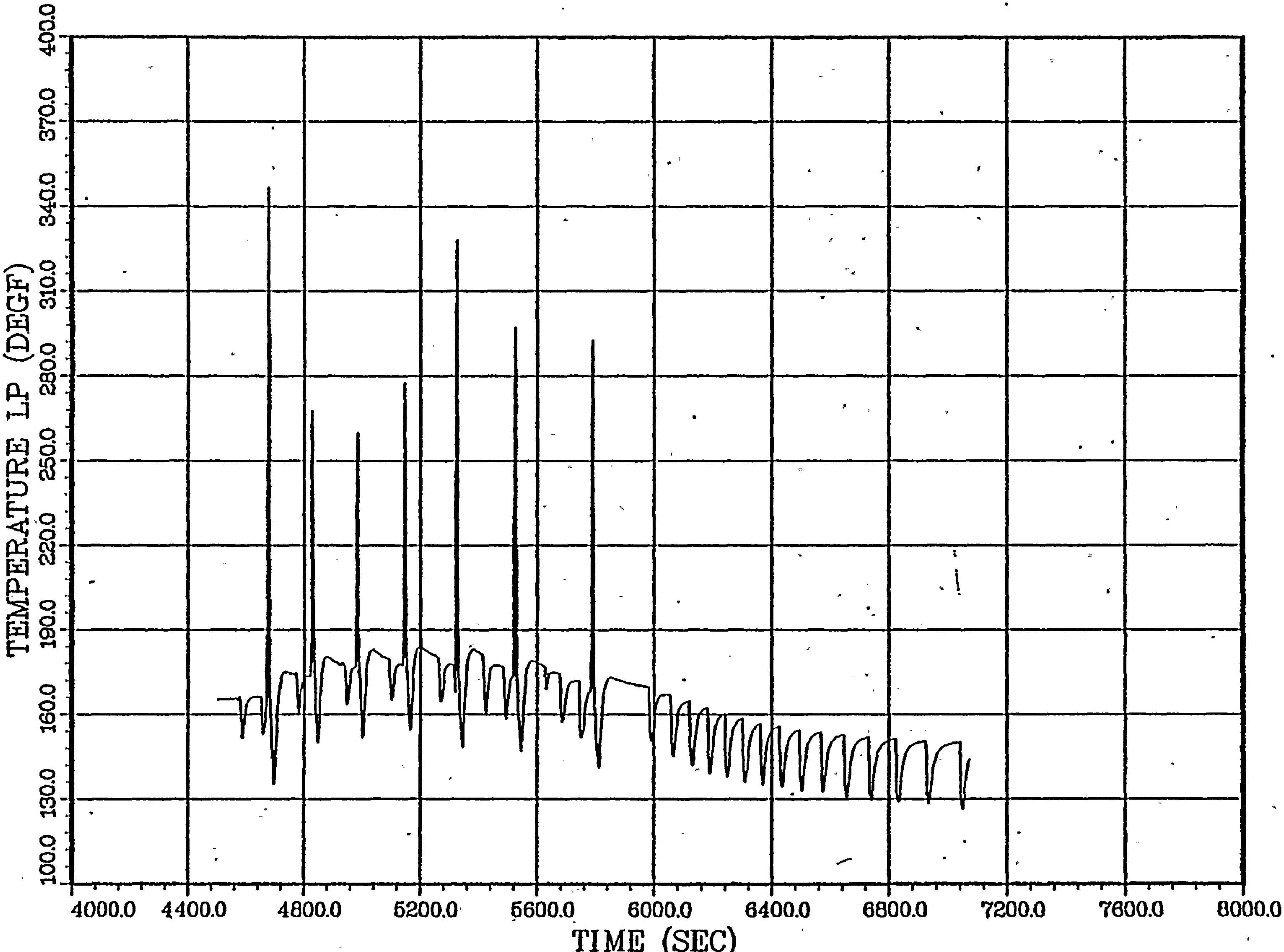
NUMBER OF BURNS PREDICTED	
LOWER COMPARTMENT	8
LOWER PLENUM	0
UPPER PLENUM	27*
UPPER COMPARTMENT	0
DEAD-ENDED VOLUME	0
FAN/ACCUMULATOR ROOMS	0
PEAK ATMOSPHERIC TEMPERATURE (^{o}F)	
LOWER COMPARTMENT	1076
LOWER PLENUM	477
UPPER PLENUM	1191
UPPER COMPARTMENT	170
DEAD-ENDED VOLUME	264
FAN/ACCUMULATOR ROOMS	234
PEAK PRESSURE (PSIG)	
LOWER COMPARTMENT	14.8
LOWER PLENUM	13.9
UPPER PLENUM	11.6
UPPER COMPARTMENT	10.2
DEAD-ENDED VOLUME	14.1
FAN/ACCUMULATOR ROOMS	14.3

*A twenty-eighth UP burn is in progress at the termination of the transient.

PLOT 1 20.14.18 FRI 22 JAN, 1982 JOB-ANZRIHE , CYBERNET NOS 1.0 DISSPLA VER 8.2



COOK, OLD BASE CASE



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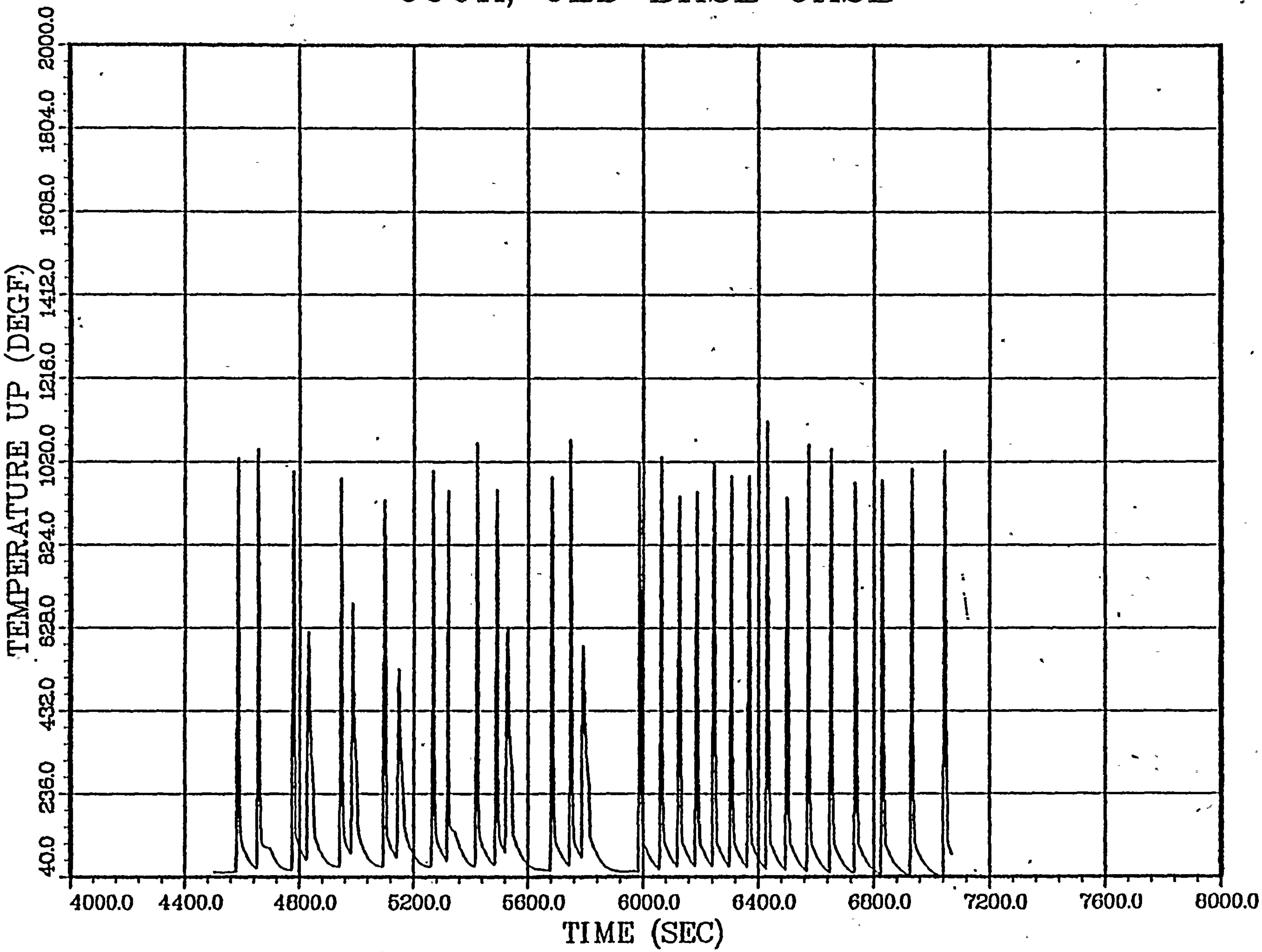
Case B - Figure 3.0-2

COOK, OLD BASE CASE



Case B - Figure 3.0-3

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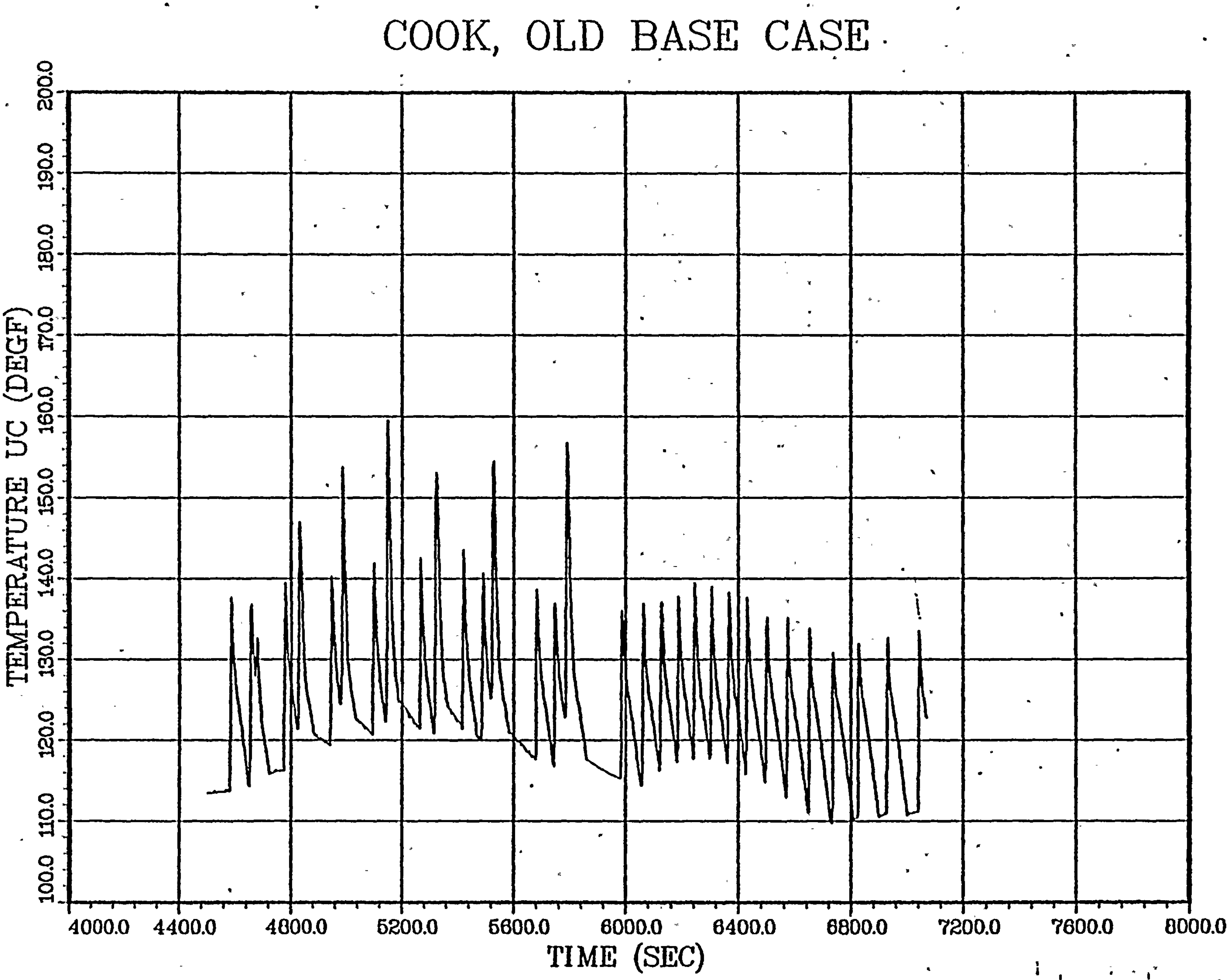

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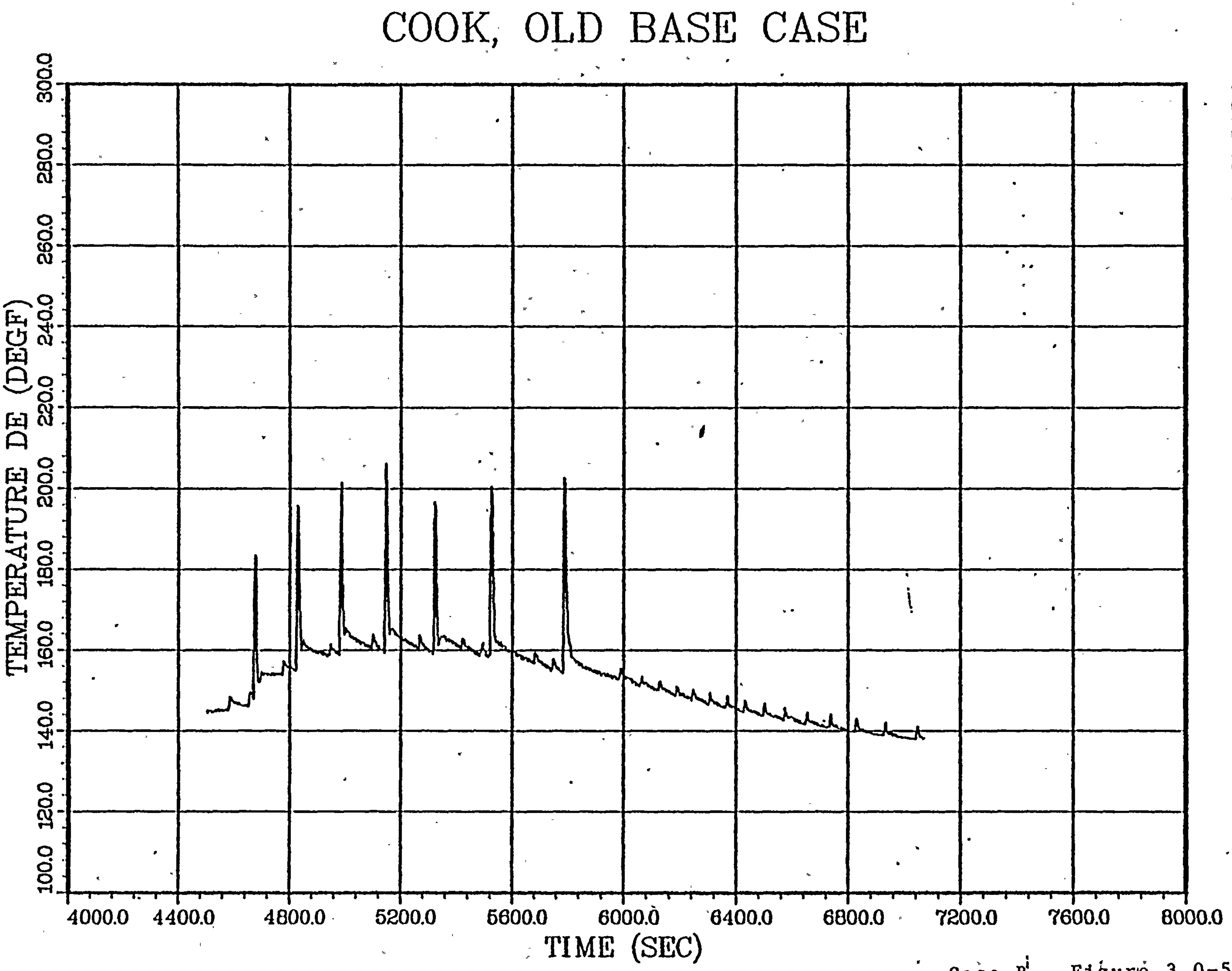
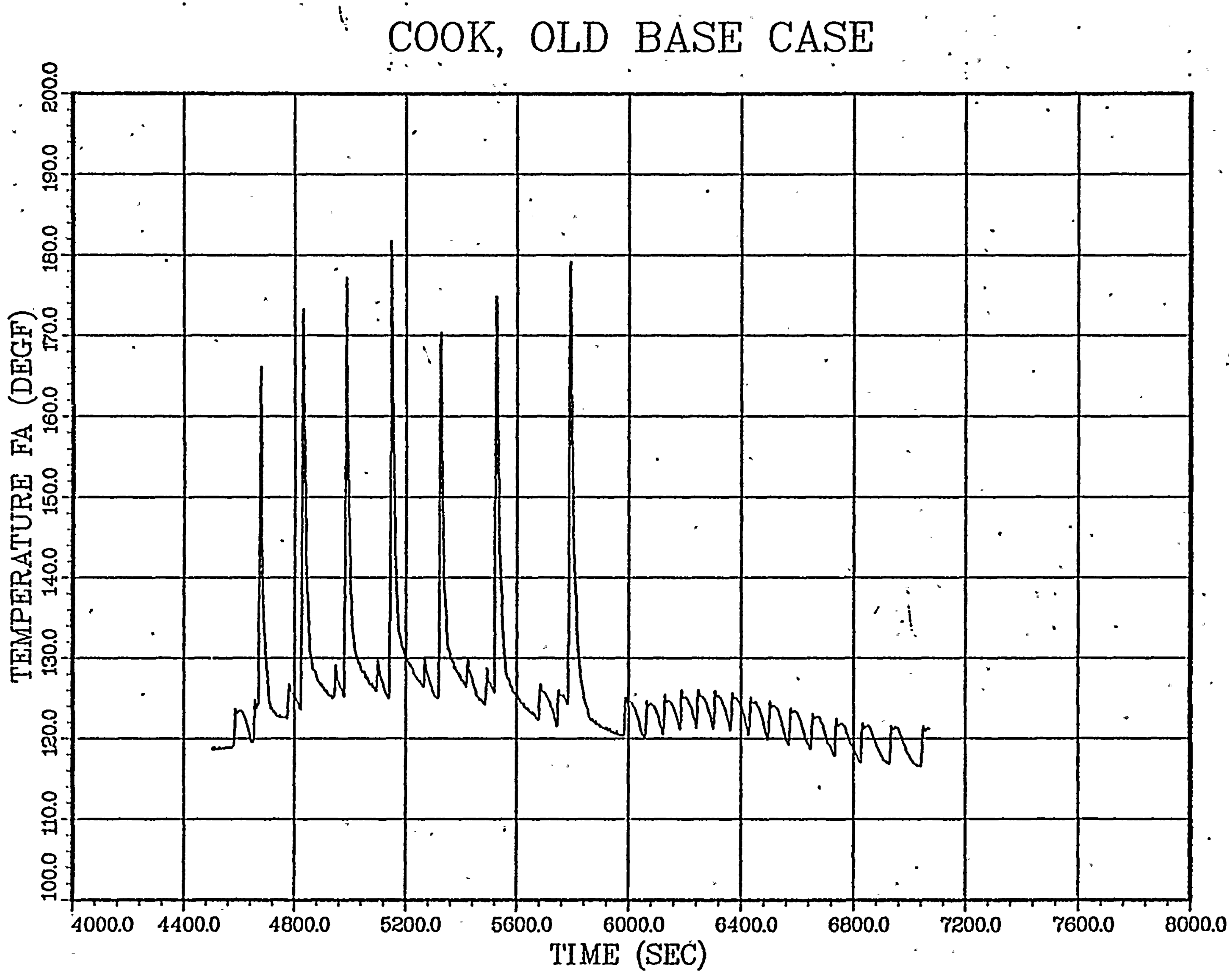


Case B - Figure 3.0-5

PLOT 6 20.14.36 FRI 22 JAN, 1982 JOB-ANZRINE , CYBERNET NOS 1.0 DISSPLA VER 8.2



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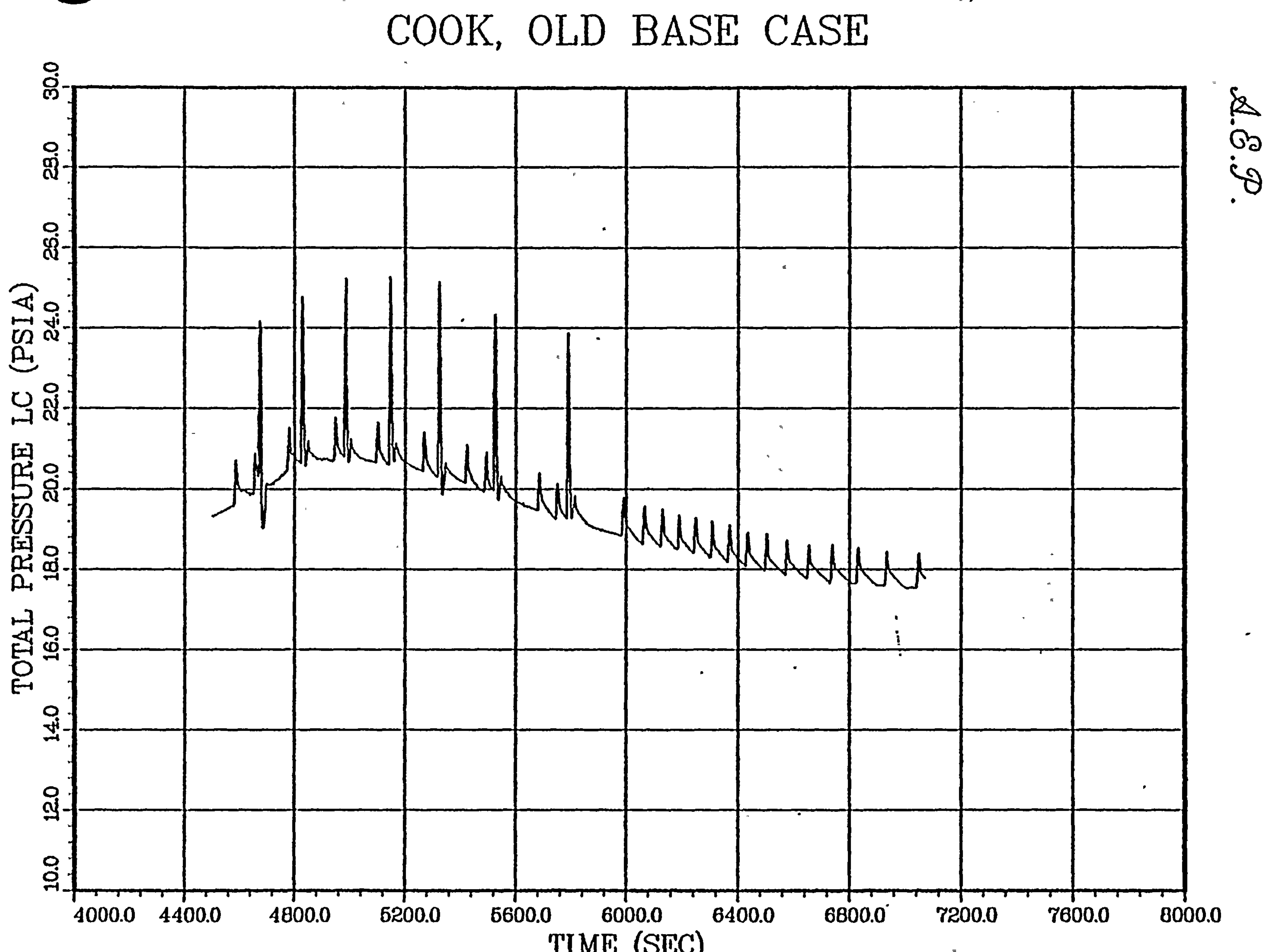
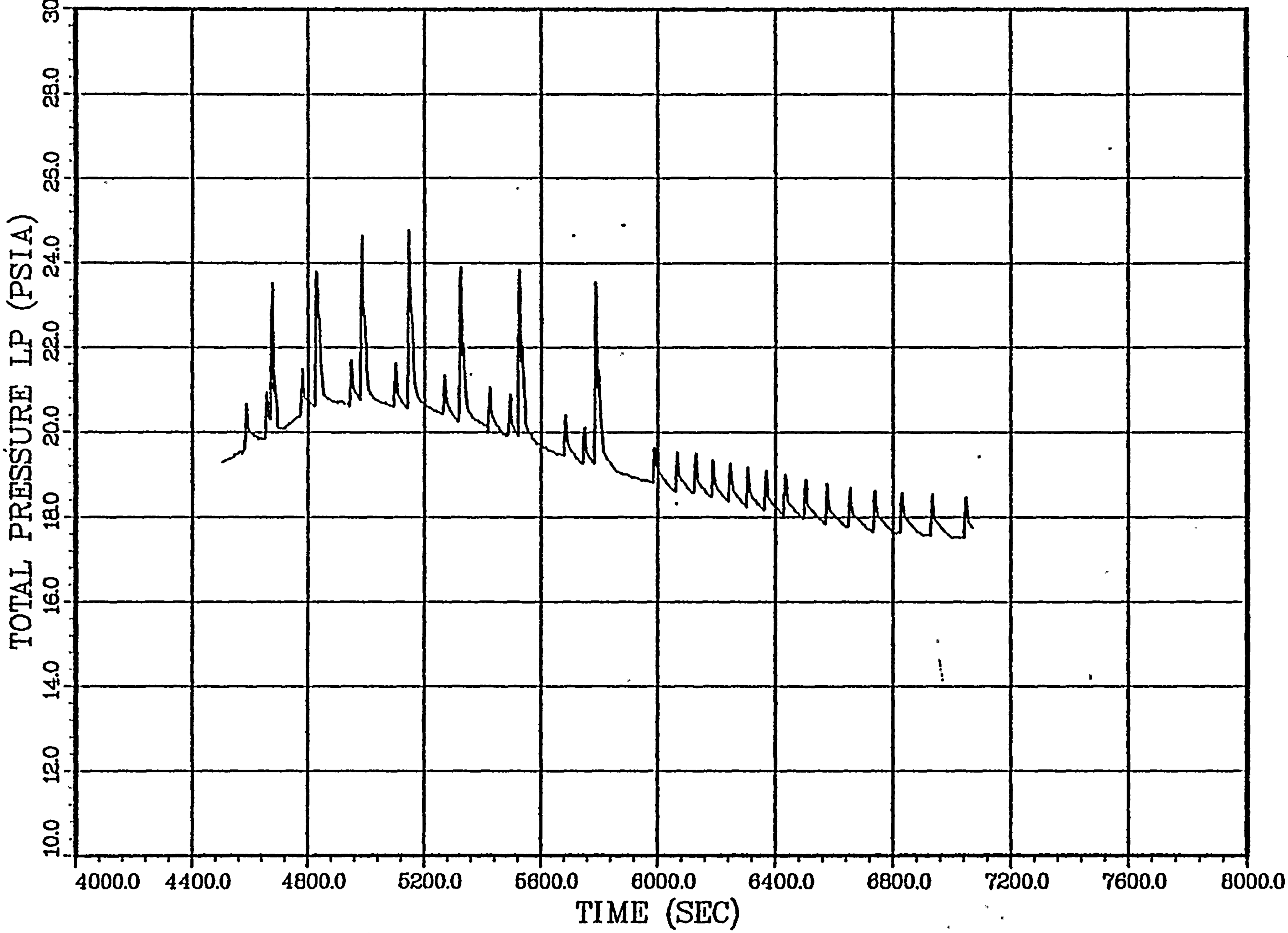


Case B - Figure 3.0-7

COOK, OLD BASE CASE



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Case B - Figure 3.0-8

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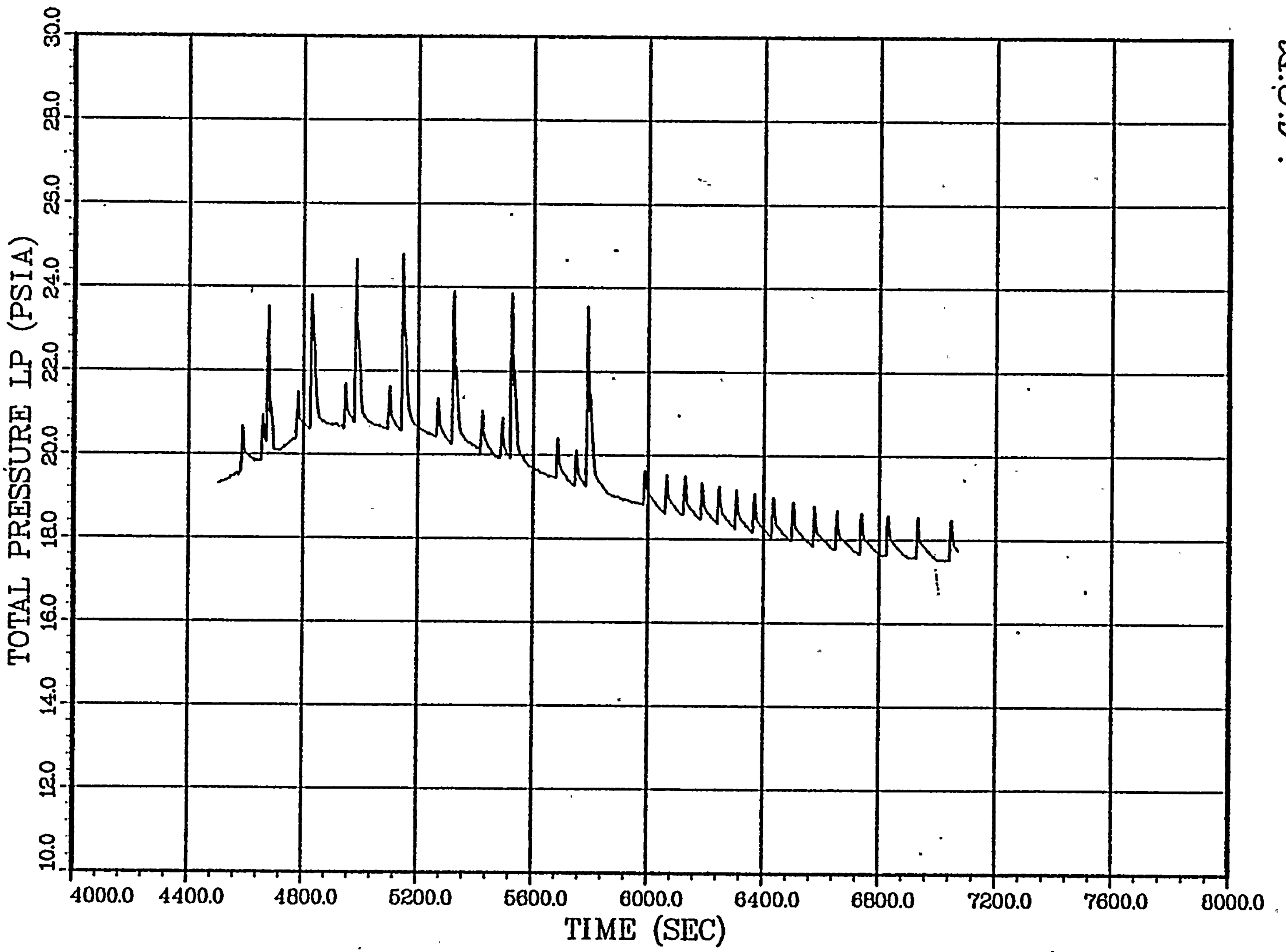

Case B - Figure 3.0-8

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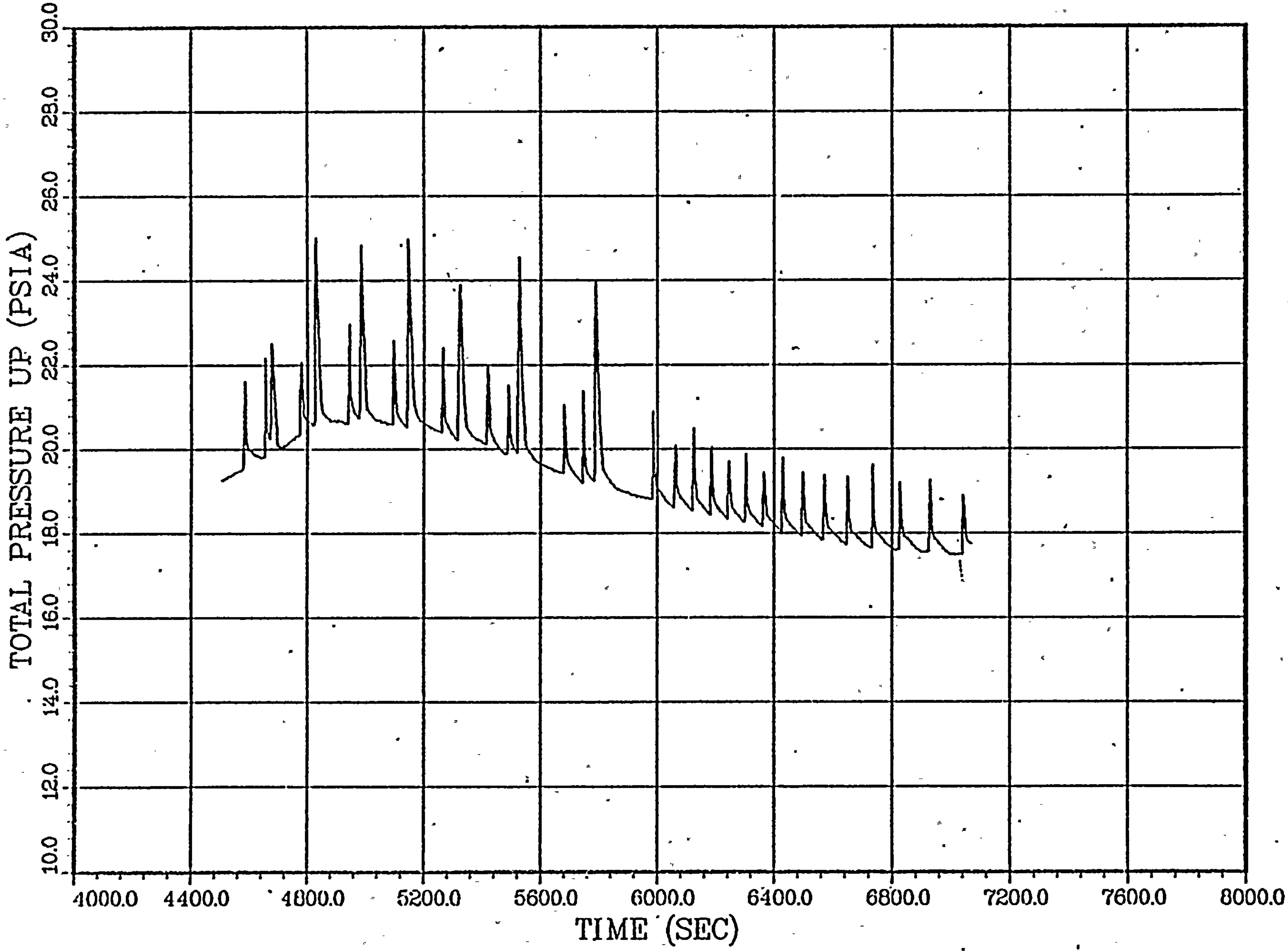

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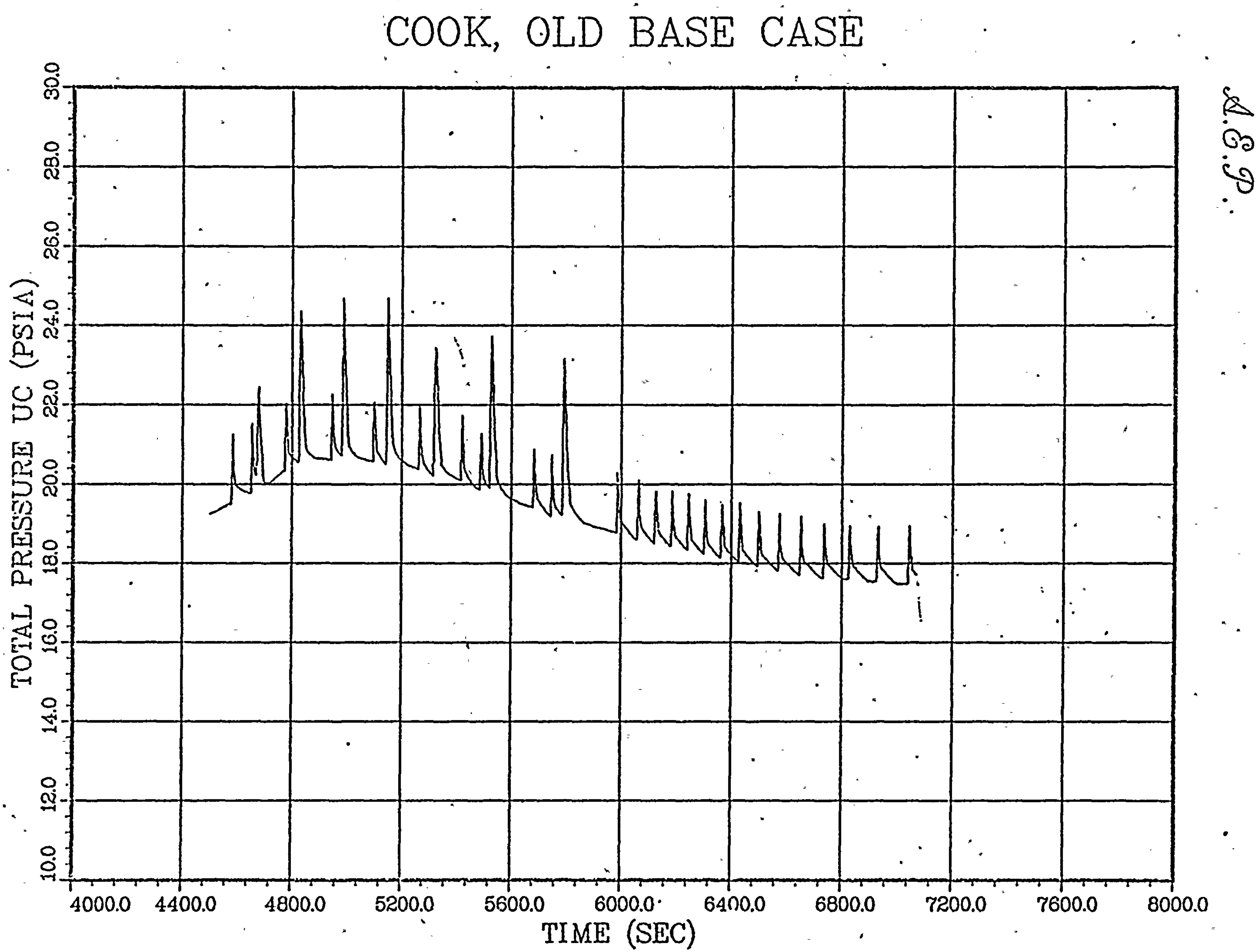
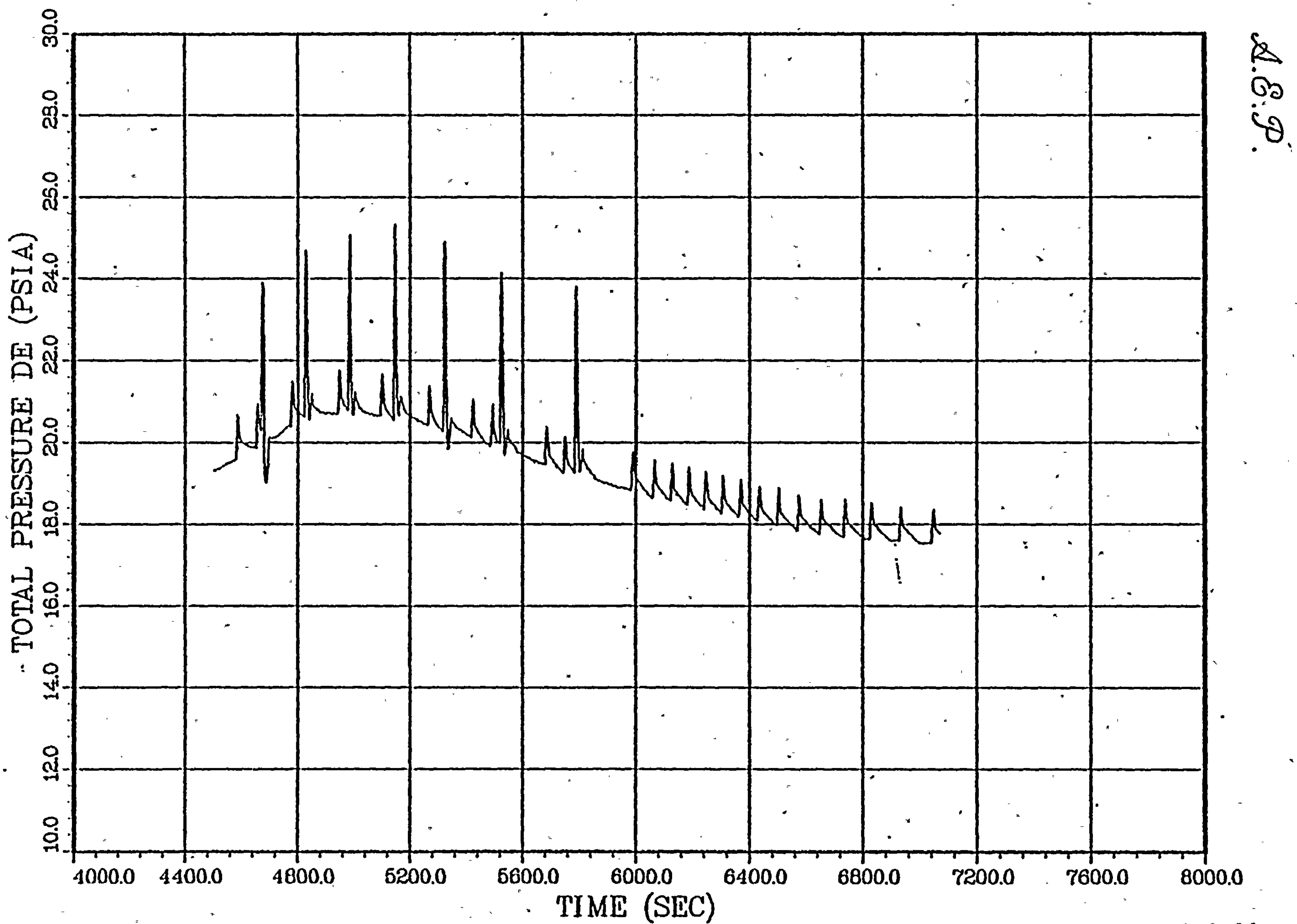
Case B - Figure 3.0-9



Case B - Figure 3.0-10

COOK, OLD BASE CASE



Case B - Figure 3.0-11

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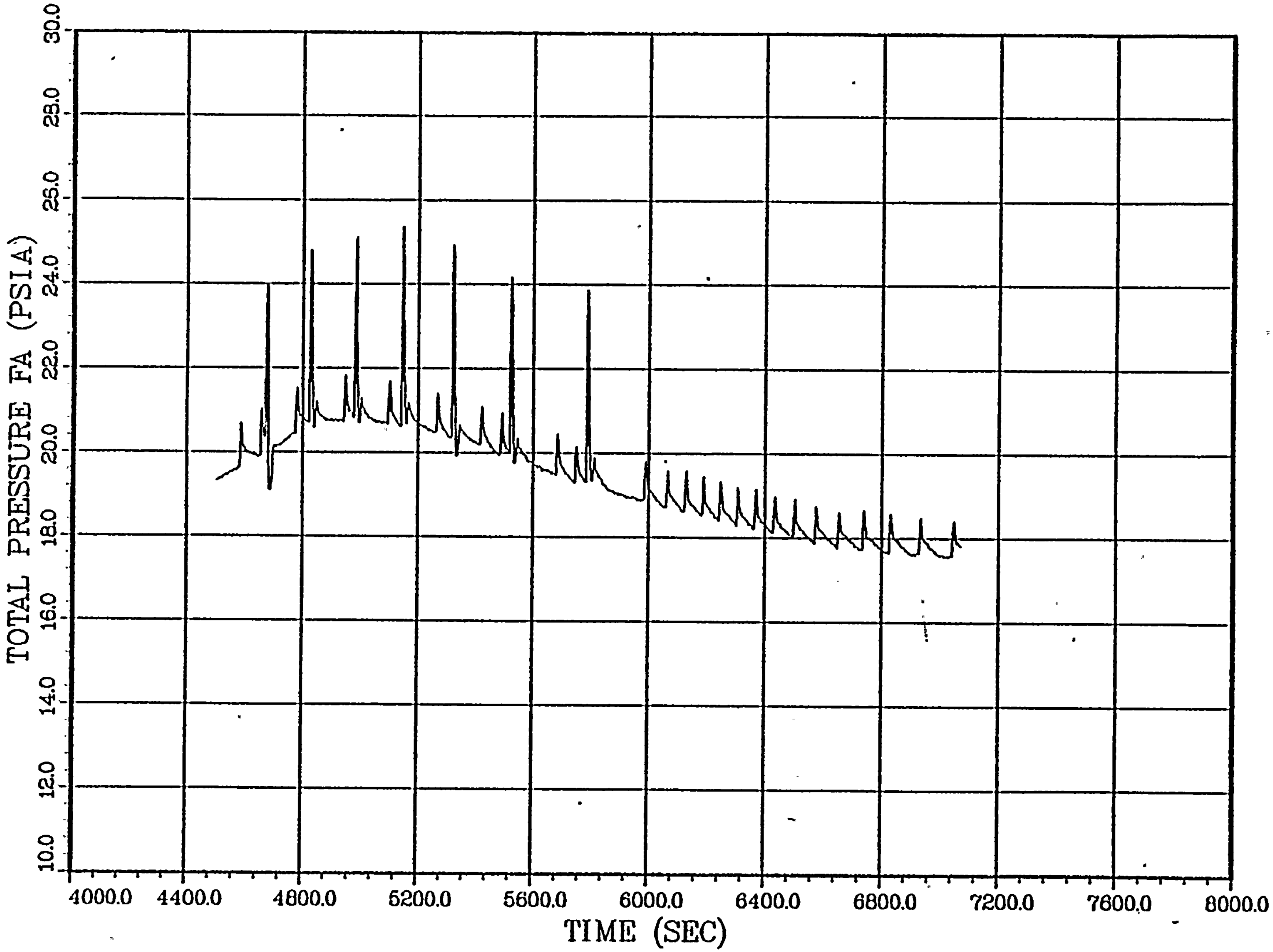

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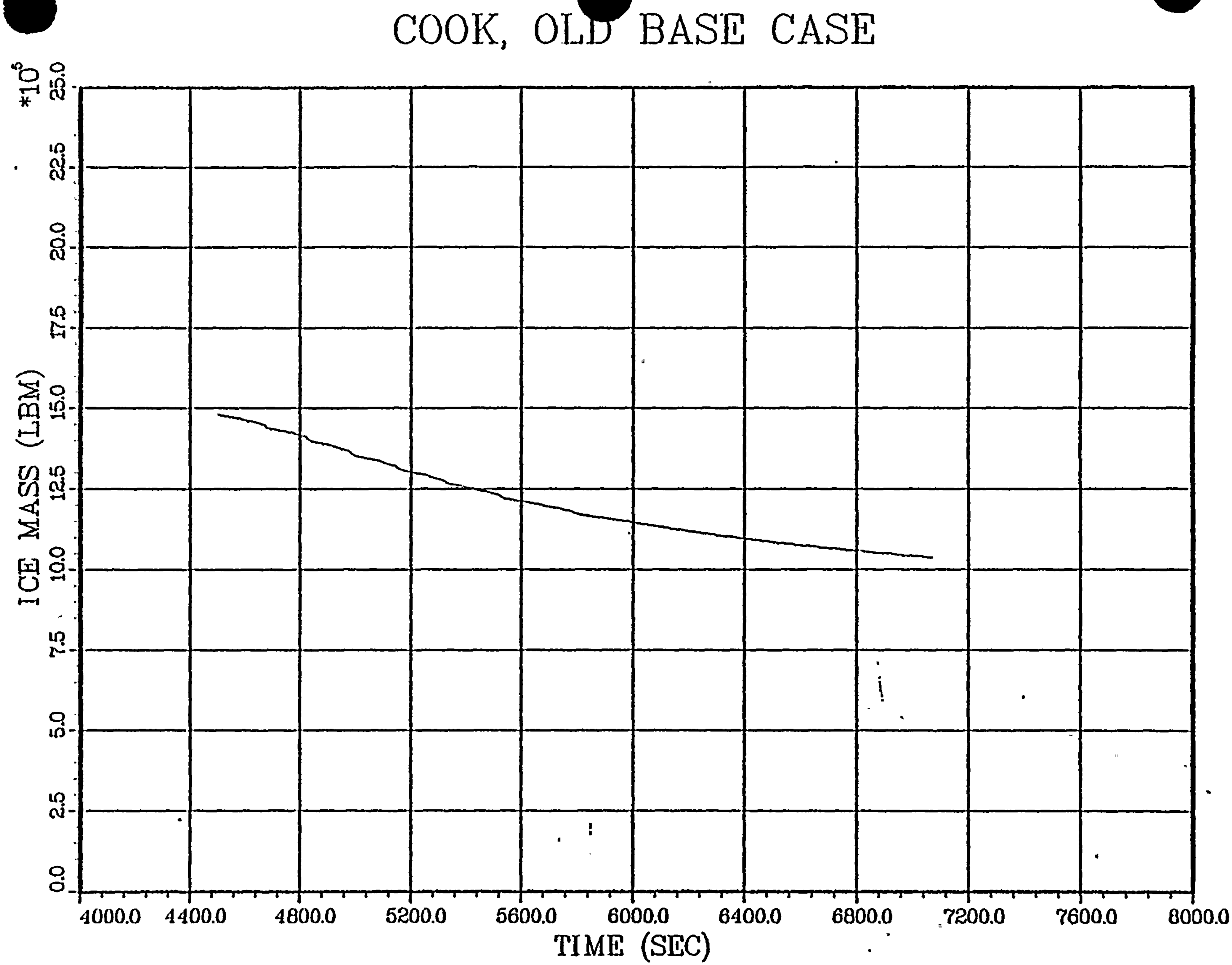
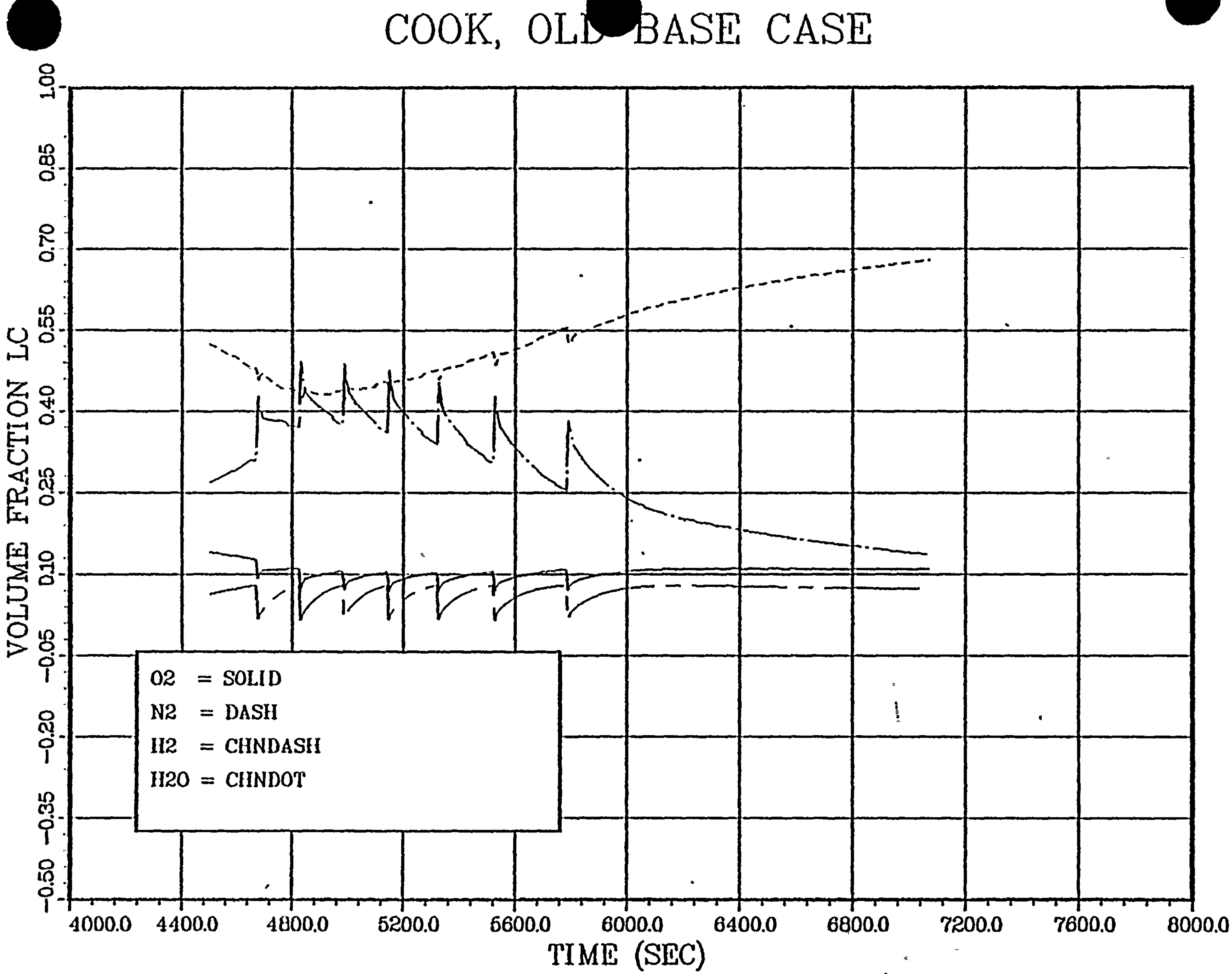
Case B - Figure 3.0-12



Case B - Figure 3.0-13



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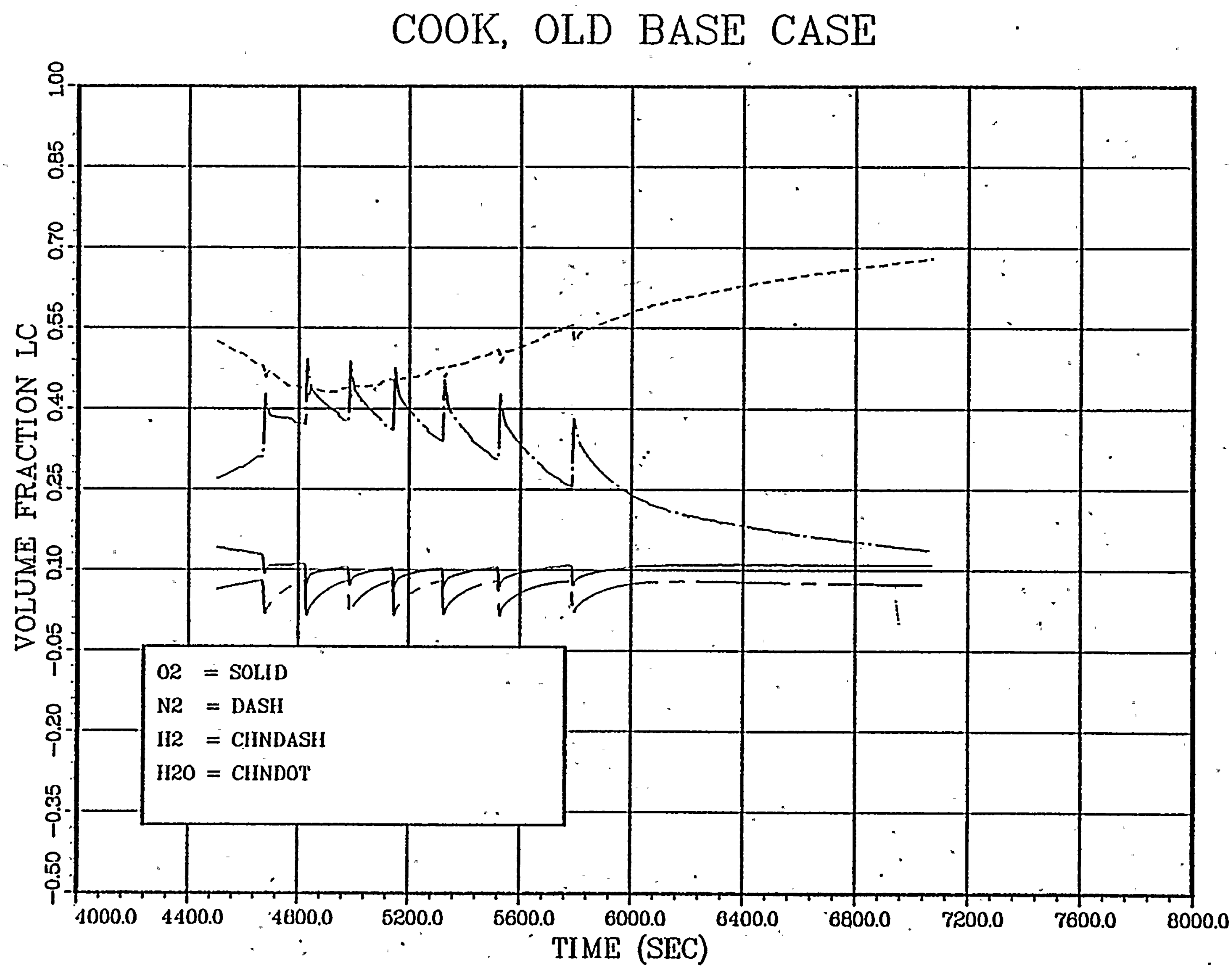
Case B - Figure 3.0-14



Case B' - Figure 3.0-14

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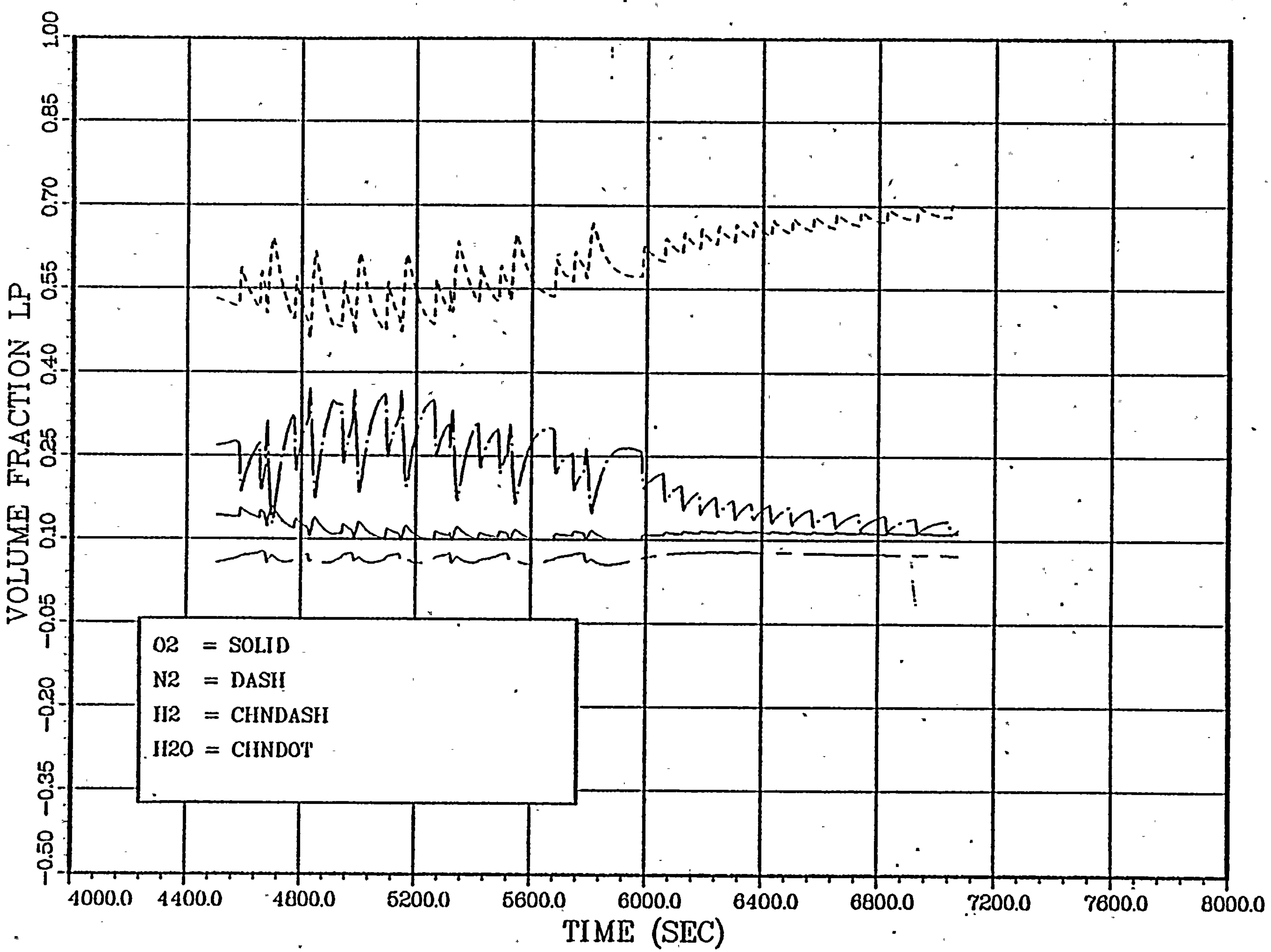

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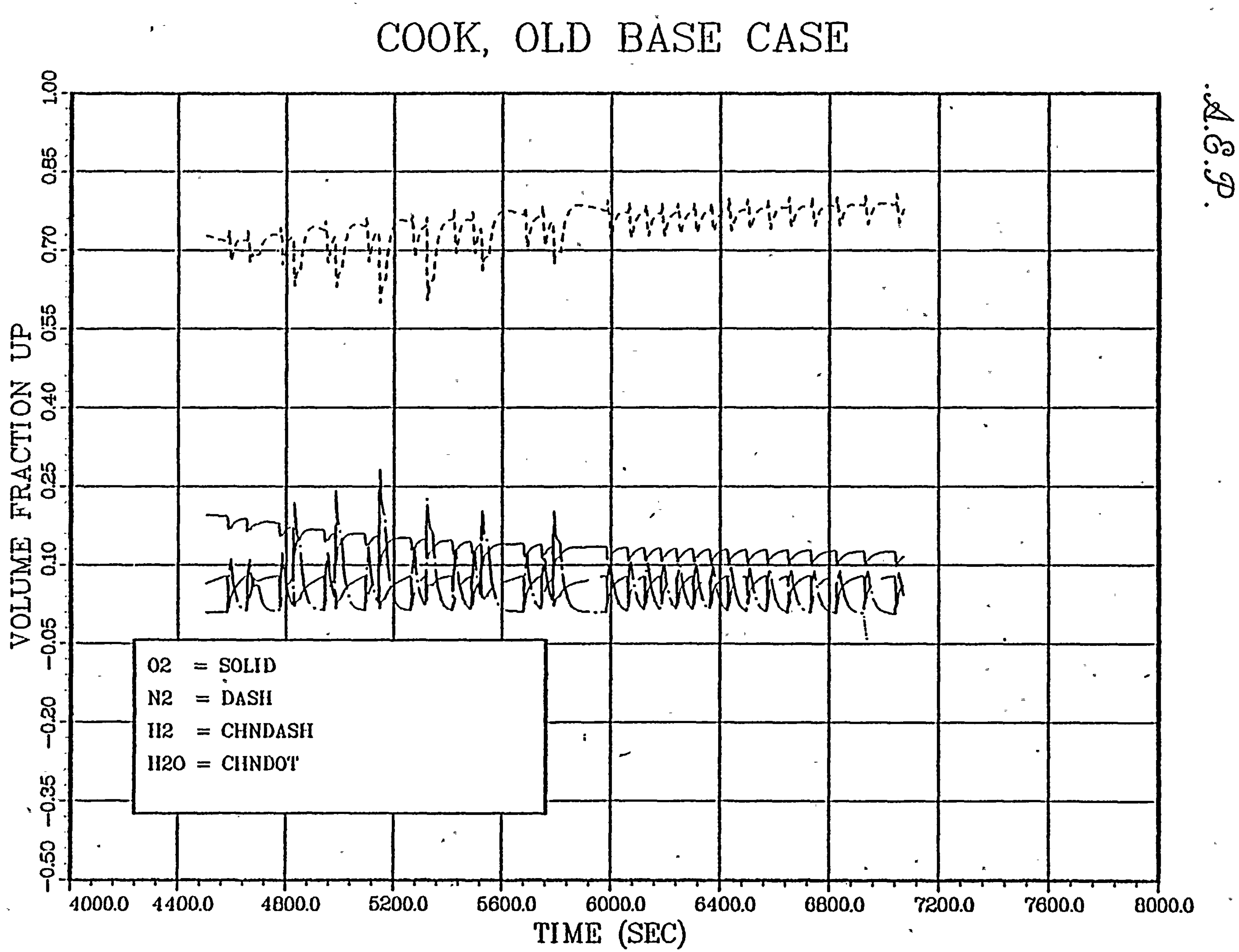
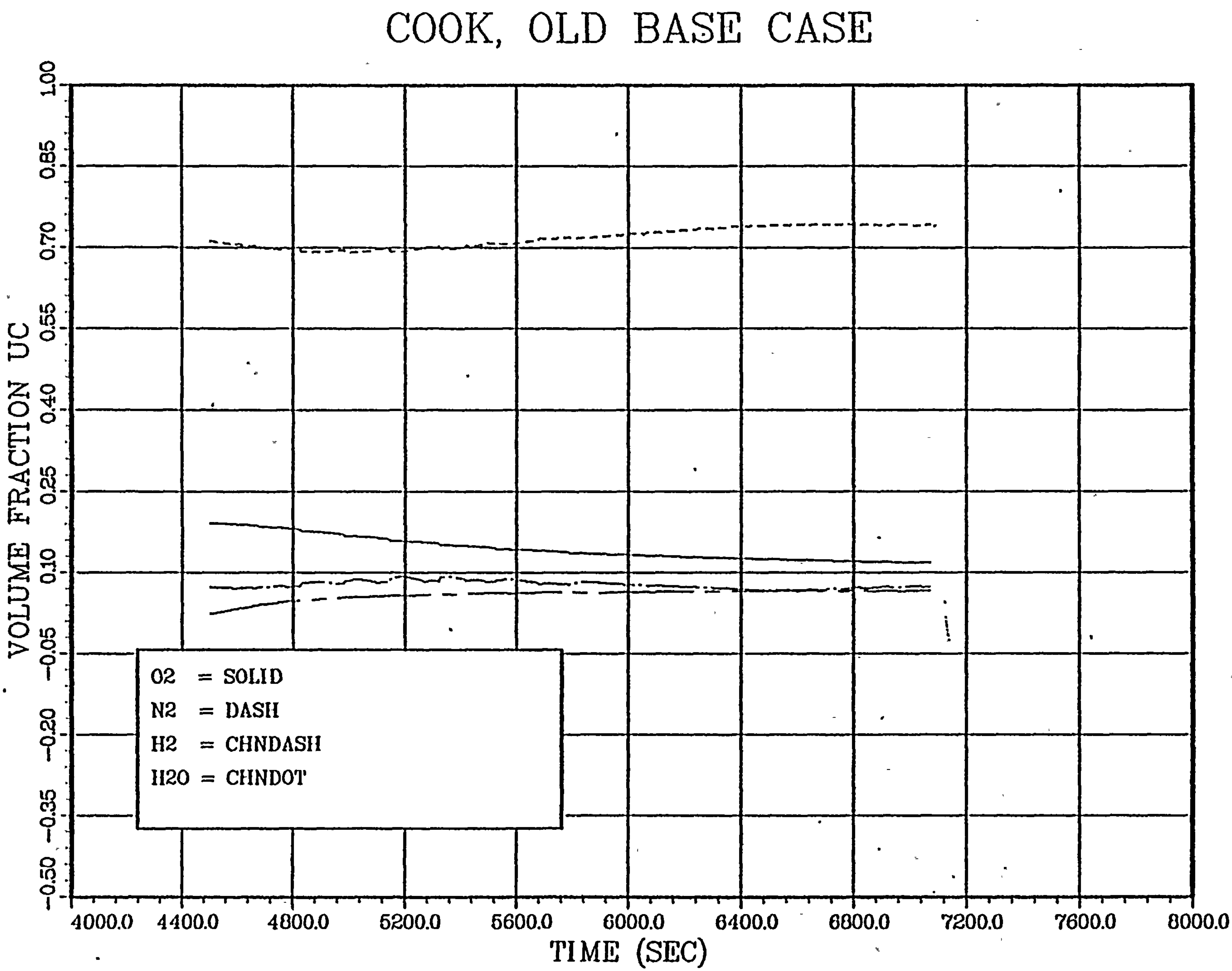


Case B - Figure 3.0-16



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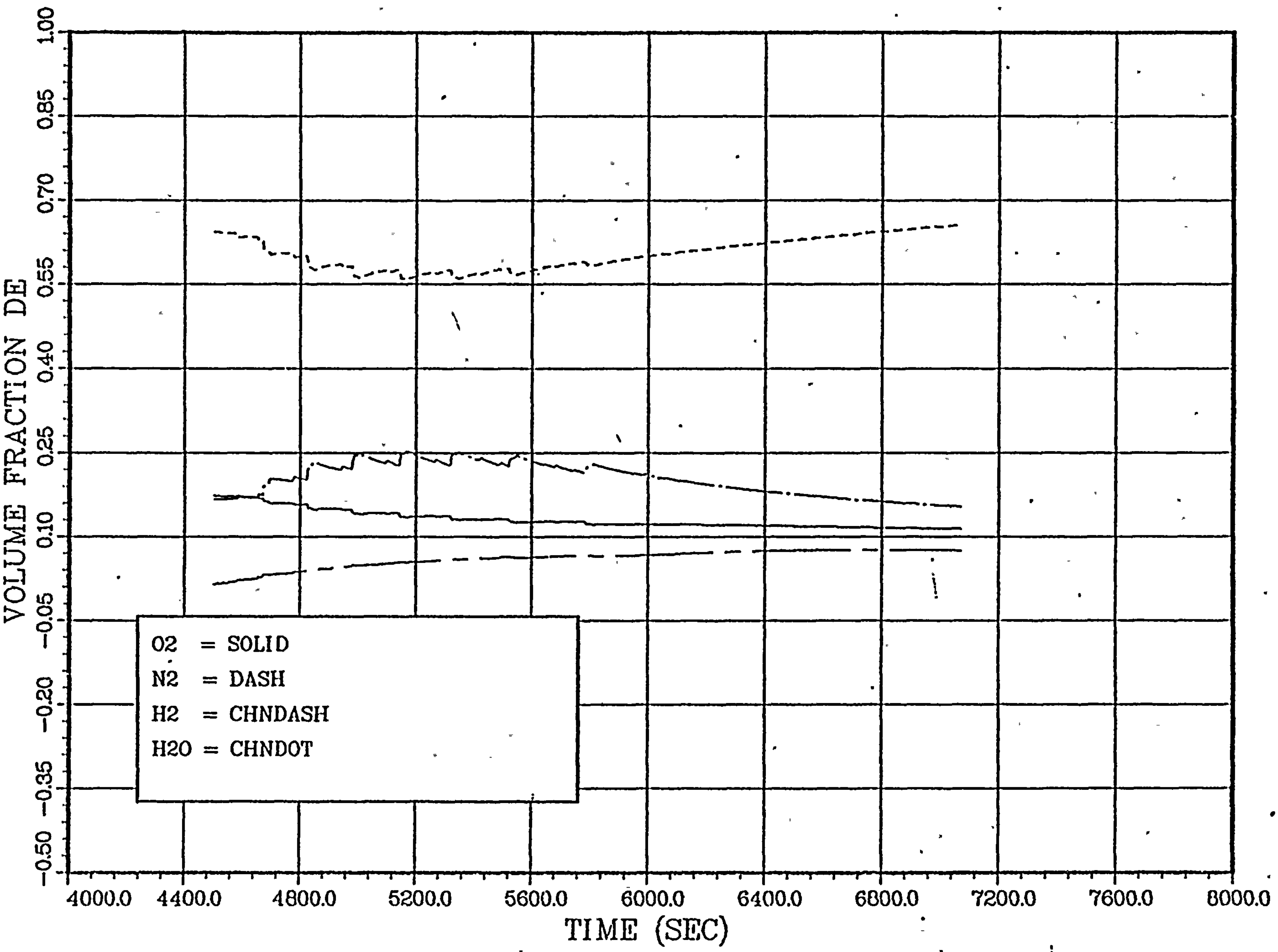
Case B - Figure 3.0-17

COOK, OLD BASE CASE



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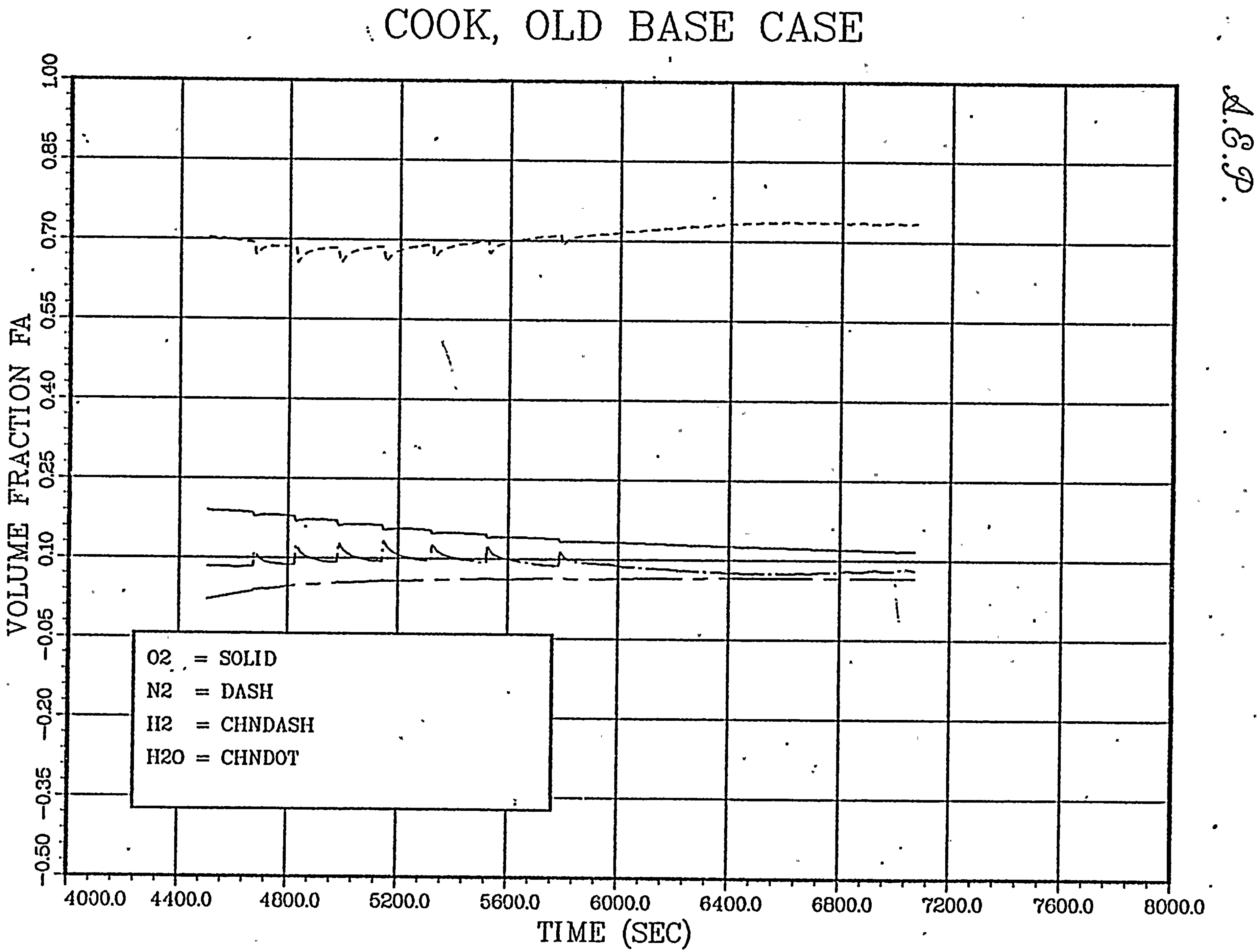
Case B - Figure 3.0-18



Case B - Figure 3.0-19

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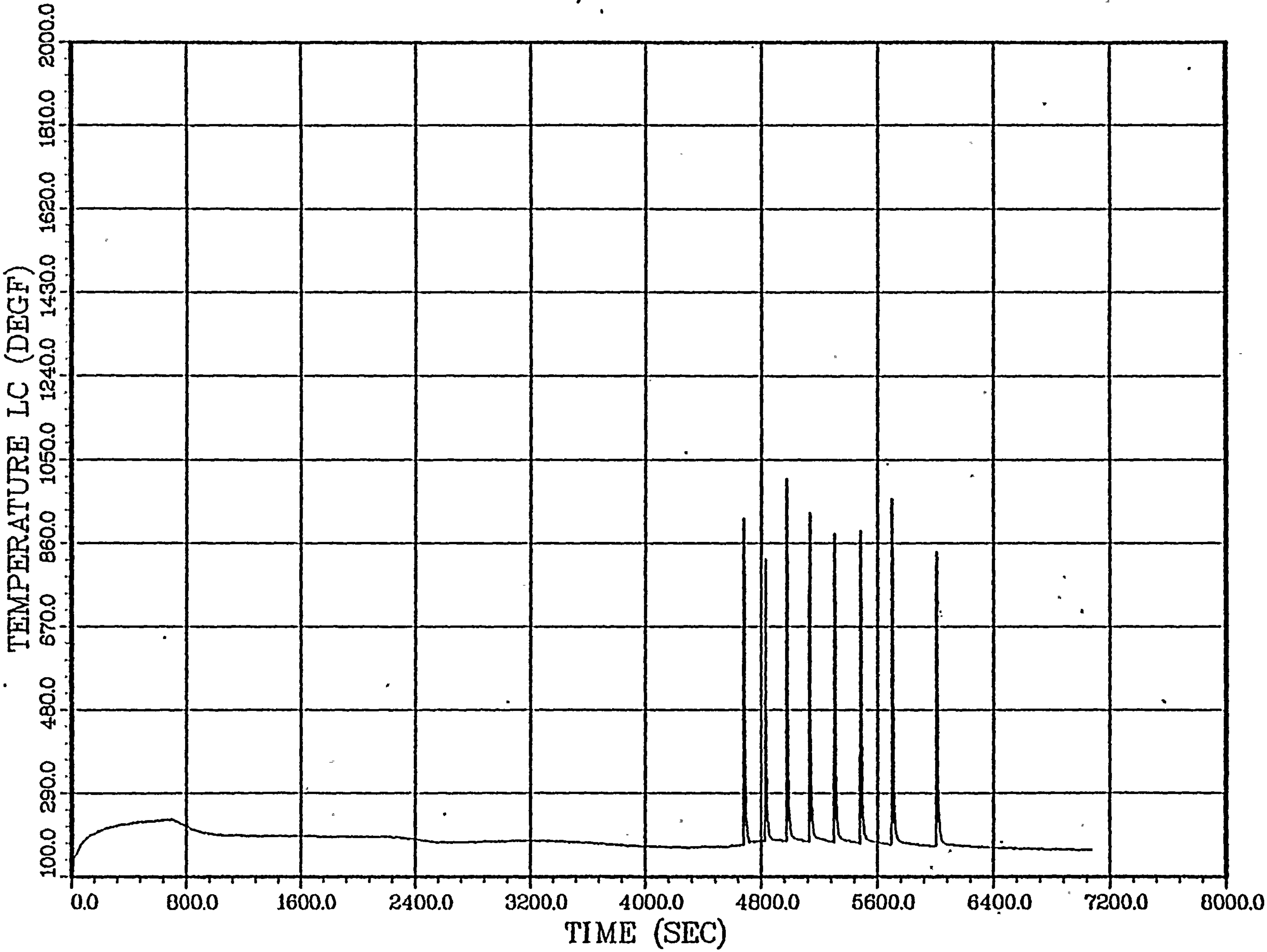

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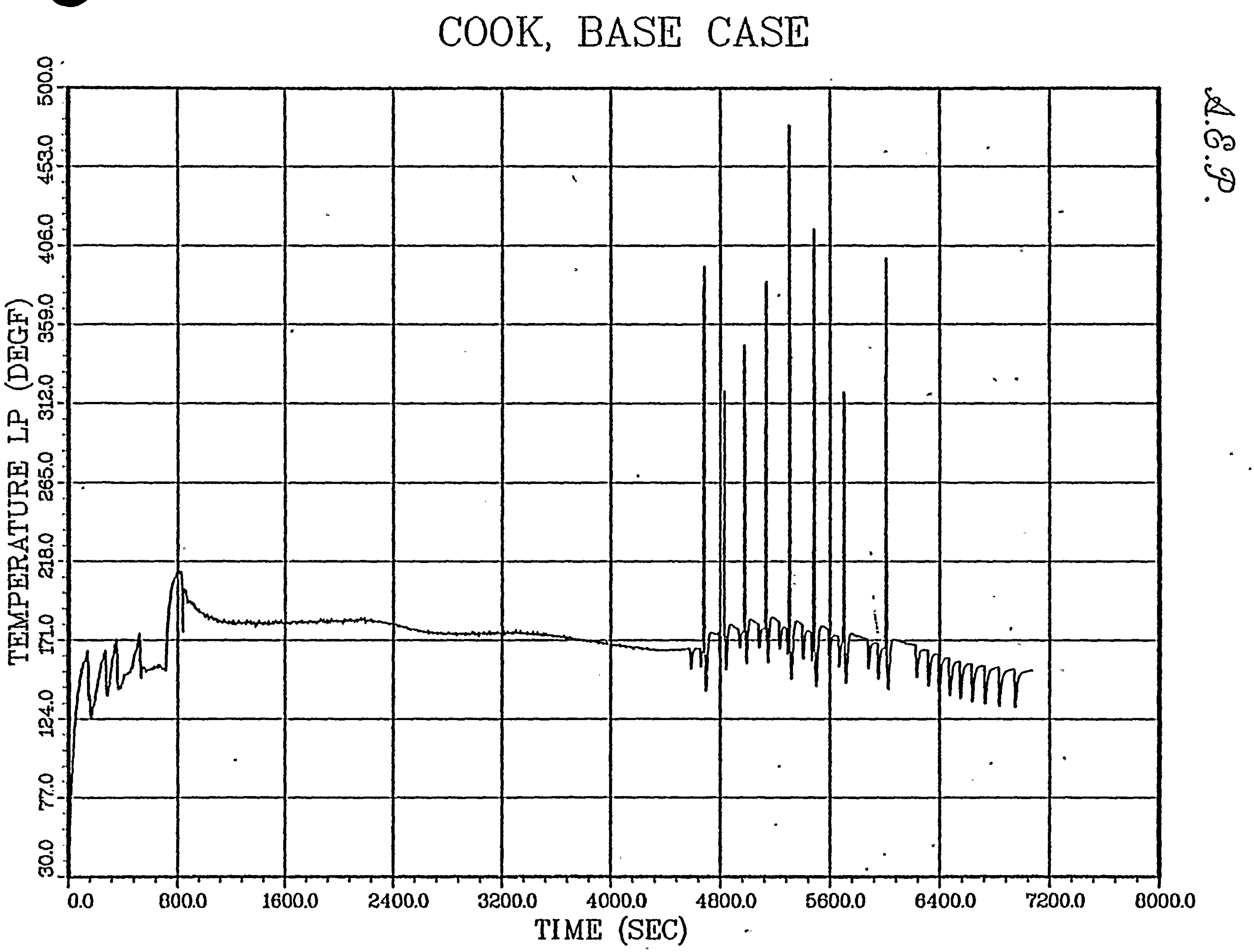
Case C - Figure 3.0-20



Case C - Figure 3.0-21

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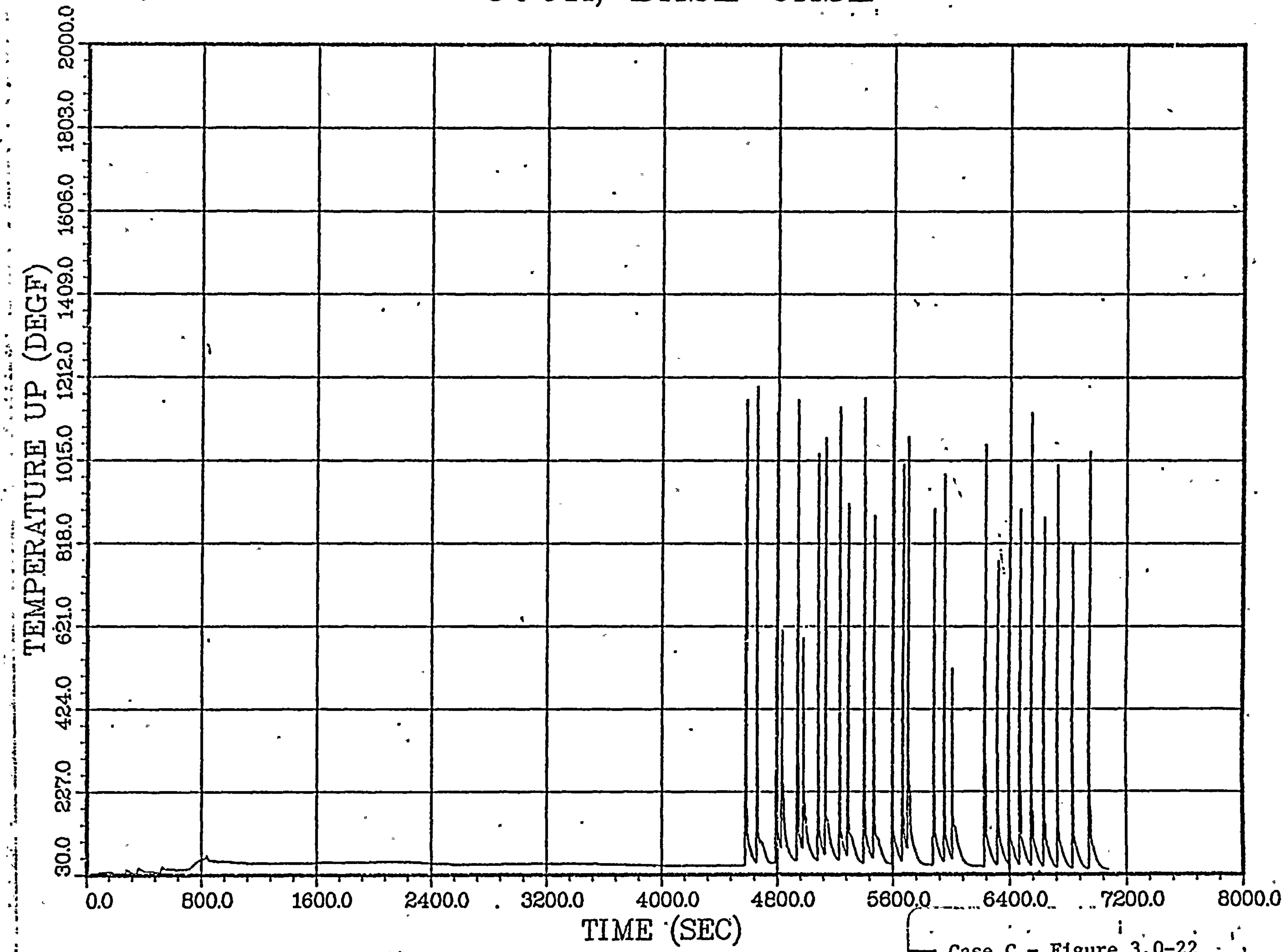

Case C – Figure 3.0-22

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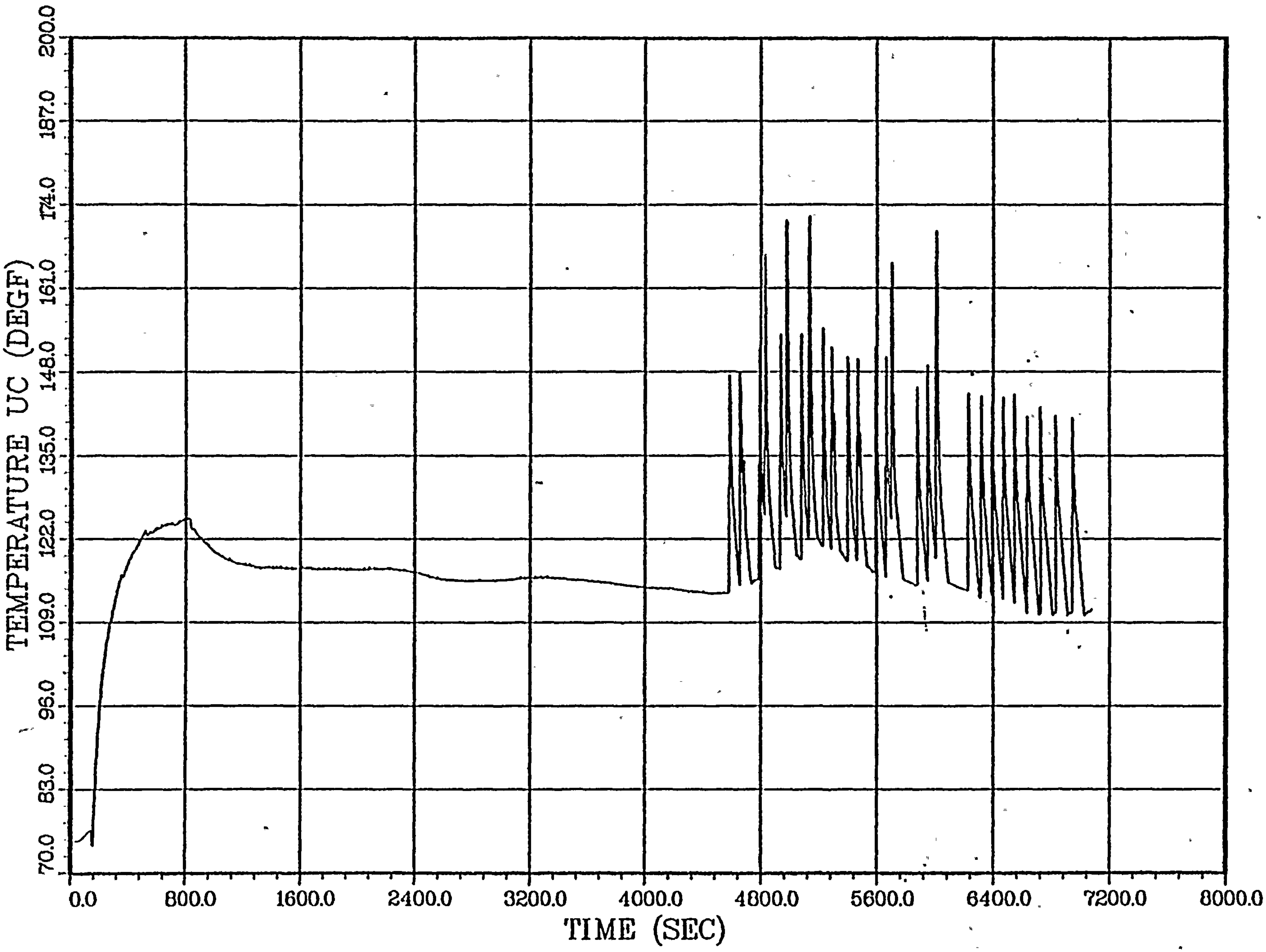

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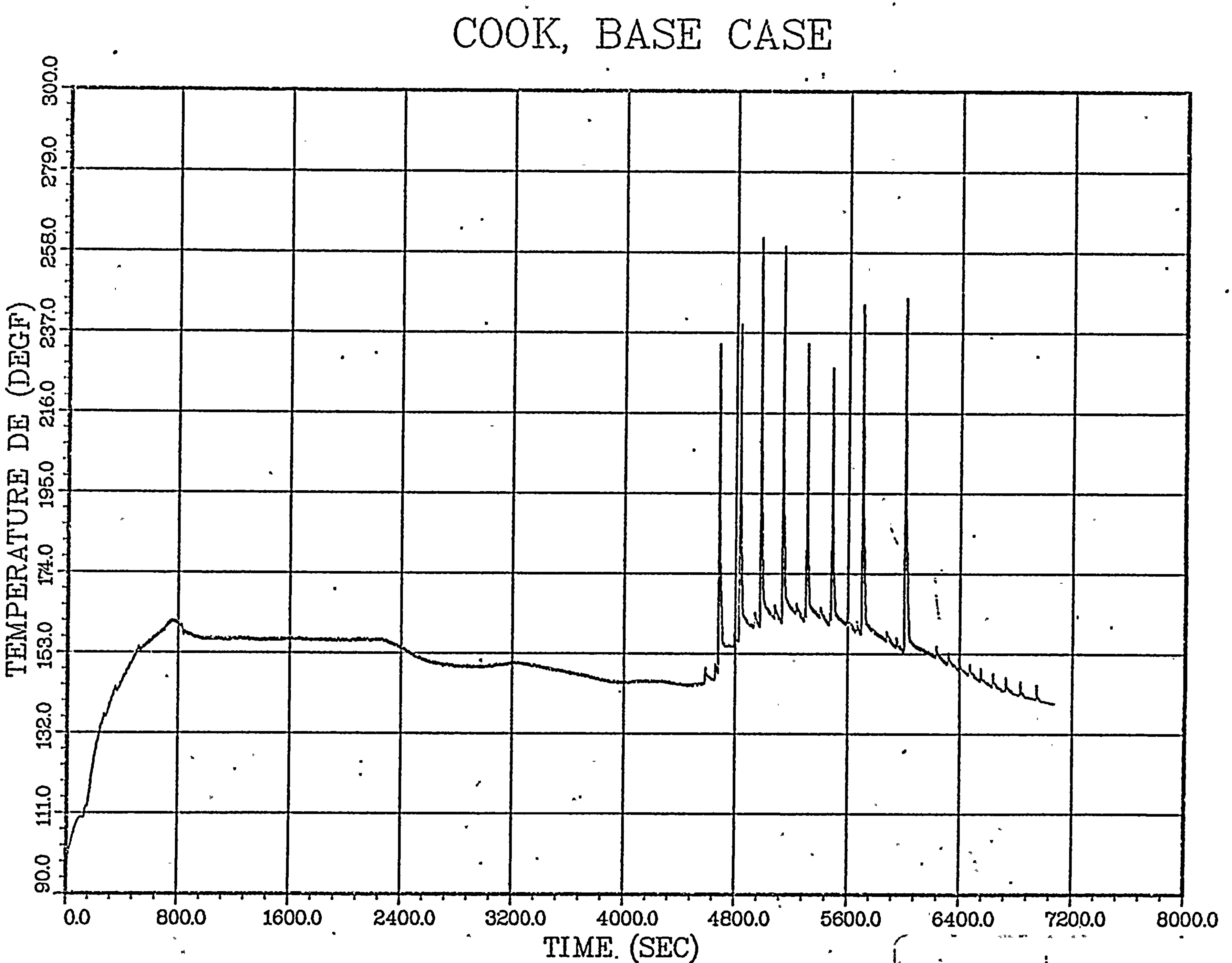
Case C - Figure 3.0-23



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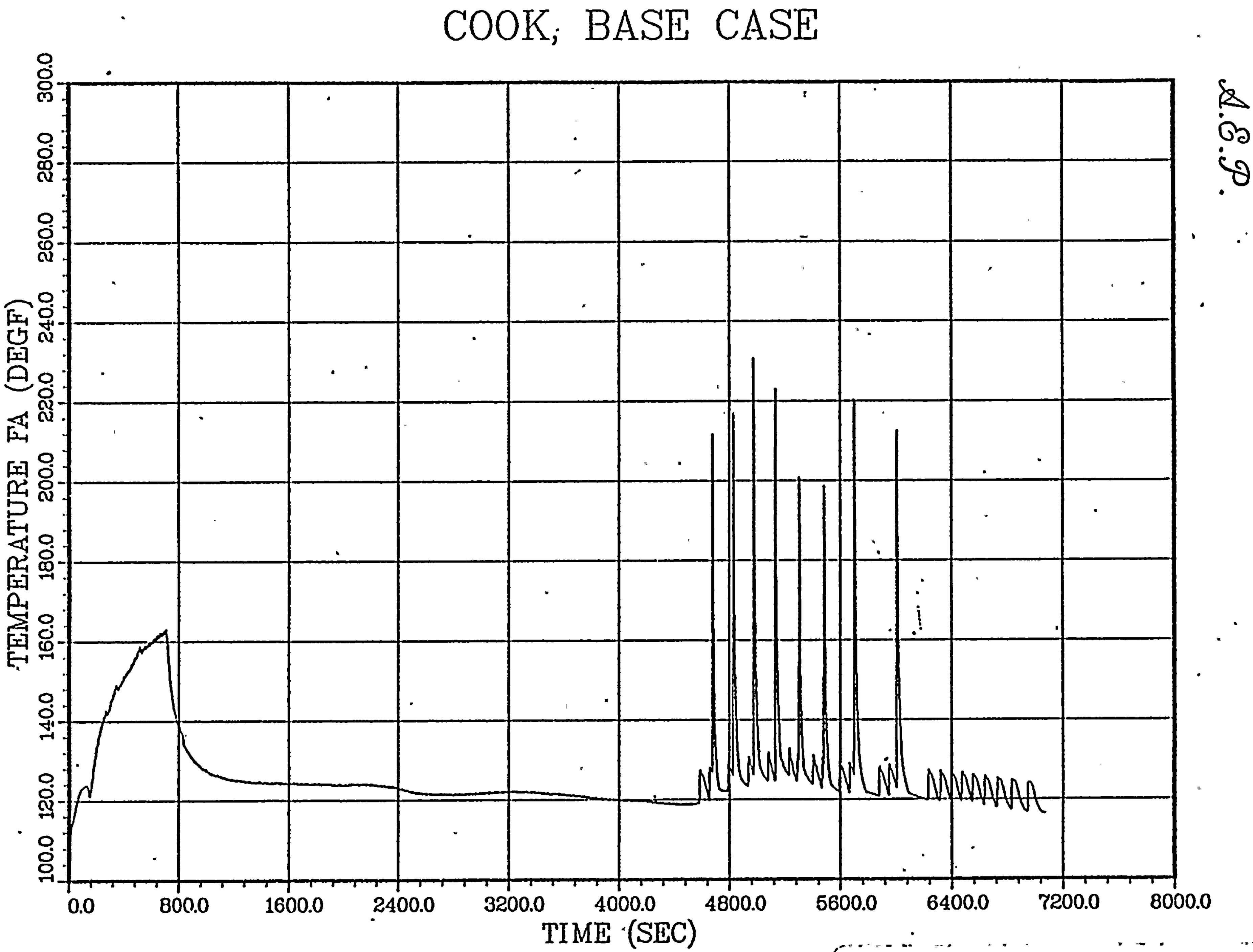

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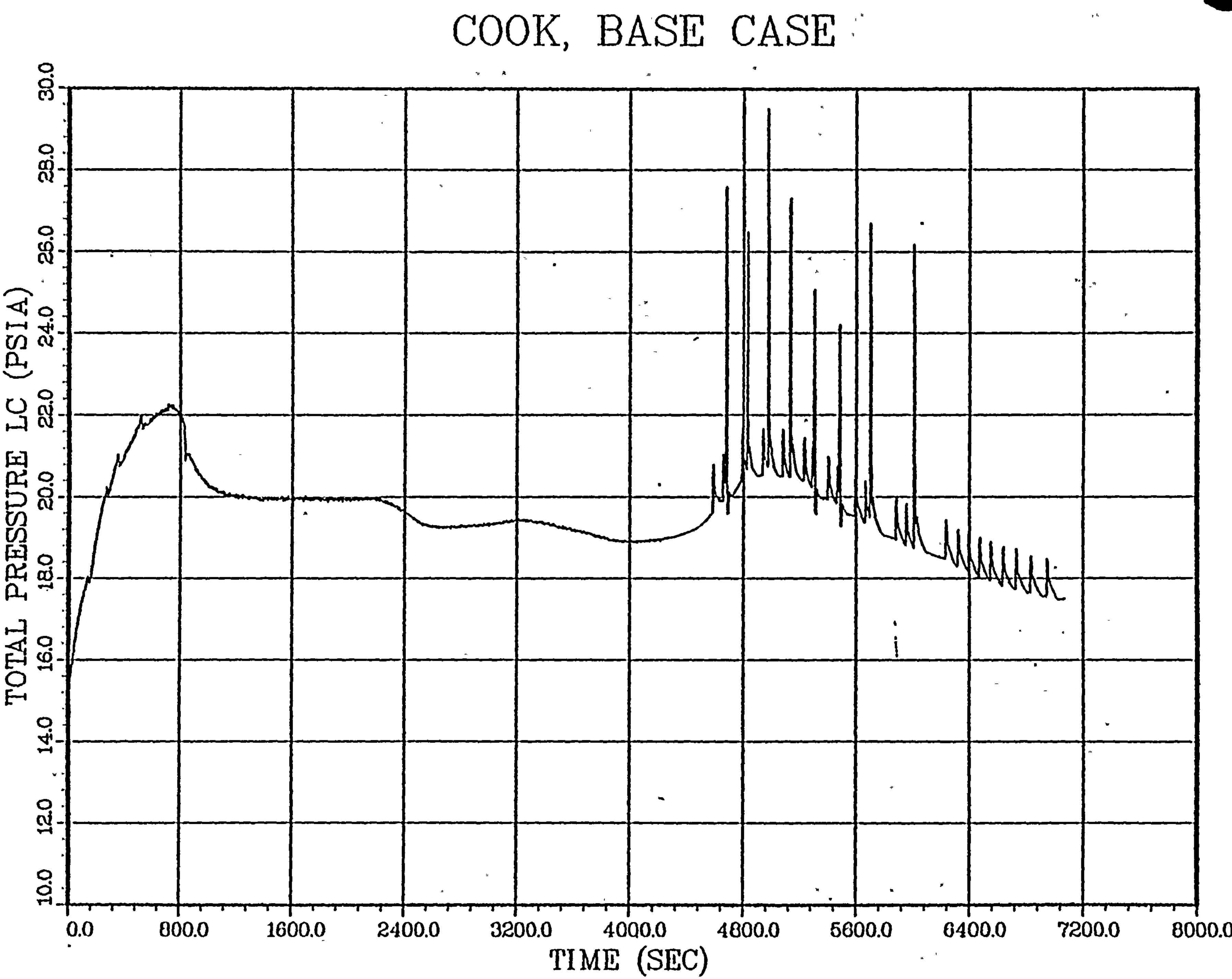

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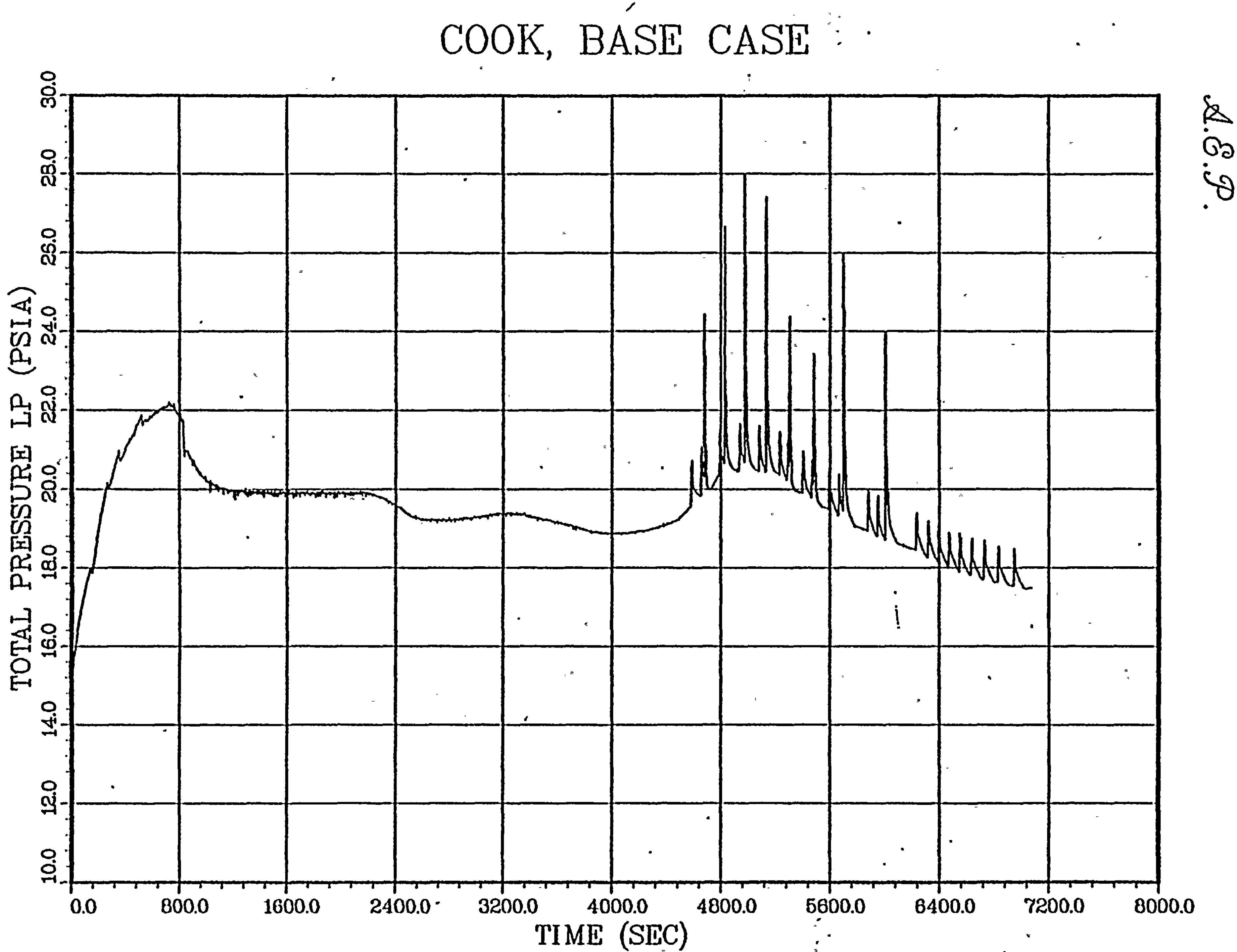

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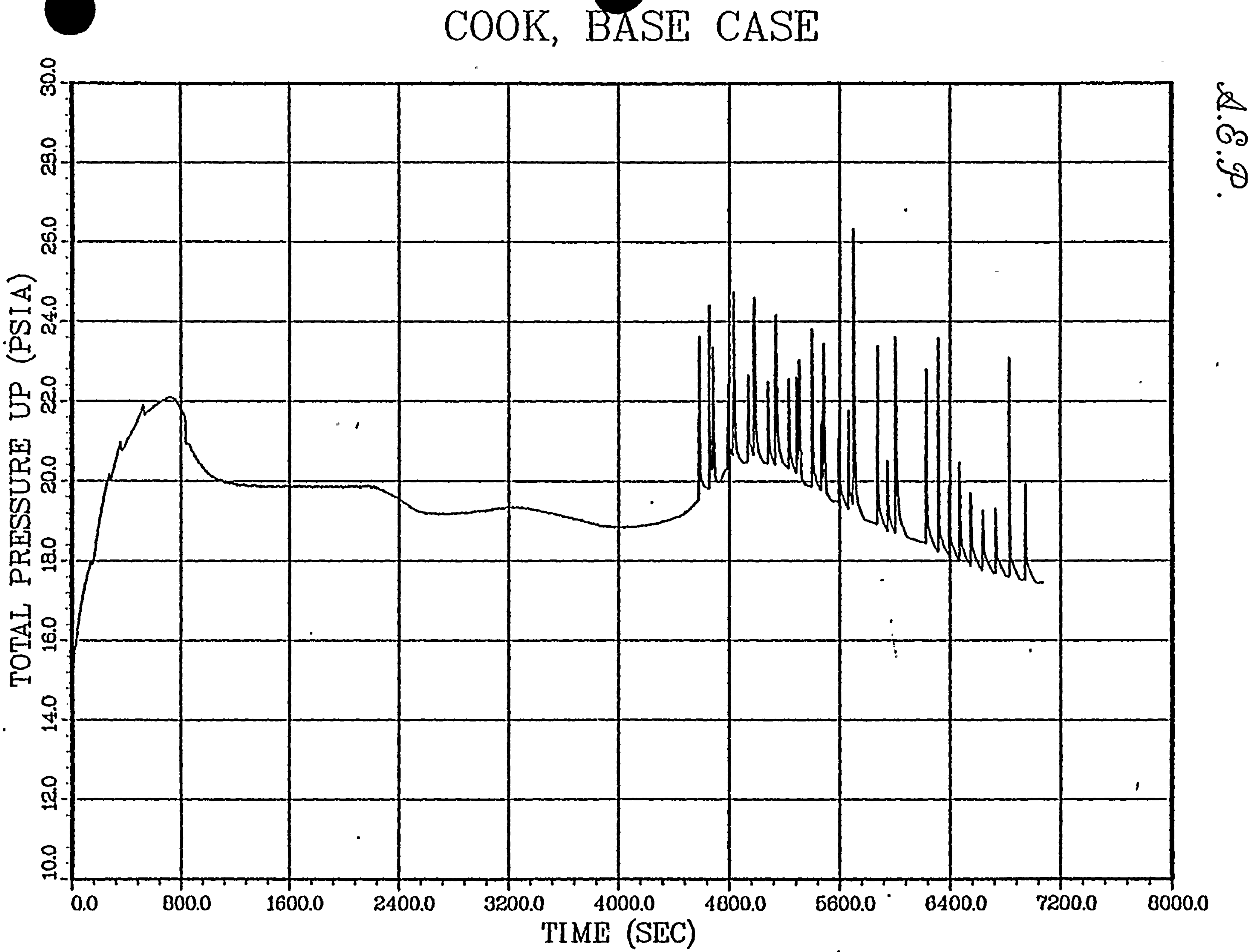
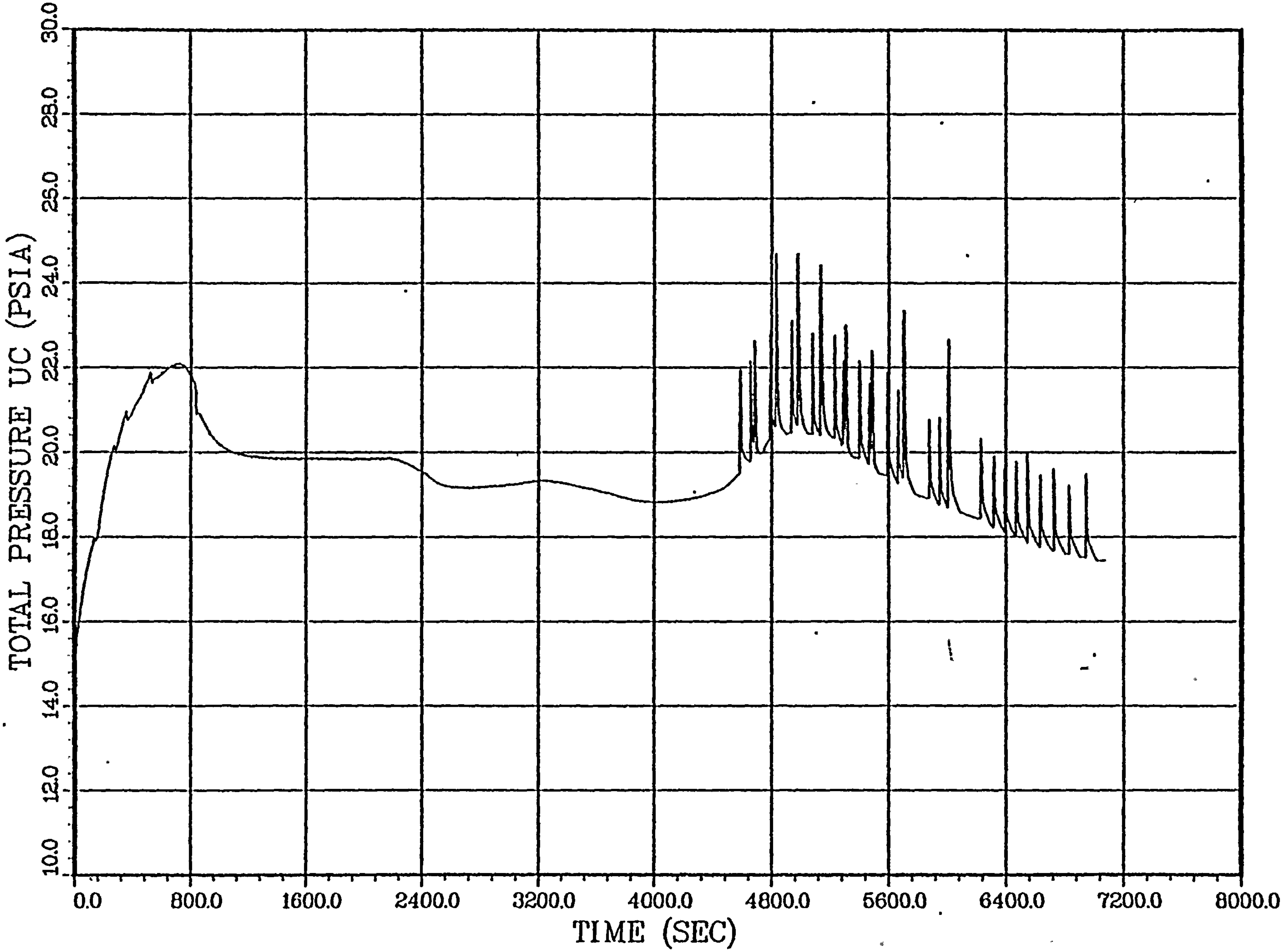


Case C - Figure 3.0-28

COOK, BASE CASE



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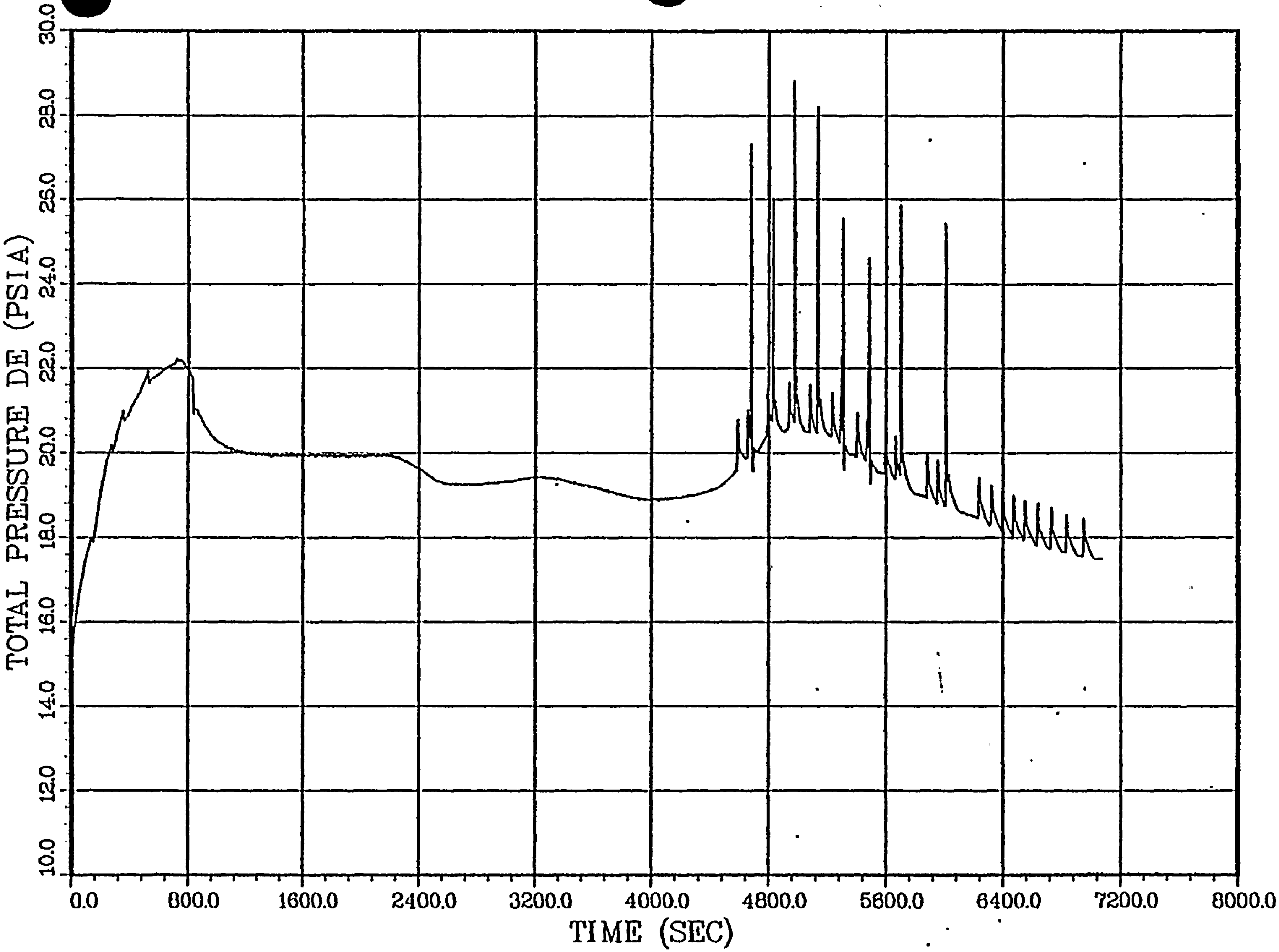
Case C - Figure 3.0-29

COOK, BASE CASE



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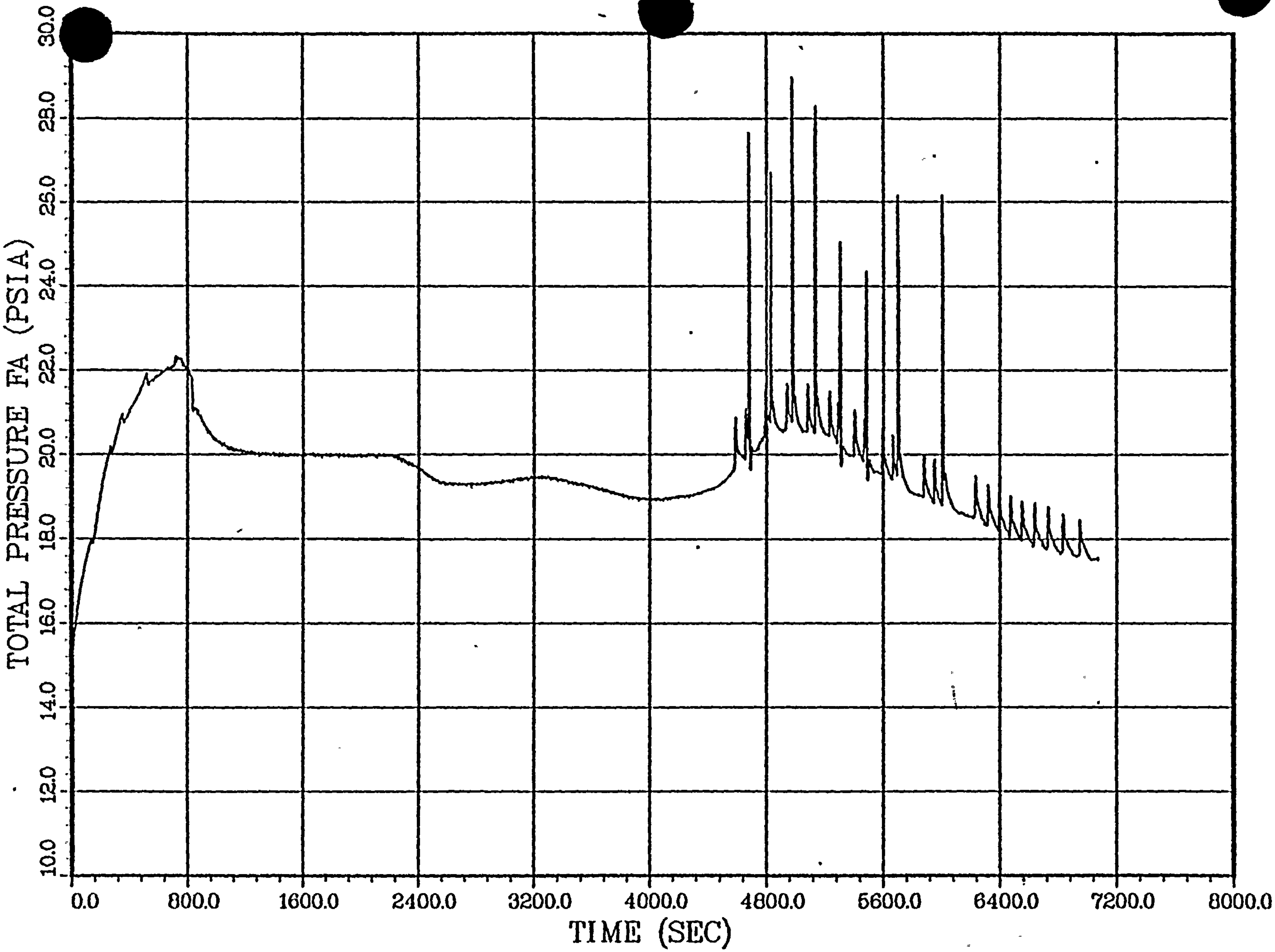
Case C - Figure 3.0-30

COOK, BASE CASE



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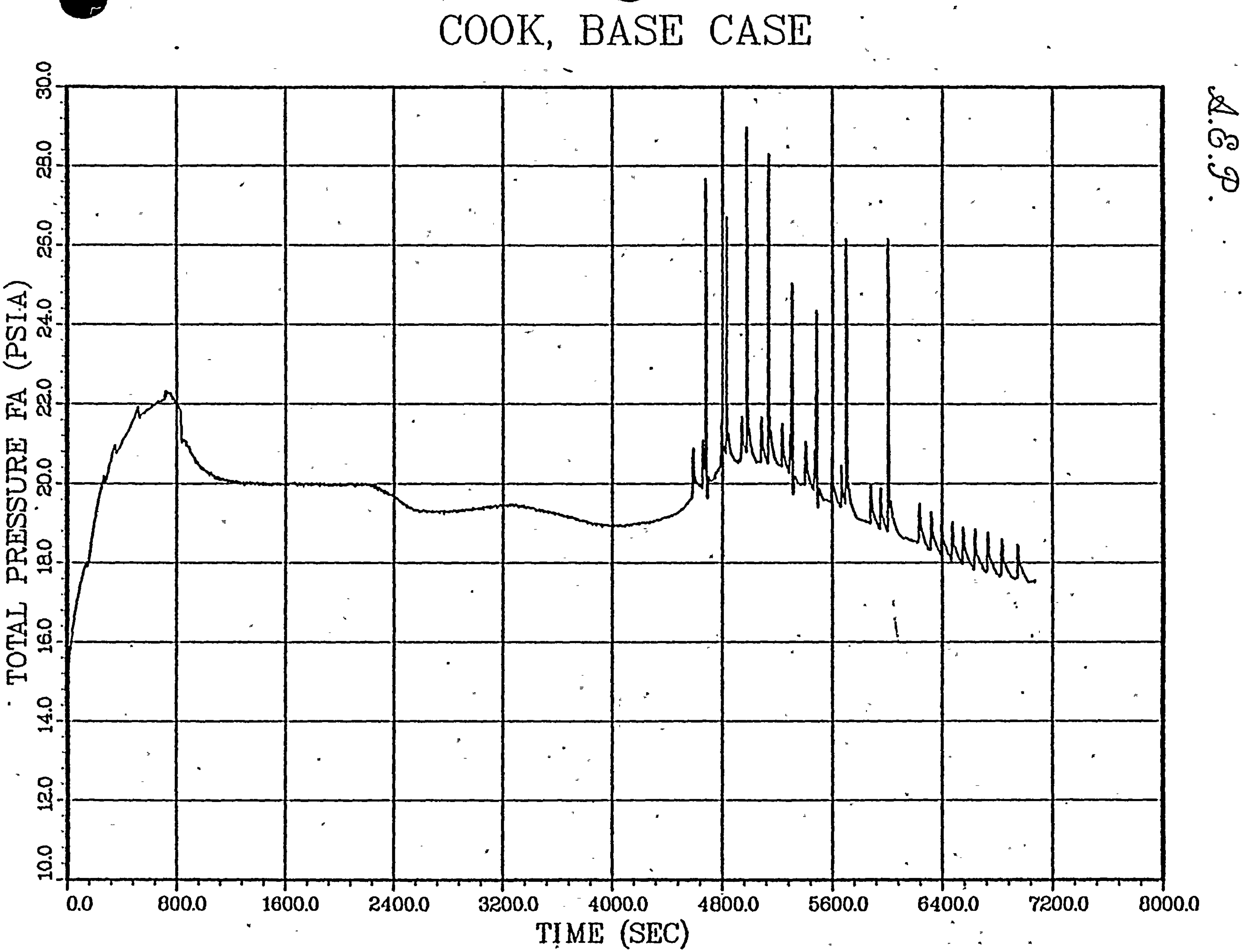
Case C - Figure 3.0-31



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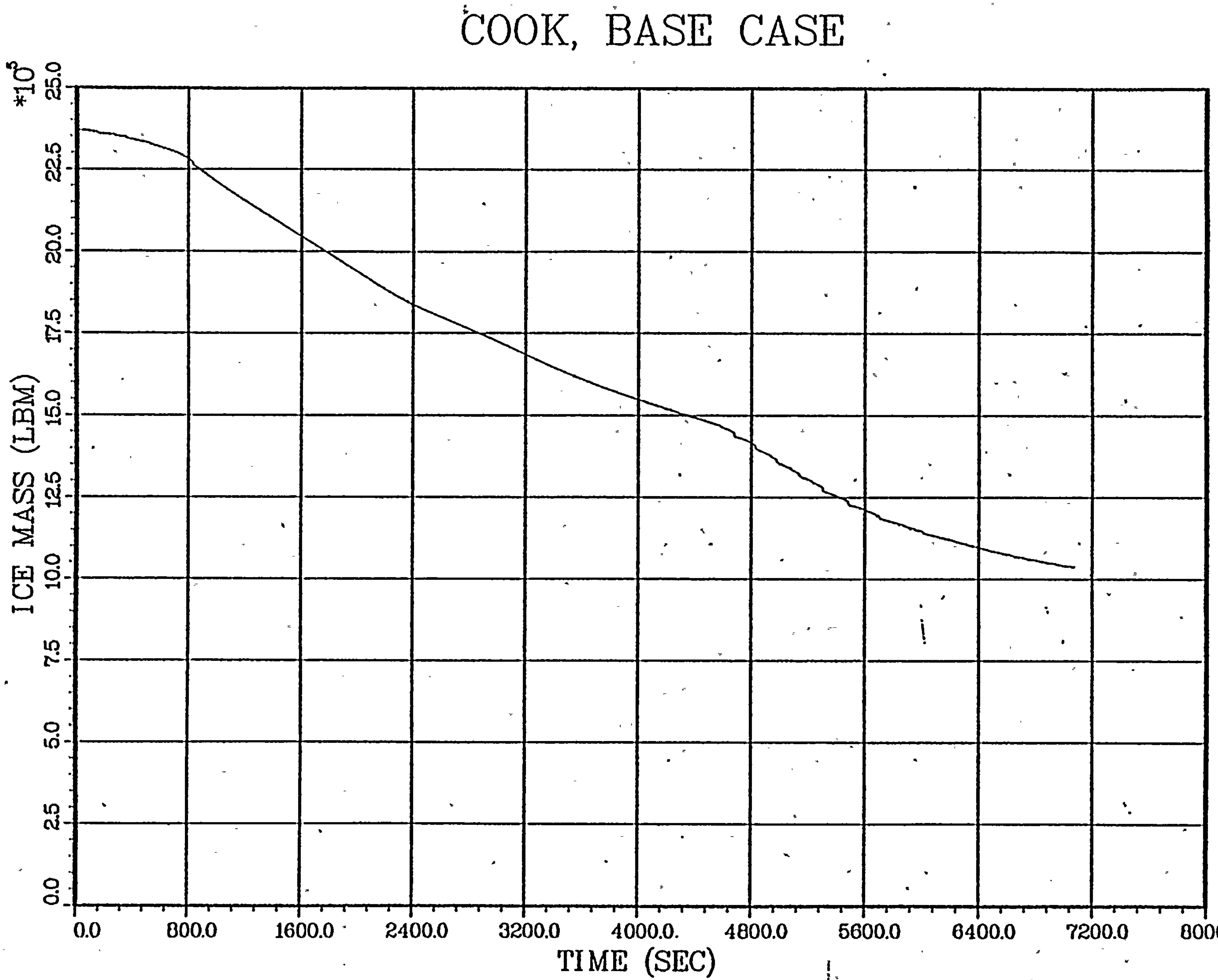

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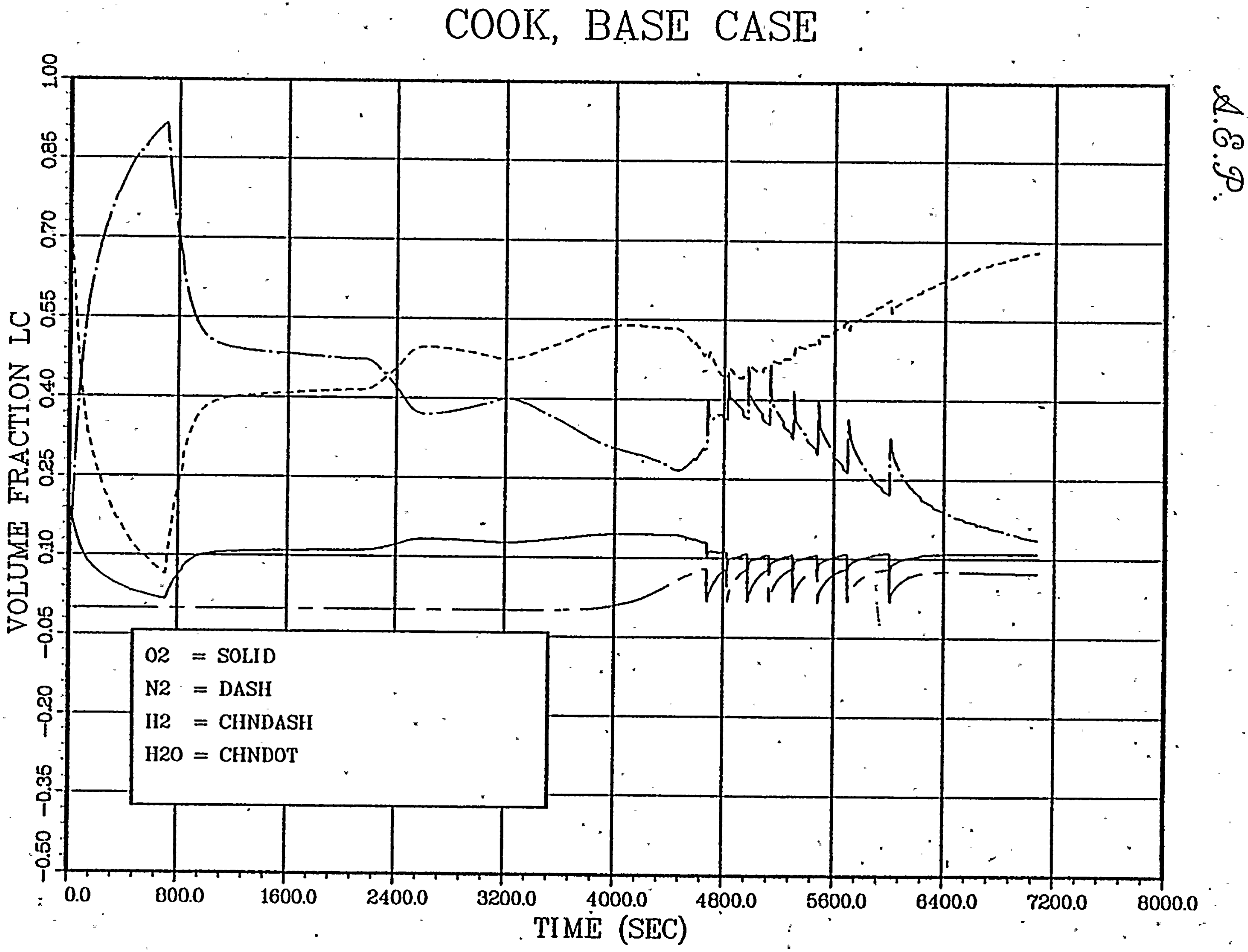
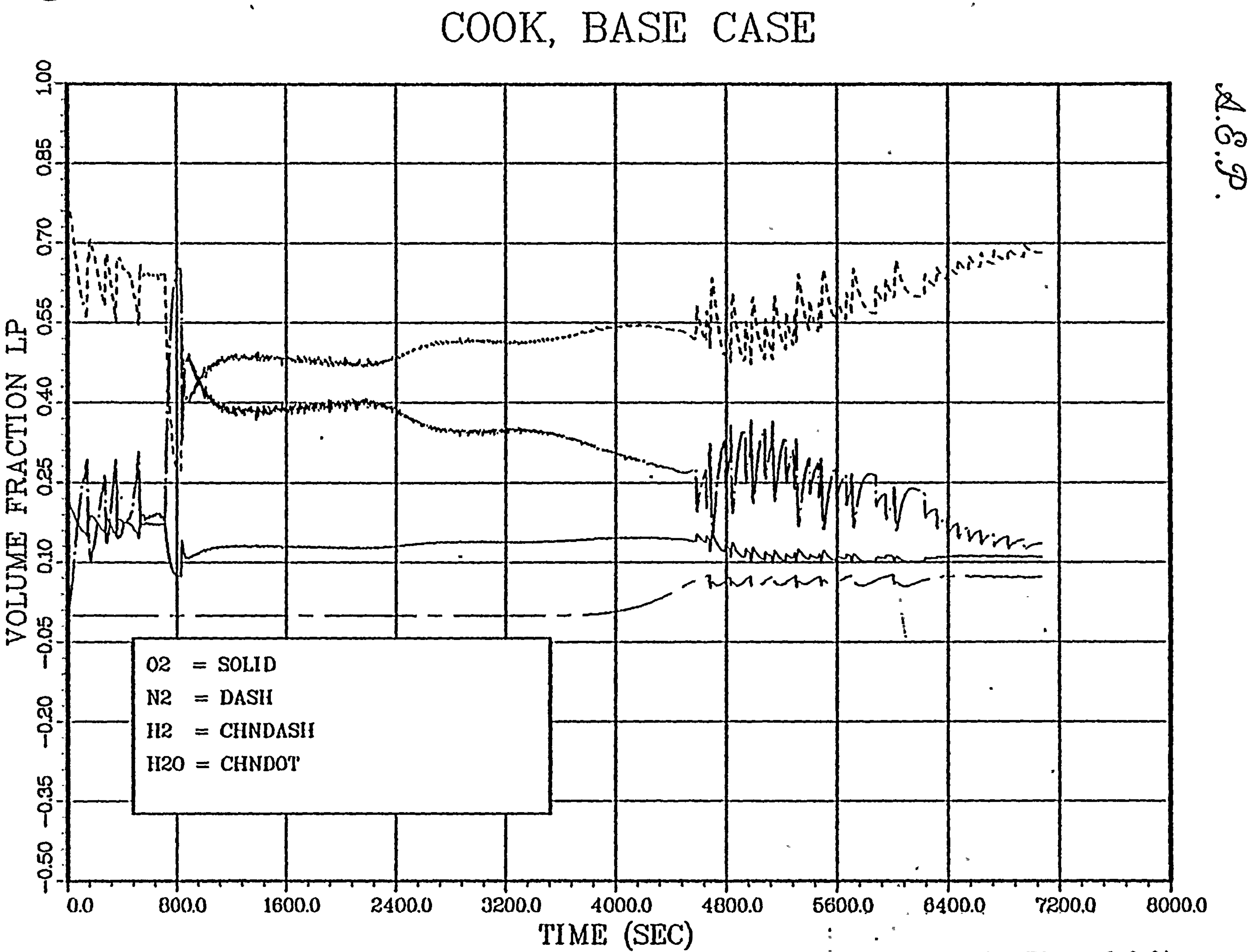
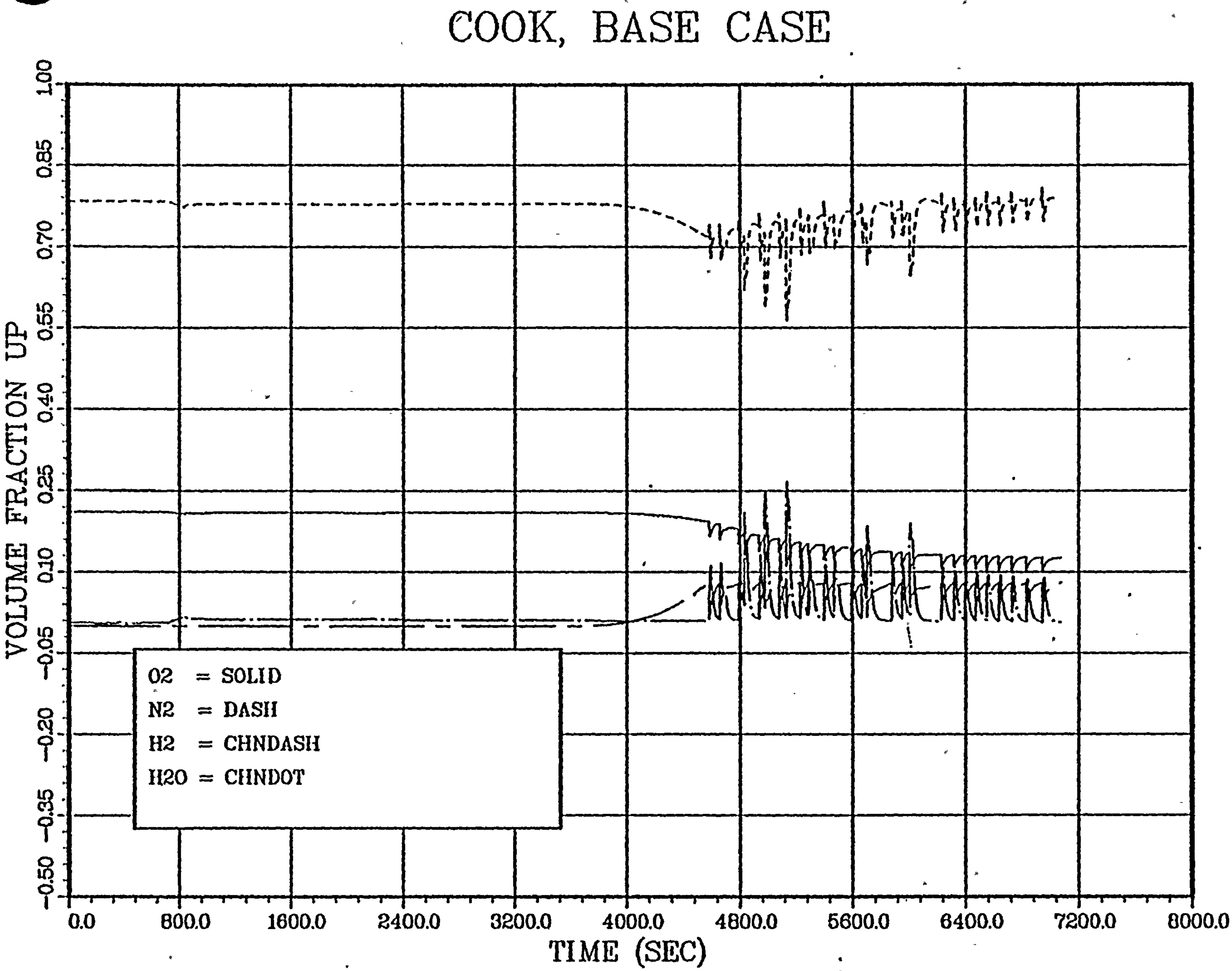


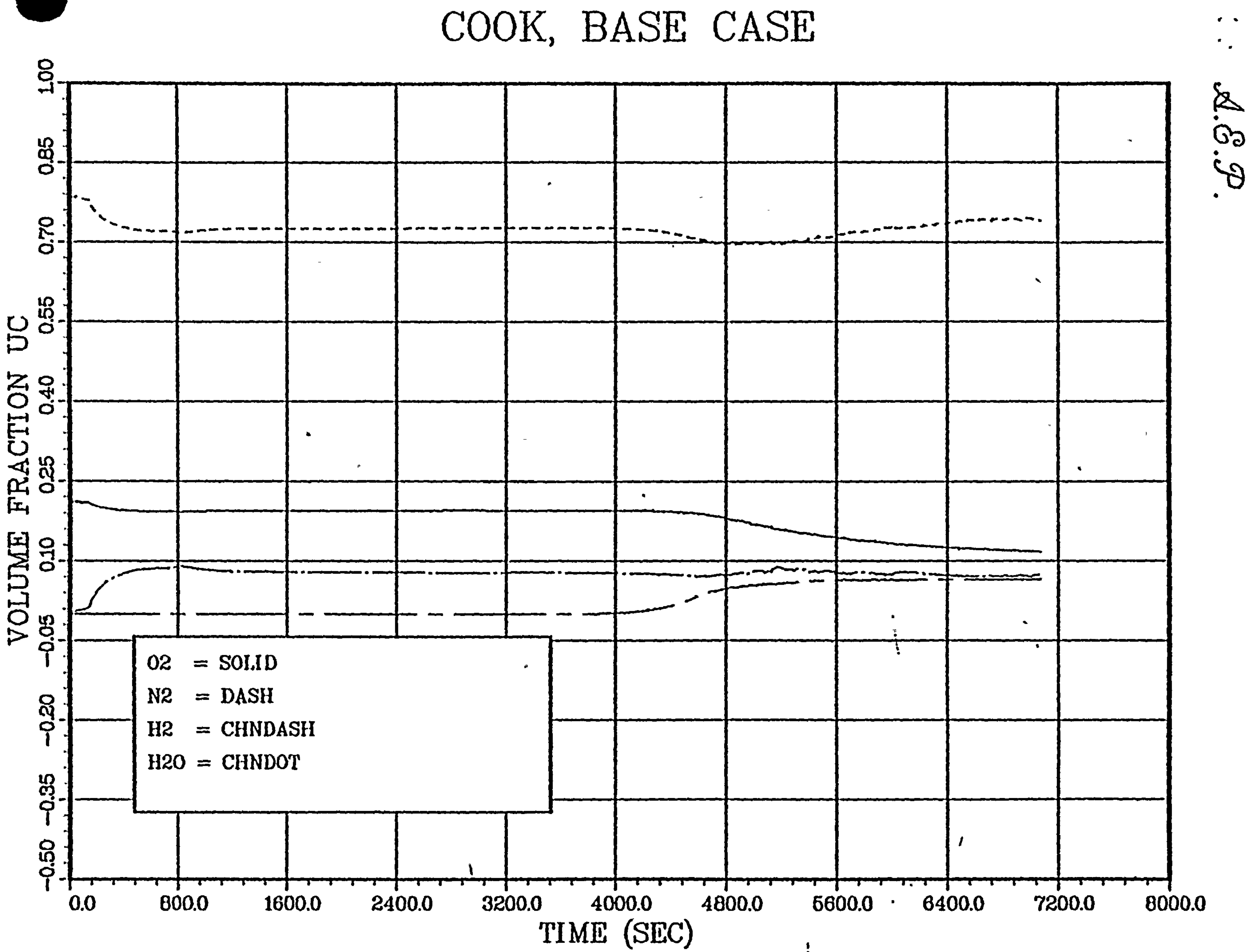
Case C - Figure 3.0-33



Case C - Figure 3.0-34

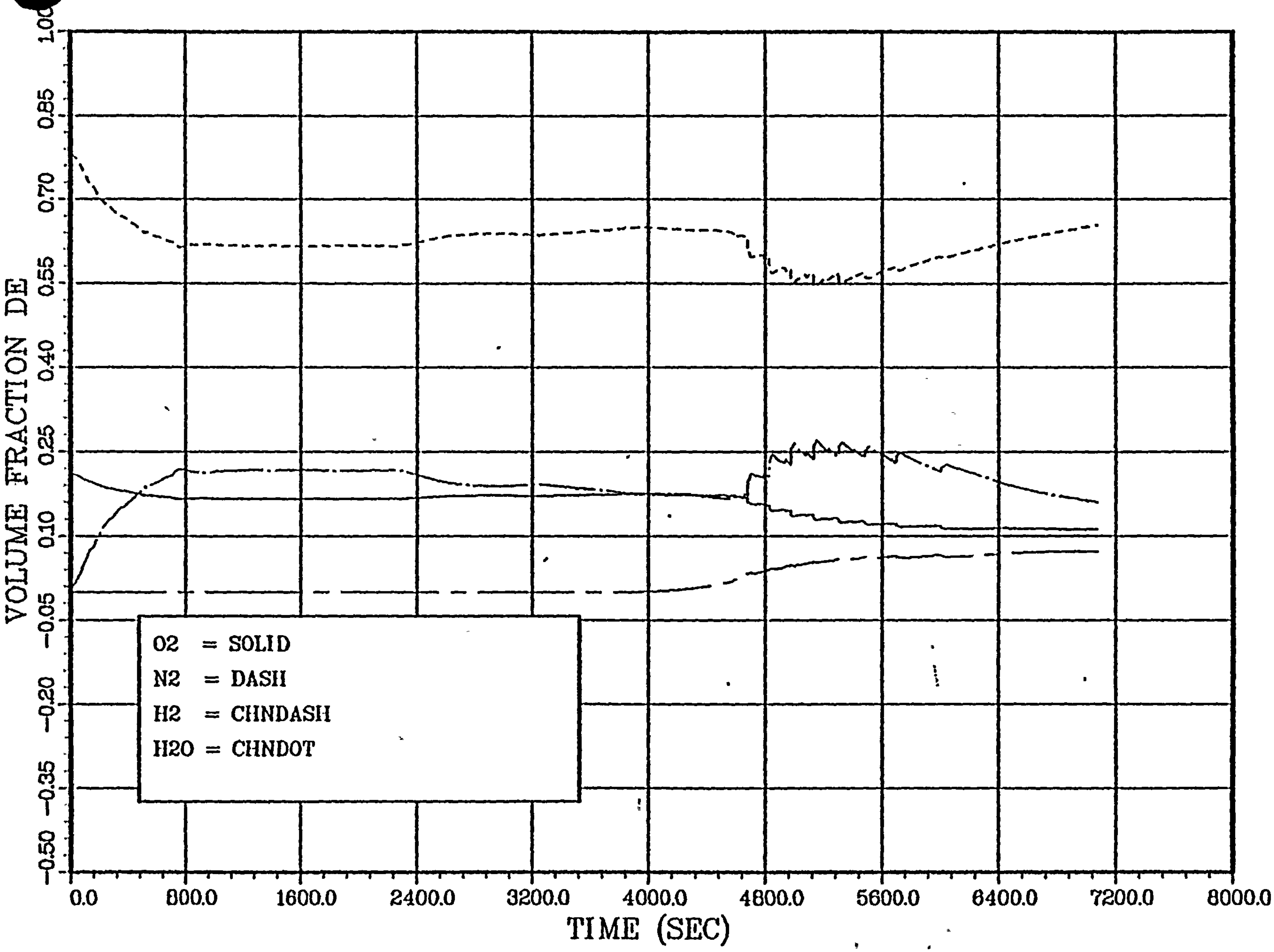


Case C - Figure 3.0-35



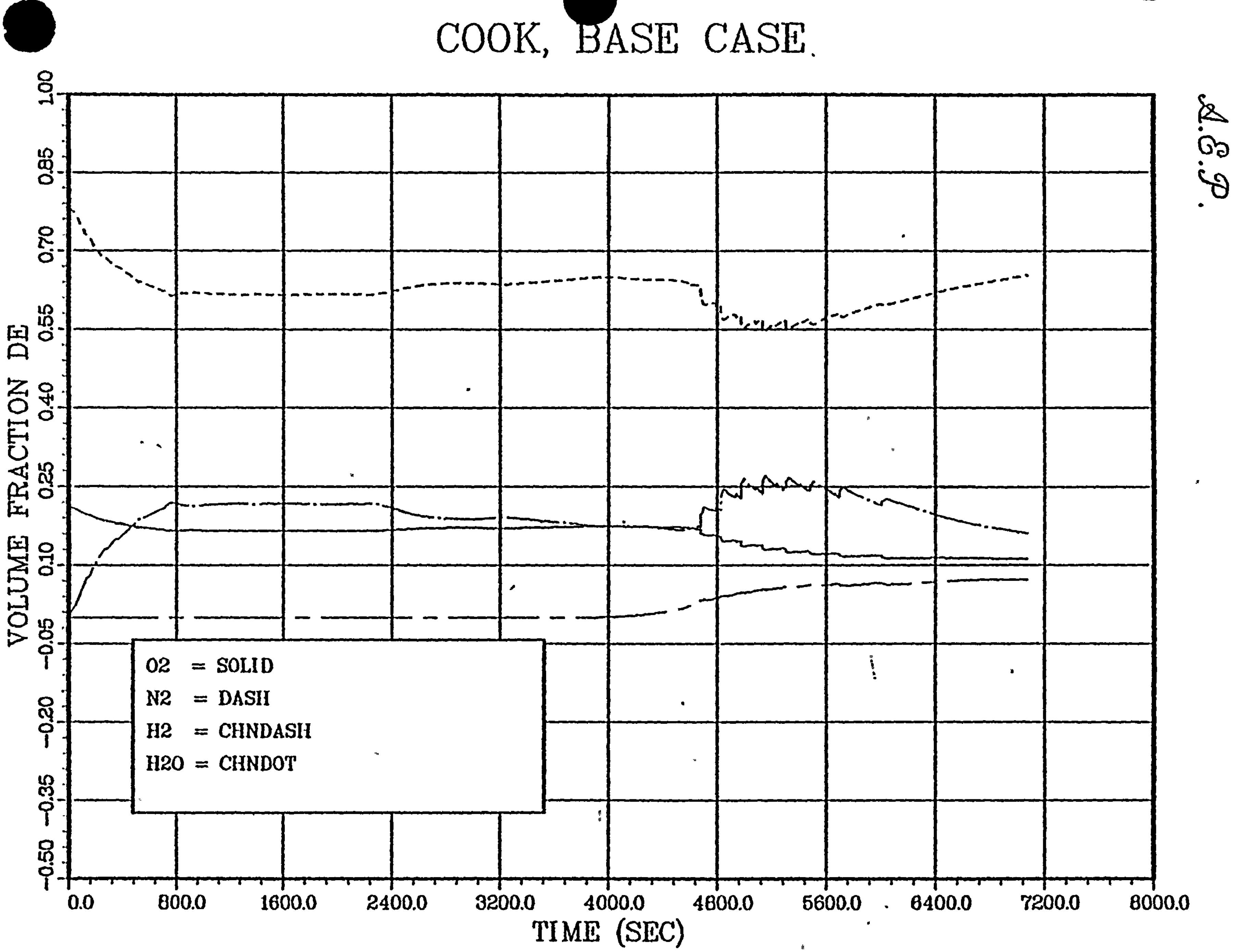
Case C - Figure 3.0-36

COOK, [illegible]SE CASE



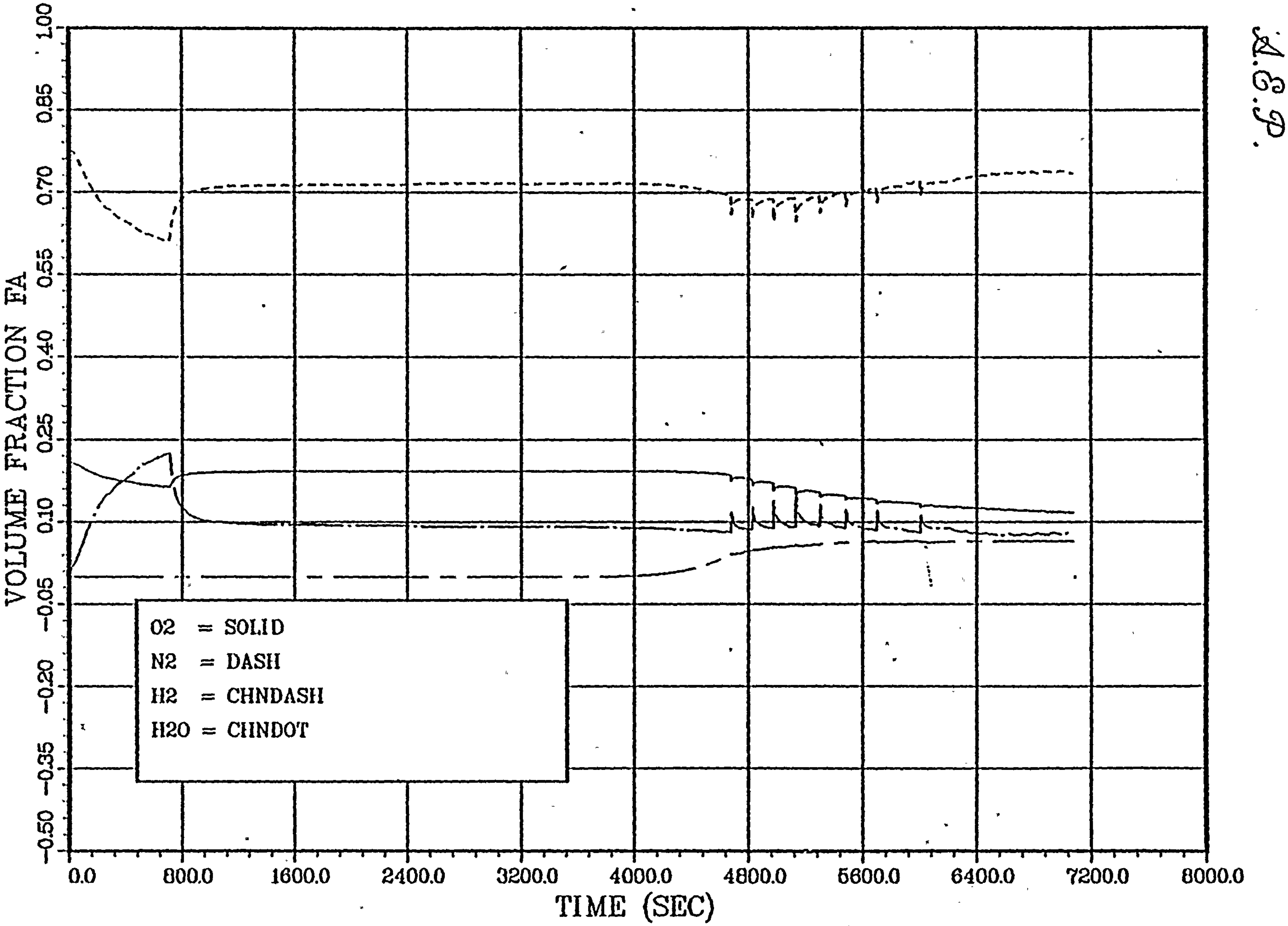
A.E.P.

Case C – Figure 3.0-37



Case C - Figure 3.0-37

COOK, BASE CASE



Case C - Figure 3.0-38

4.0 Parametric Analyses

Further analyses have been performed to assess the effects of variations of ignition criteria in general and within different compartments, and the effect of a variation in flame speed. These analyses are meant to supplement analyses performed for other plants and to verify that the results of such parametric analyses are applicable to the Cook Plant. The results of the analyses indicate that for all cases analyzed the containment pressure remains well within the structural capability of the Cook Plant containment.

An analysis, Case D, has been performed using a hydrogen ignition limit of 10% and a burn completion fraction of 100%. This analysis is similar to Sequoyah sensitivity run "1B" described in TVA's Report "Containment Response to Degraded Core Events" (Attachment No. 3 to Reference 5). The results of the Case D analysis are summarized in Table 4.0-1 and shown in Figures 4.0-1 through 4.0-19.

Case E investigated the effects of varying the hydrogen ignition limits in different regions of the containment. Specifically, a hydrogen ignition limit of 8 v/o with a 85% burn completion factor was used for the lower compartment, inlet plenum, upper plenum, and fan/accumulator rooms while an ignition limit of 6 v/o with a 60% burn completion factor was used for upper compartment and dead-ended regions. Use of the lower hydrogen ignition limit in the upper compartment and dead-ended regions resulted in the prediction of three burns in each of those areas. No combustion was predicted to occur in the fan/accumulator rooms during this transient. This analysis is similar to Sequoyah's sensitivity run "1E" described in the above referenced TVA report. The results of the Case E analysis are summarized in Table 4.0-2 and shown in Figures 4.0-20 through 4.0-38.

Case F investigated the effects of a reduced flame speed with hydrogen ignition limit and burn completion fraction values of 8 v/o and 85% respectively. This analysis is similar to Sequoyah's sensitivity run "1G" described in TVA's "Containment Response to Degraded Core Events" report. The changes in the input values for the burn times necessary to reflect the decreased flame speed are given in Table 4.0-3. The results of the analysis are summarized in Table 4.0-4 and shown in Figures 4.0-39 through 4.0-57.

Further discussions of the effects of varying key input parameters to CLASIX and a discussion of the accident sequences considered for operation of the Distributed Ignition System are contained in Section 5.0 of this Attachment.

TABLE 4.0-1

SUMMARY OF RESULTS - CASE D *

NUMBER OF BURNS PREDICTED	
LOWER COMPARTMENT	1
LOWER PLENUM	0
UPPER PLENUM	31
UPPER COMPARTMENT	0
DEAD-ENDED VOLUME	0
FAN/ACCUMULATOR ROOMS	0
PEAK ATMOSPHERIC TEMPERATURE (^{o}F)	
LOWER COMPARTMENT	1294
LOWER PLENUM	540
UPPER PLENUM	1813
UPPER COMPARTMENT	202
DEAD-ENDED VOLUME	313
FAN/ACCUMULATOR ROOMS	272
PEAK PRESSURE (PSIG)	
LOWER COMPARTMENT	17.8
LOWER PLENUM	16.4
UPPER PLENUM	16.9
UPPER COMPARTMENT	11.7
DEAD-ENDED VOLUME	18.3
FAN/ACCUMULATOR ROOMS	18.5

* HYDROGEN CONCENTRATION FOR IGNITION IS ASSUMED TO BE 10 V/O AND THE BURN FRACTION ASSUMED TO BE 100%. REMAINING INPUT PARAMETERS ARE THE SAME AS THOSE USED FOR THE CASE C ANALYSIS.

TABLE 4.0-2

SUMMARY OF RESULTS - CASE E *

NUMBER OF BURNS PREDICTED	
LOWER COMPARTMENT	5
LOWER PLENUM	0
UPPER PLENUM	20
UPPER COMPARTMENT	3
DEAD-ENDED VOLUME	3
FAN/ACCUMULATOR ROOMS	0
PEAK ATMOSPHERIC TEMPERATURE (°F)	
LOWER COMPARTMENT	1008
LOWER PLENUM	476
UPPER PLENUM	1191
UPPER COMPARTMENT	615
DEAD-ENDED VOLUME	688
FAN/ACCUMULATOR ROOMS	375
PEAK PRESSURE (PSIG)	
LOWER COMPARTMENT	14.8
LOWER PLENUM	17.4
UPPER PLENUM	19.2
UPPER COMPARTMENT	19.8
DEAD-ENDED VOLUME	14.1
FAN/ACCUMULATOR ROOMS	14.3

* HYDROGEN CONCENTRATION FOR IGNITION IS ASSUMED TO BE 8 V/O AND THE BURN FRACTION ASSUMED TO BE 85% FOR THE LOWER COMPARTMENT, INLET PLENUM, UPPER PLENUM, AND FAN/ACCUMULATOR ROOMS. THE HYDROGEN IGNITION LIMIT AND BURN FRACTION FOR THE UPPER COMPARTMENT AND THE DEAD-ENDED REGIONS WERE 6 V/O AND 60%, RESPECTIVELY. REMAINING INPUT PARAMETERS ARE THE SAME AS THOSE USED FOR THE CASE C ANALYSIS.

TABLE 4.0-3

CLASIX INPUT PARAMETERS - CASE F *

BURN PARAMETERS

(1)

COMPARTMENT	BURN TIME (SECONDS)
LOWER COMPARTMENT (LC)	22.80
LOWER PLENUM (LP)	26.16
UPPER PLENUM (UP)	10.80
UPPER COMPARTMENT (UC)	58.20
DEAD-ENDED VOLUME (DE)	14.52
FAN/ACCUMULATOR ROOMS (F/A)	15.48

(2)

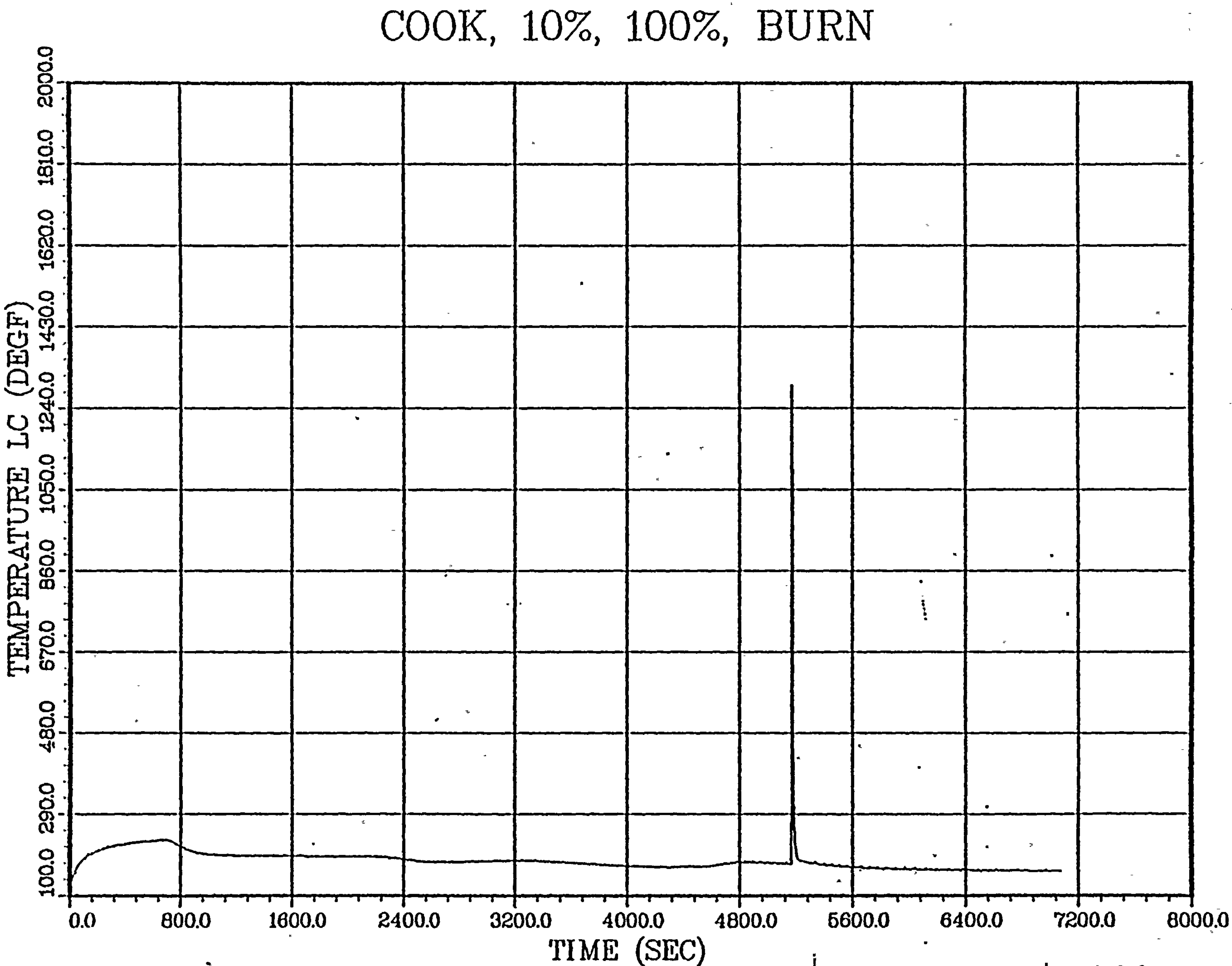
JUNCTION	PROPAGATION DELAY TIME (SECONDS)
LC-IP	22.80
IP-UP	32.88
UP-UC	6.60
UC-LC	58.20
DE-LC	22.80
F/A-LC	22.80

* ALL OTHER INPUT PARAMETERS ARE THE SAME AS THOSE USED FOR THE CASE C ANALYSIS.

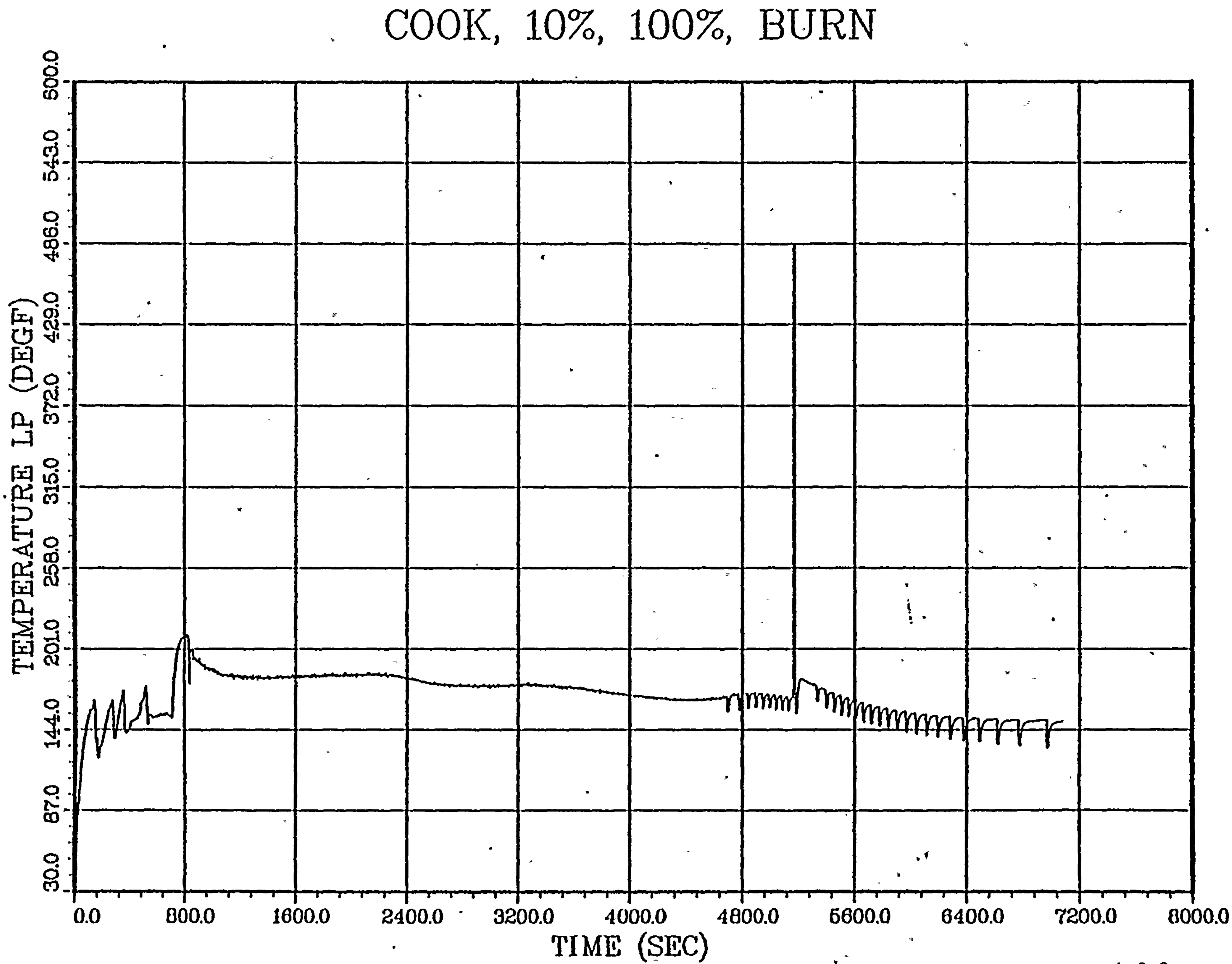
TABLE 4.0-4

SUMMARY OF RESULTS - CASE F

NUMBER OF BURNS PREDICTED	
LOWER COMPARTMENT	7
LOWER PLENUM	0
UPPER PLENUM	27
UPPER COMPARTMENT	0
DEAD-ENDED VOLUME	0
FAN/ACCUMULATOR ROOMS	0
PEAK ATMOSPHERIC TEMPERATURE (^{o}F)	
LOWER COMPARTMENT	567
LOWER PLENUM	537
UPPER PLENUM	1132
UPPER COMPARTMENT	148
DEAD-ENDED VOLUME	178
FAN/ACCUMULATOR ROOMS	159
PEAK PRESSURE (PSIG)	
LOWER COMPARTMENT	8.7
LOWER PLENUM	8.7
UPPER PLENUM	9.0
UPPER COMPARTMENT	8.6
DEAD-ENDED VOLUME	8.8
FAN/ACCUMULATOR ROOMS	8.8



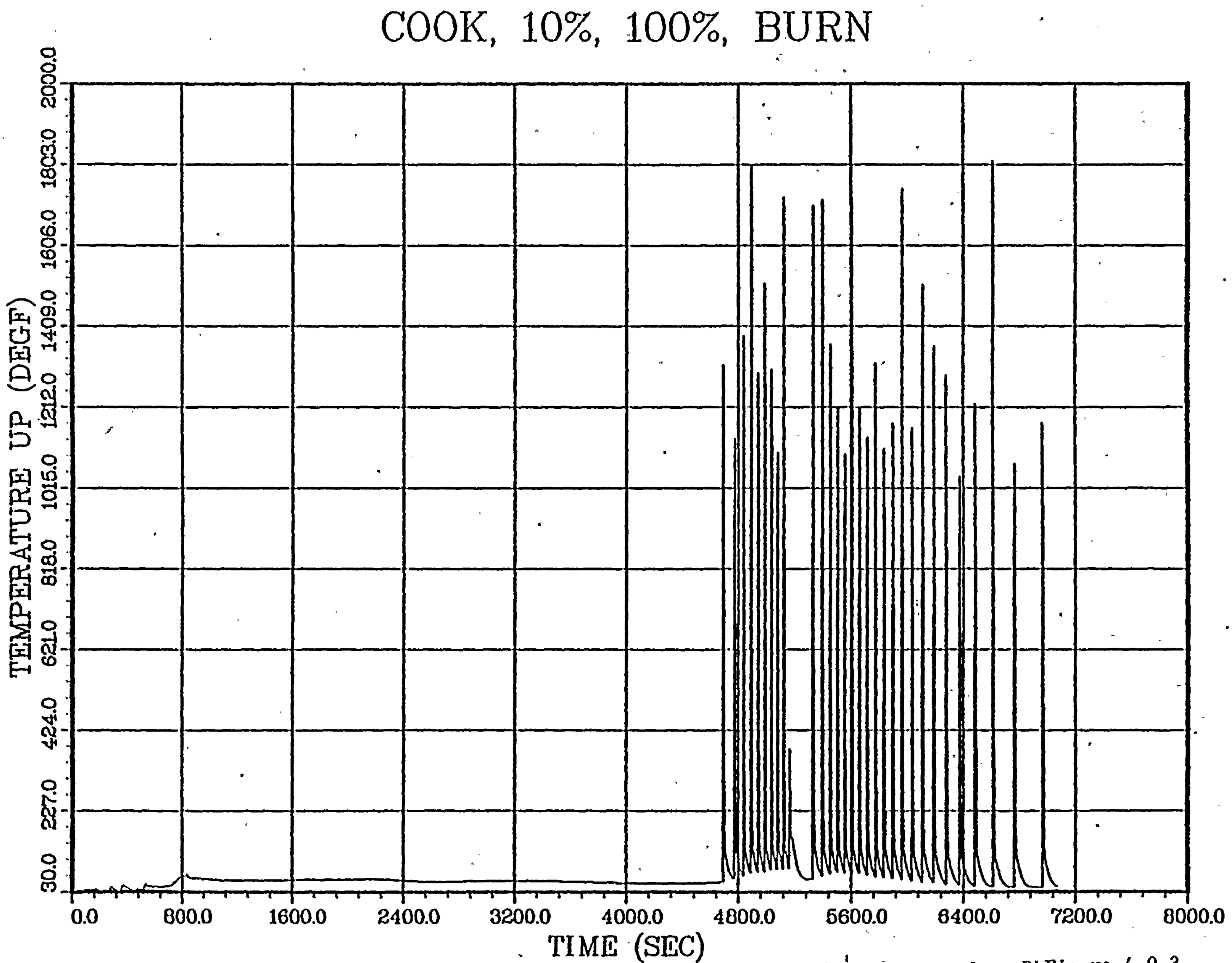
Case D Figure 4.0-1



A.C.P.

Case D Figure 4.0-2

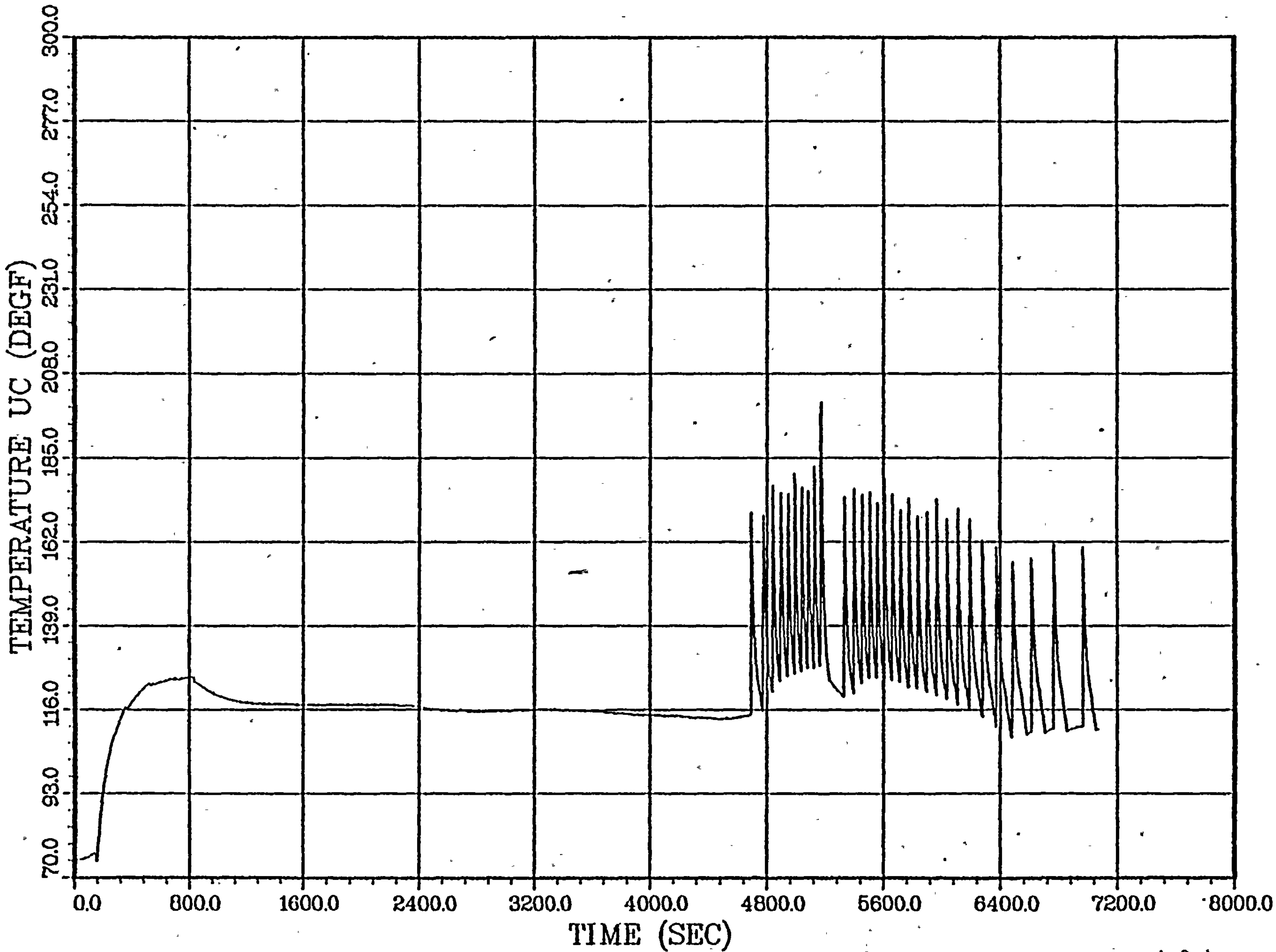
... 15 JAN, 1982 JOB-HAZRITZK ; CYBERNET NOS 1.0 DISSPLA VER 8.2



A.E.P.

Case D; Figure 4.0-3

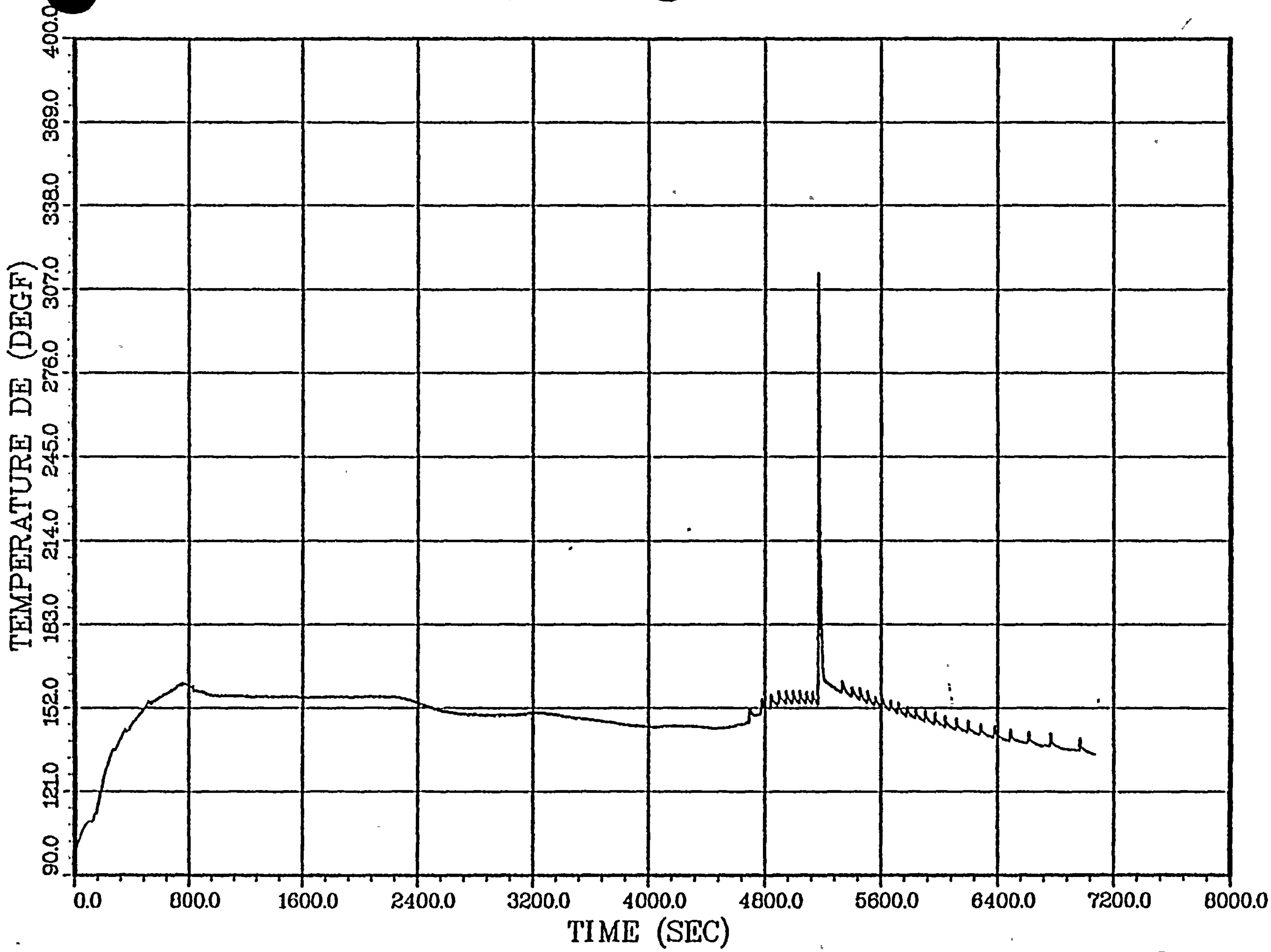
COOK, 10%, 100%, BURN



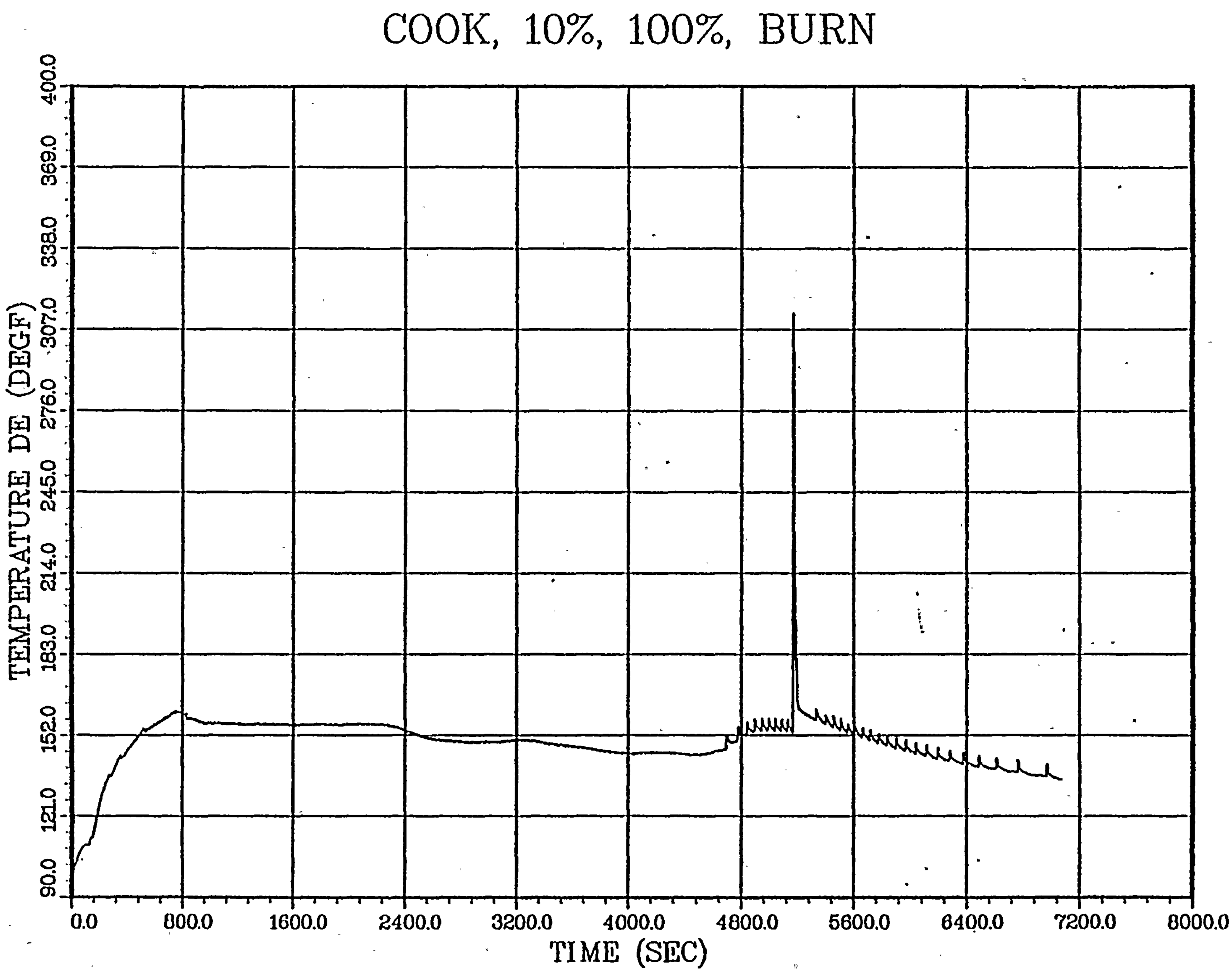
A.C.P.

Case D Figure 4.0-4

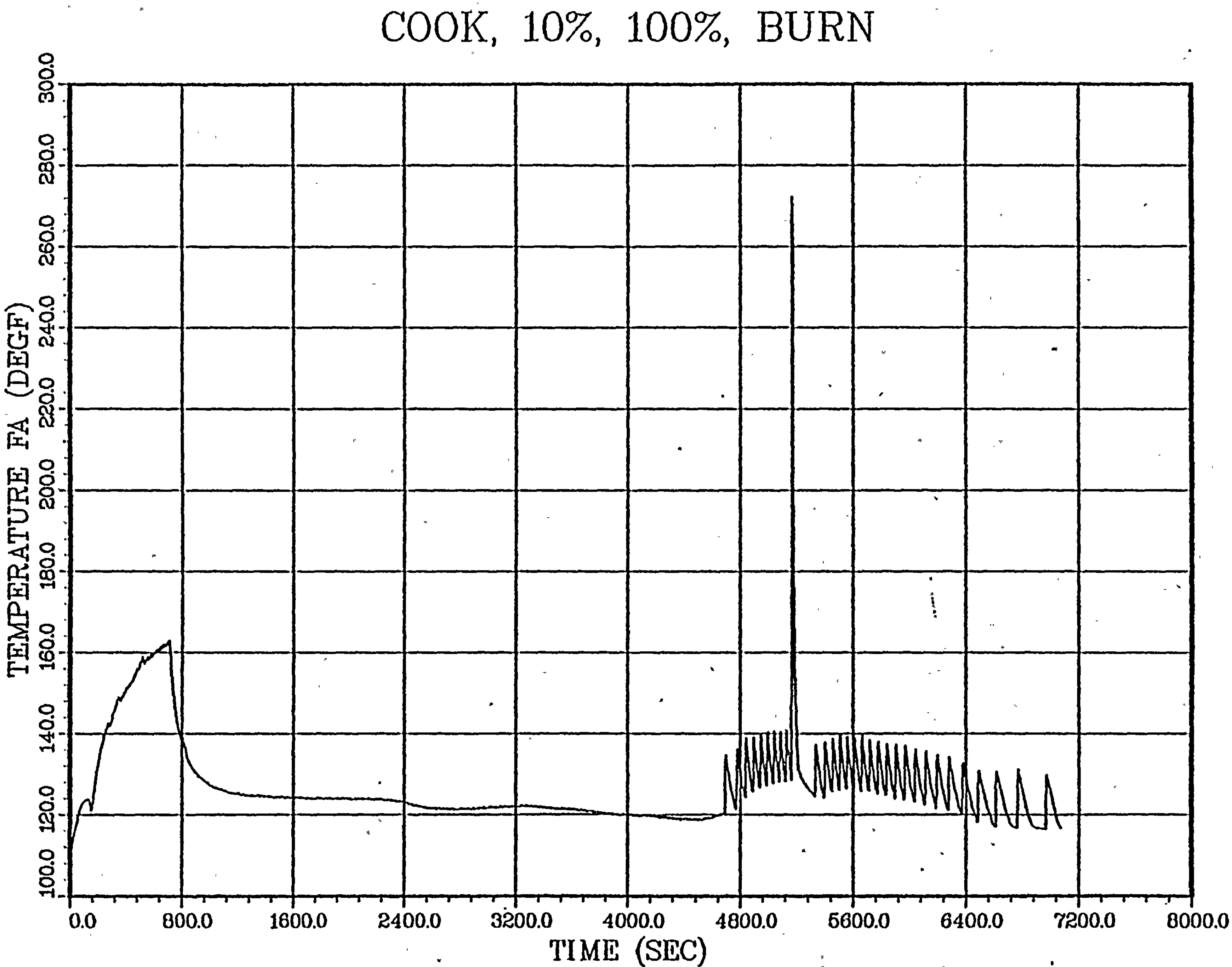
COOK, 10%, [illegible]0%, BURN



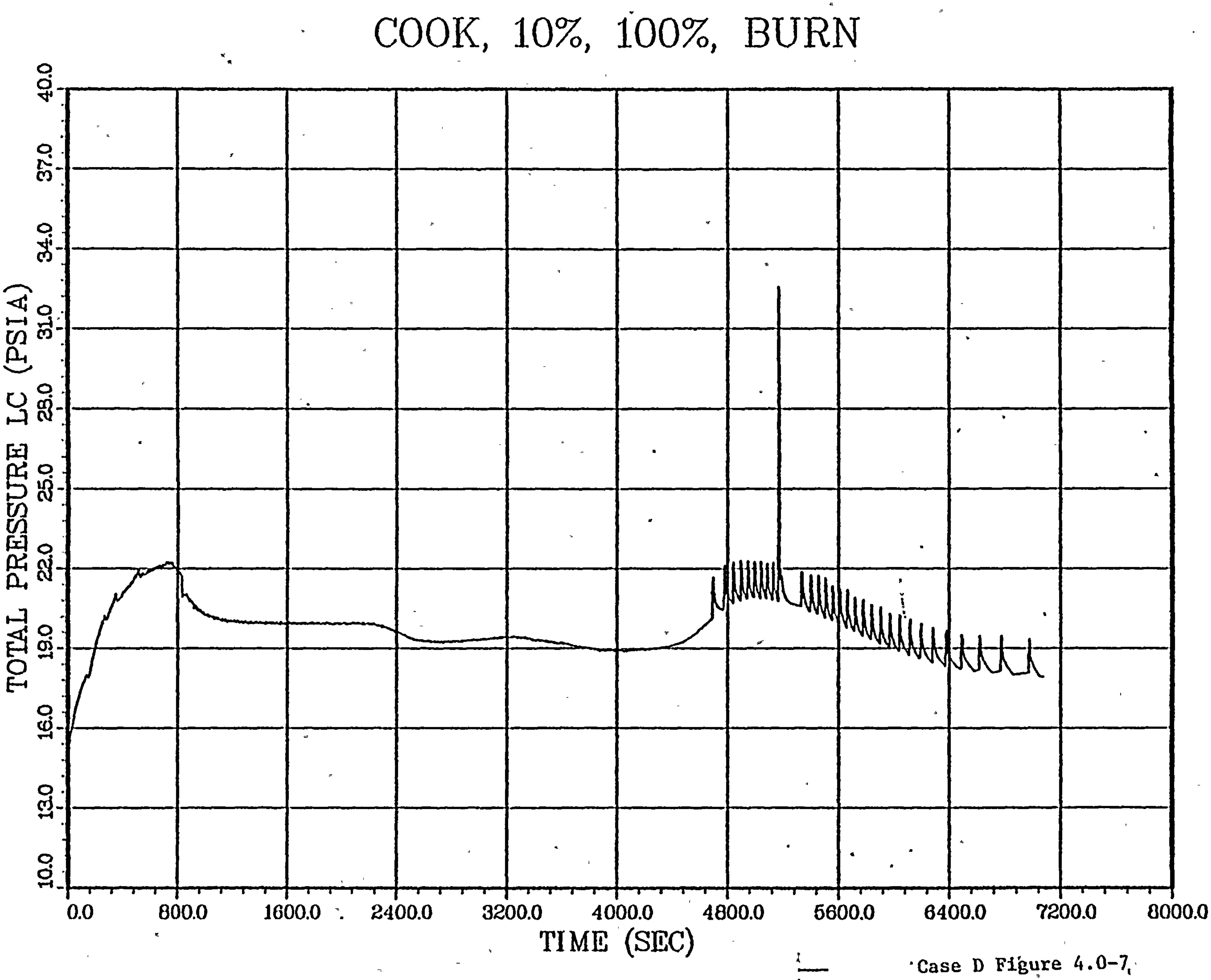
Case D Figure 4.0-5



Case D Figure 4.0-5



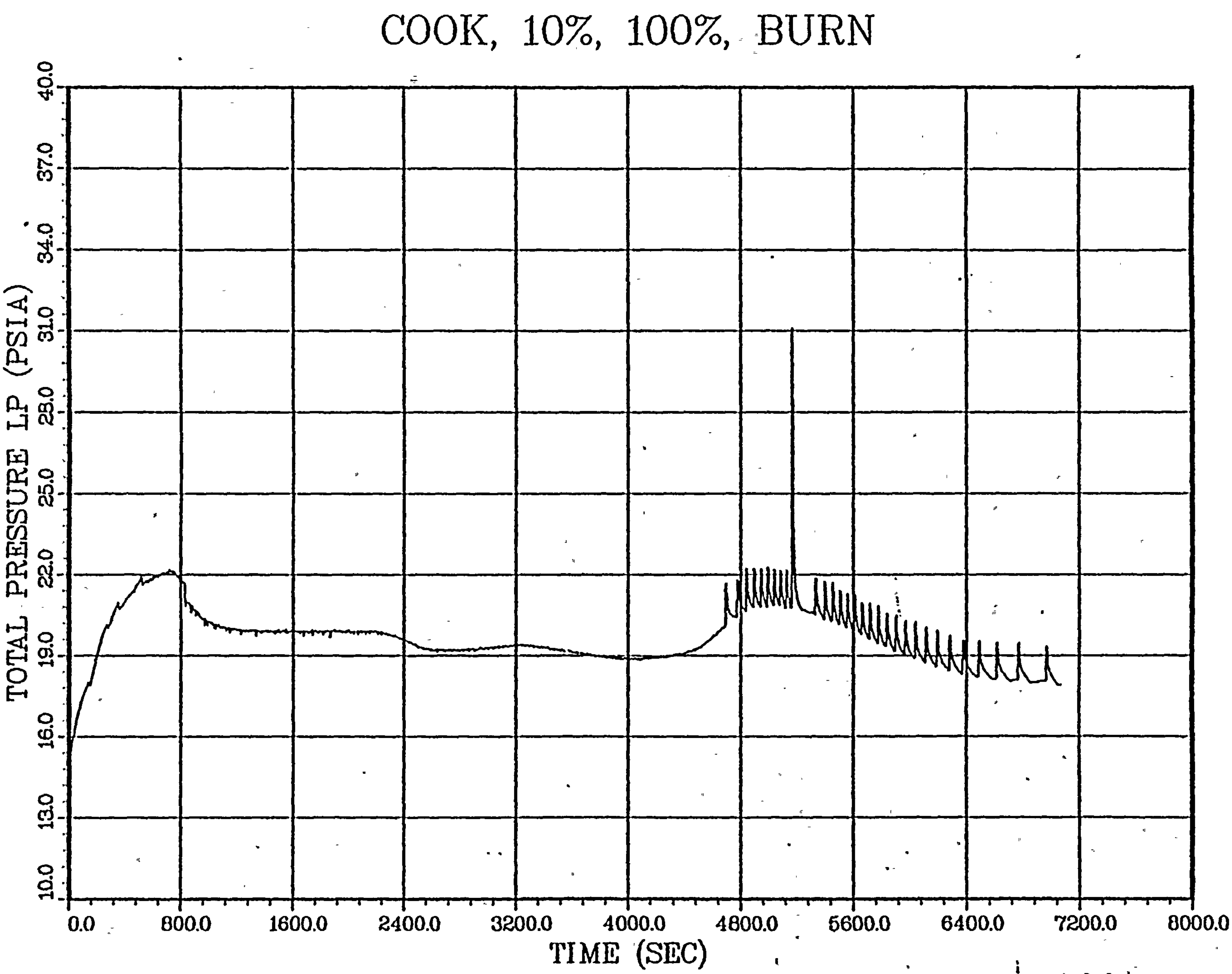
Case D Figure 4.0-6



A.E.P.

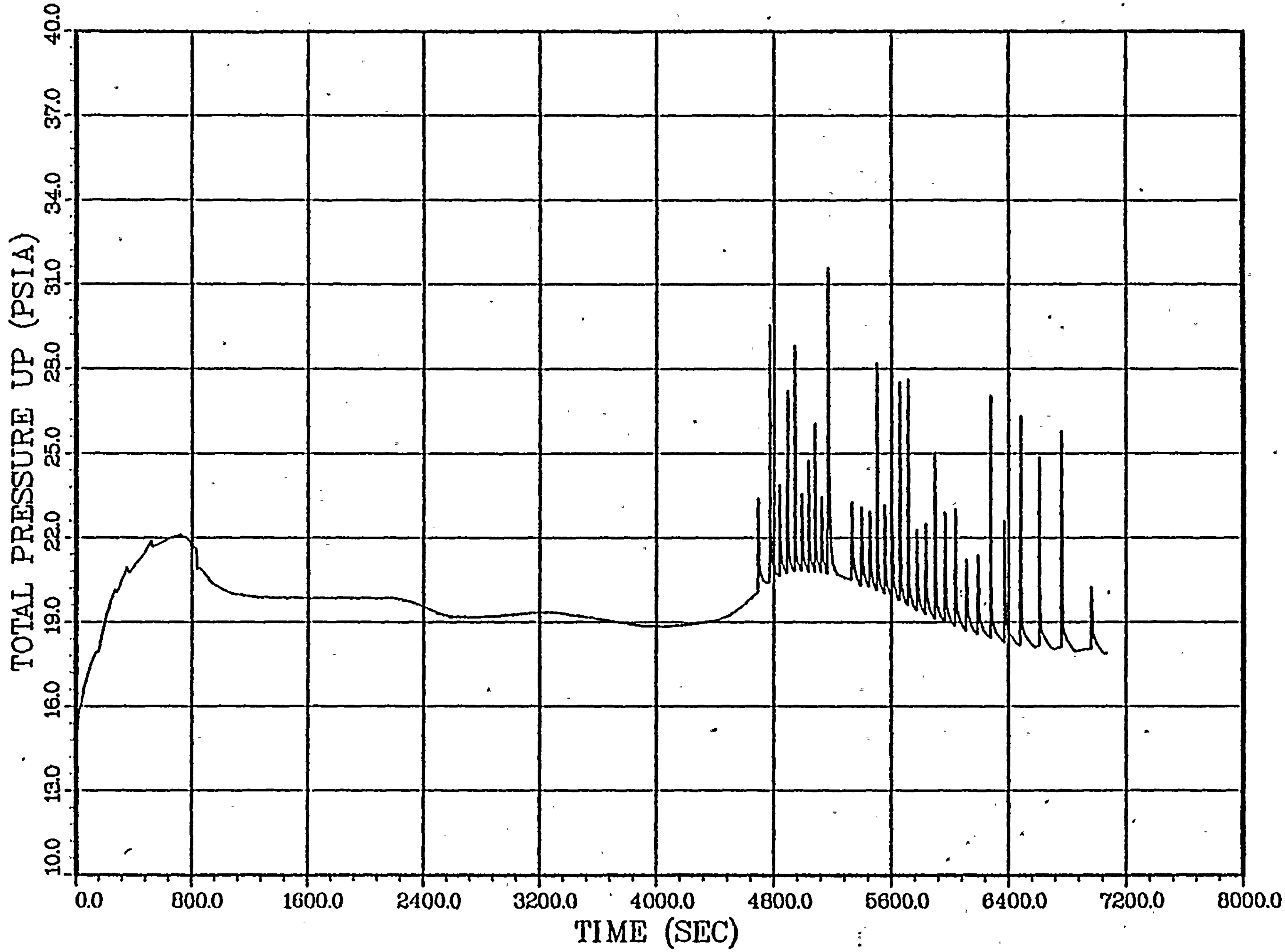
Case D Figure 4.0-7

PLOT 8 19.16.16 FRI 15 JAN, 1982 JOB-AHZRIZK , CYBERNET NOS 1.0 DIS VER 8.2



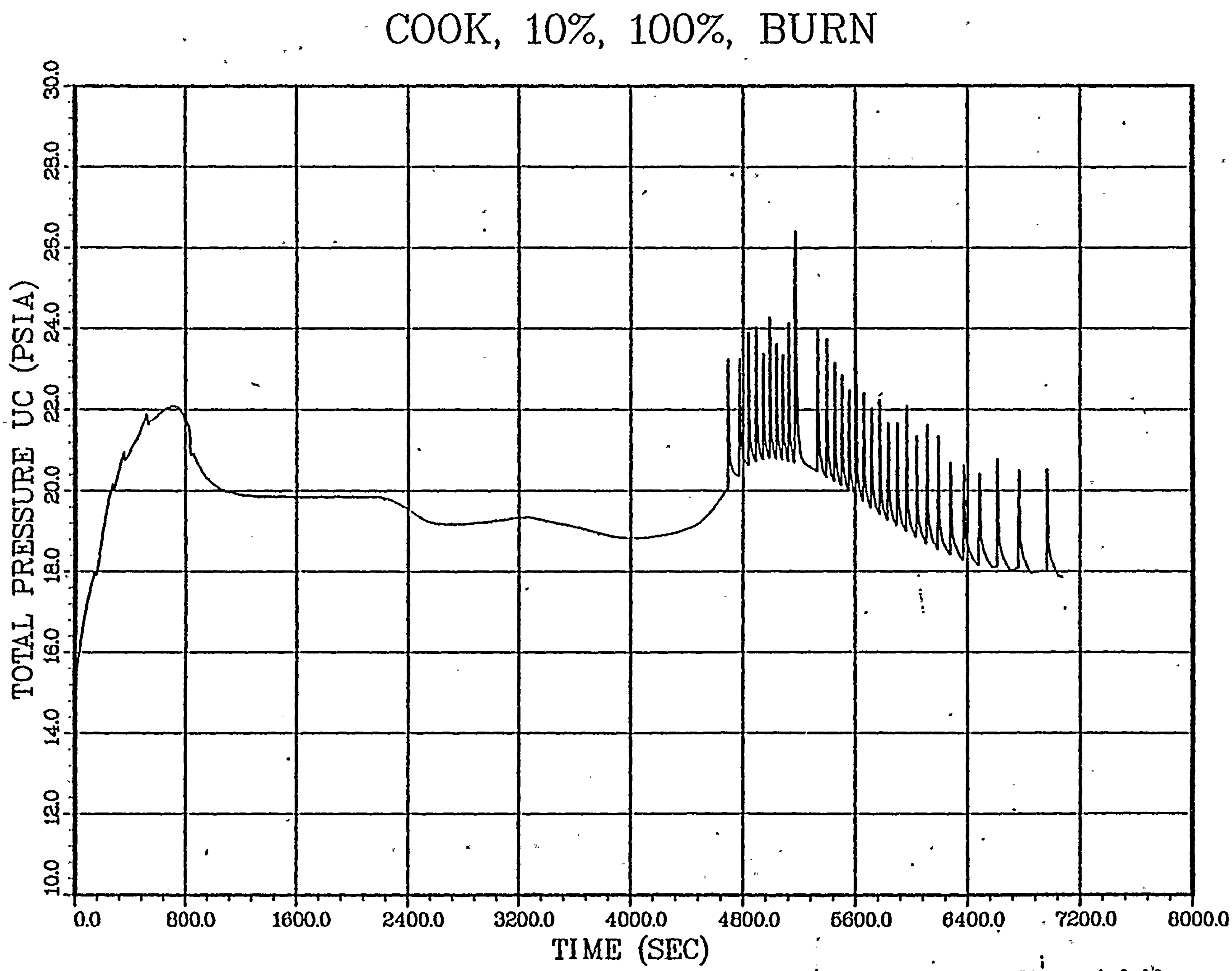
Case D Figure 4.0-8

COOK, 10%, 100%, BURN

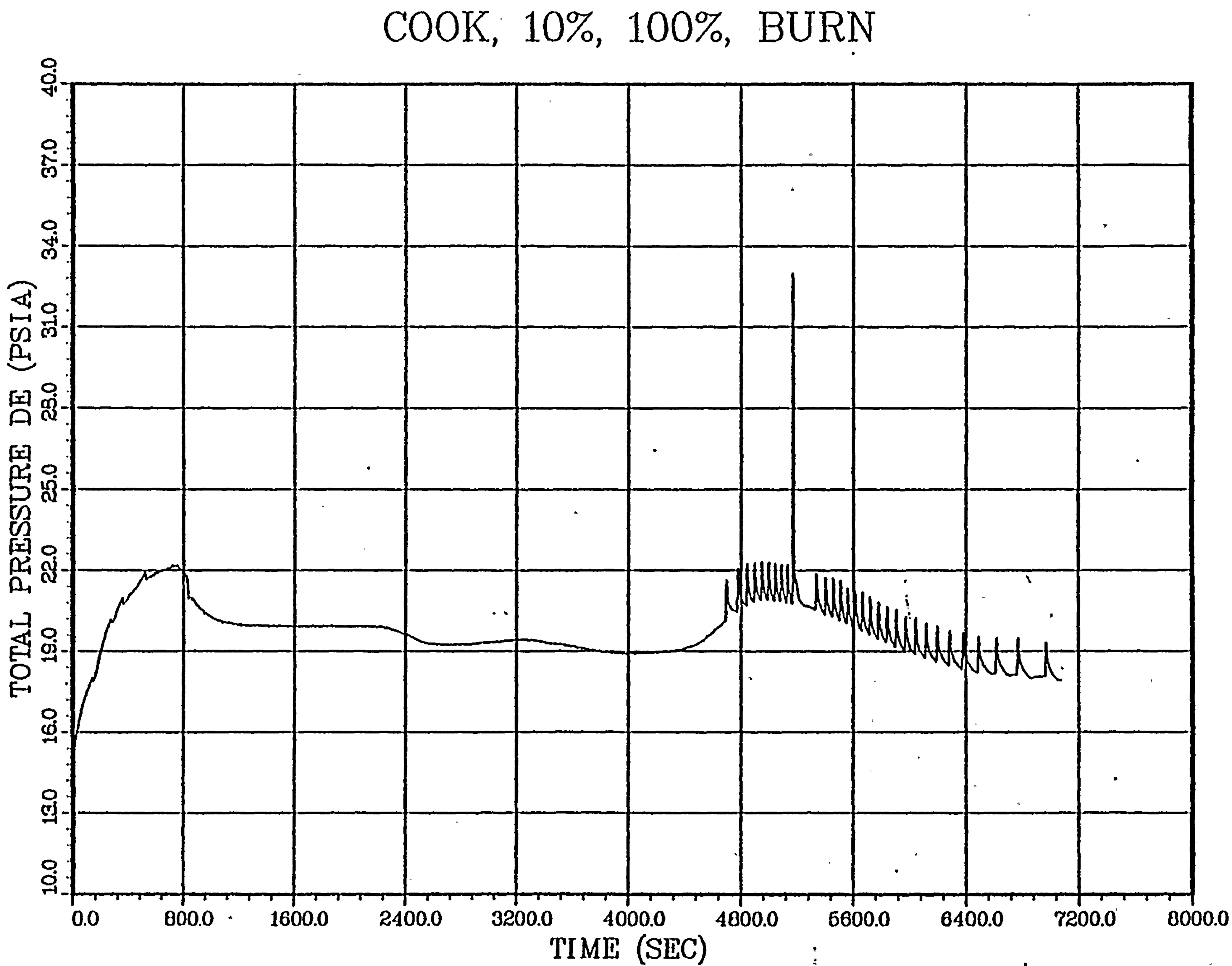


A.E.P.

Case D Figure 4.0-9

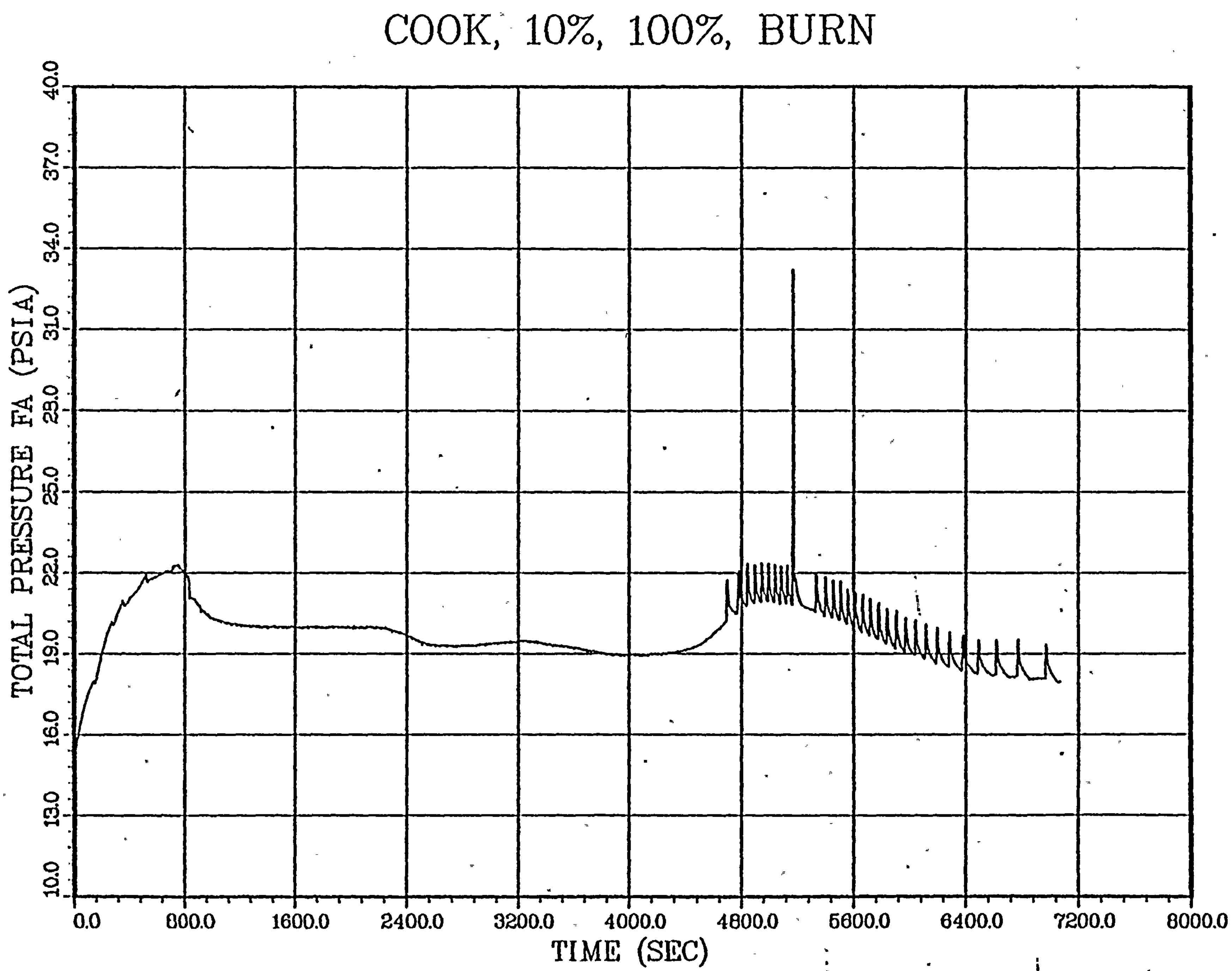


Case D Figure 4.0-10.

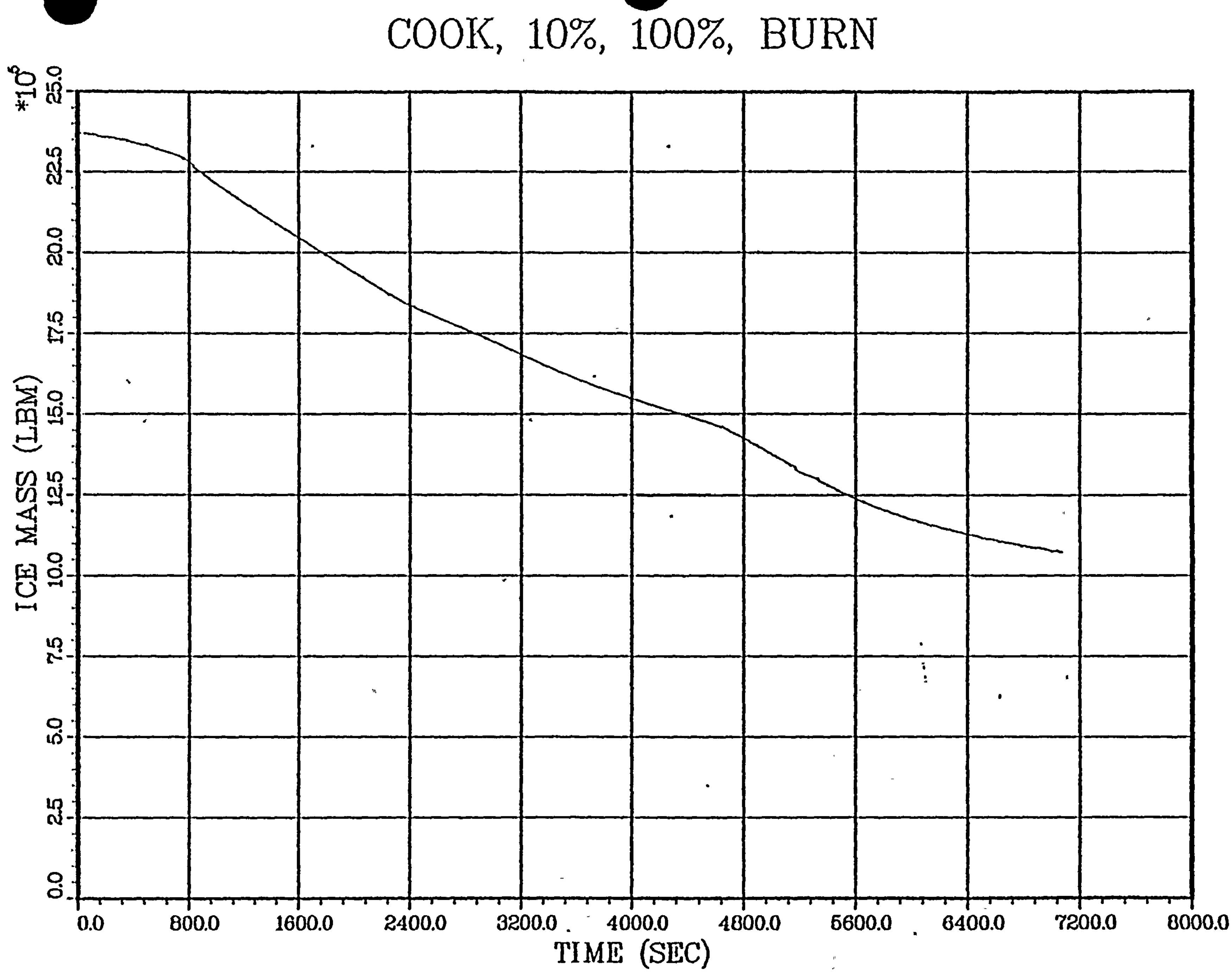


A.E.P.

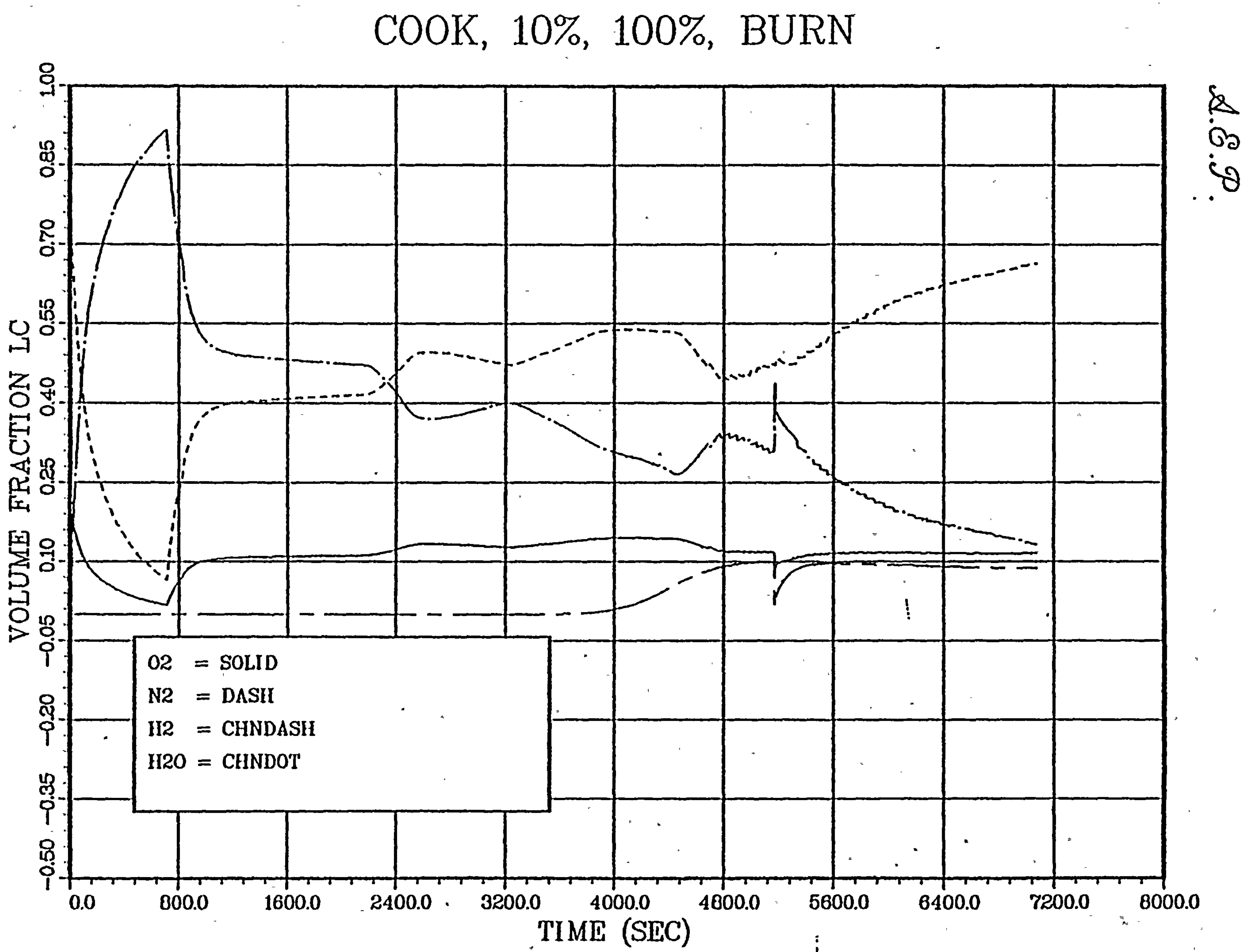
Case D Figure 4.0-11



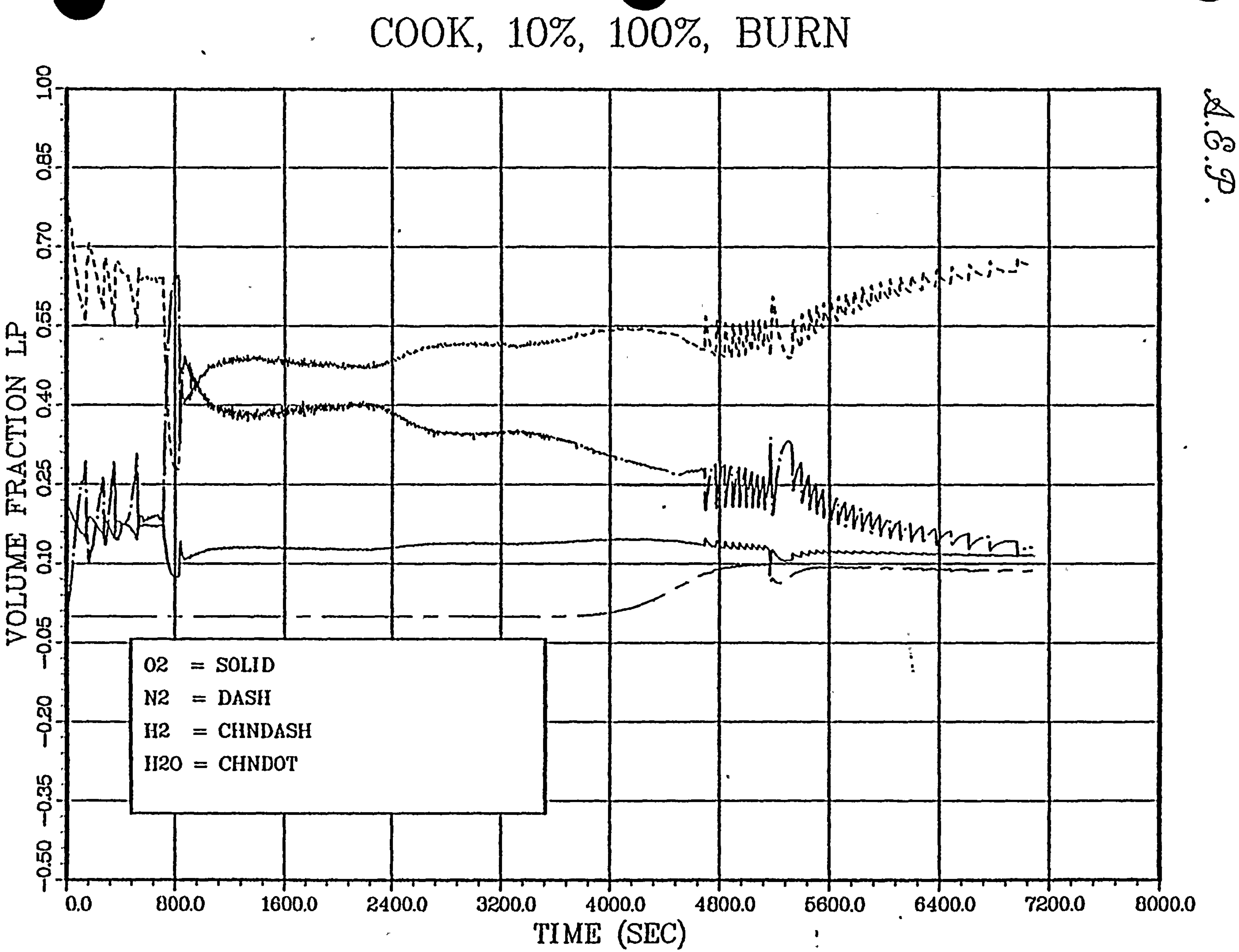
Case D Figure 4.0-12



Case D Figure 4.0-13

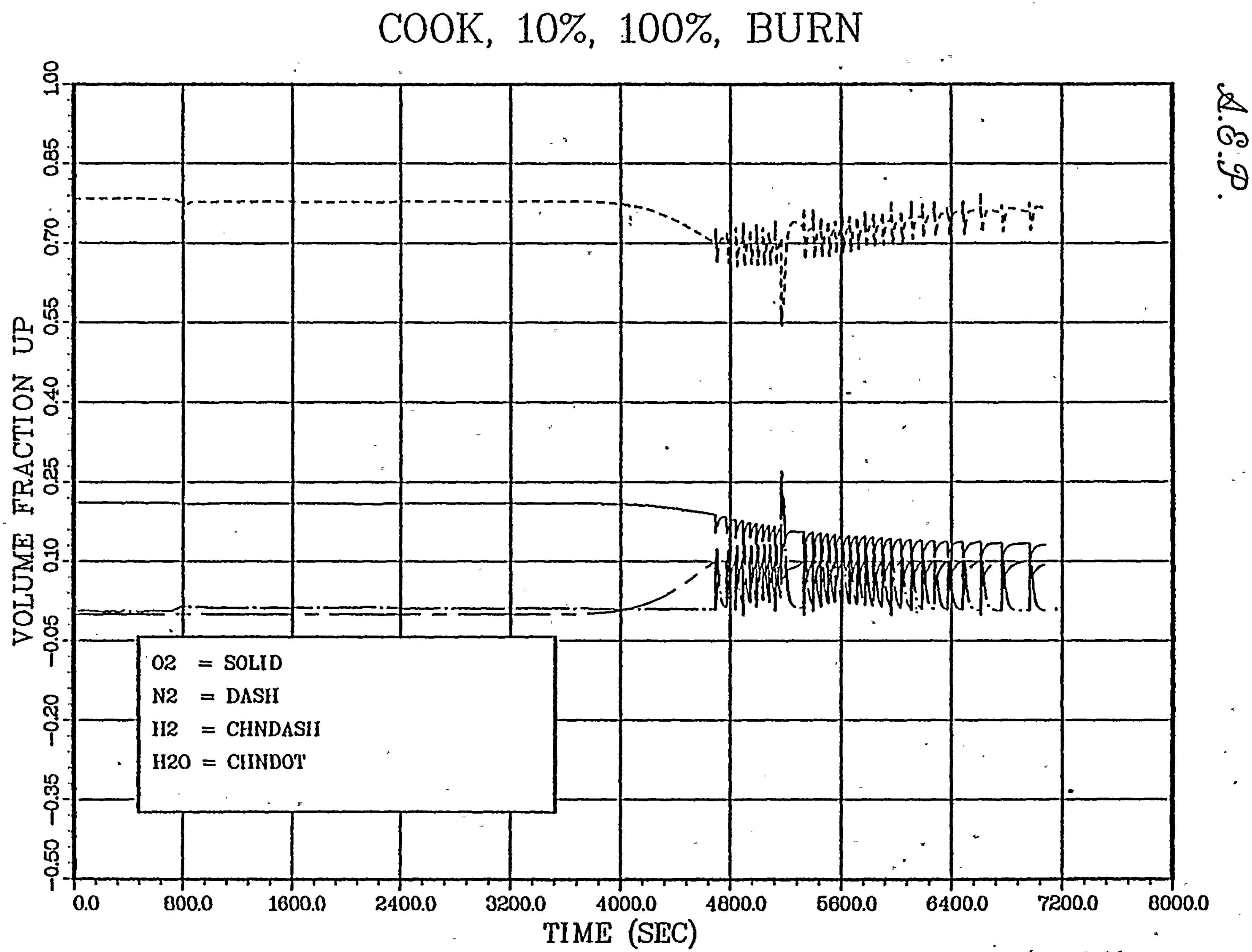


Case D Figure 4.0-14



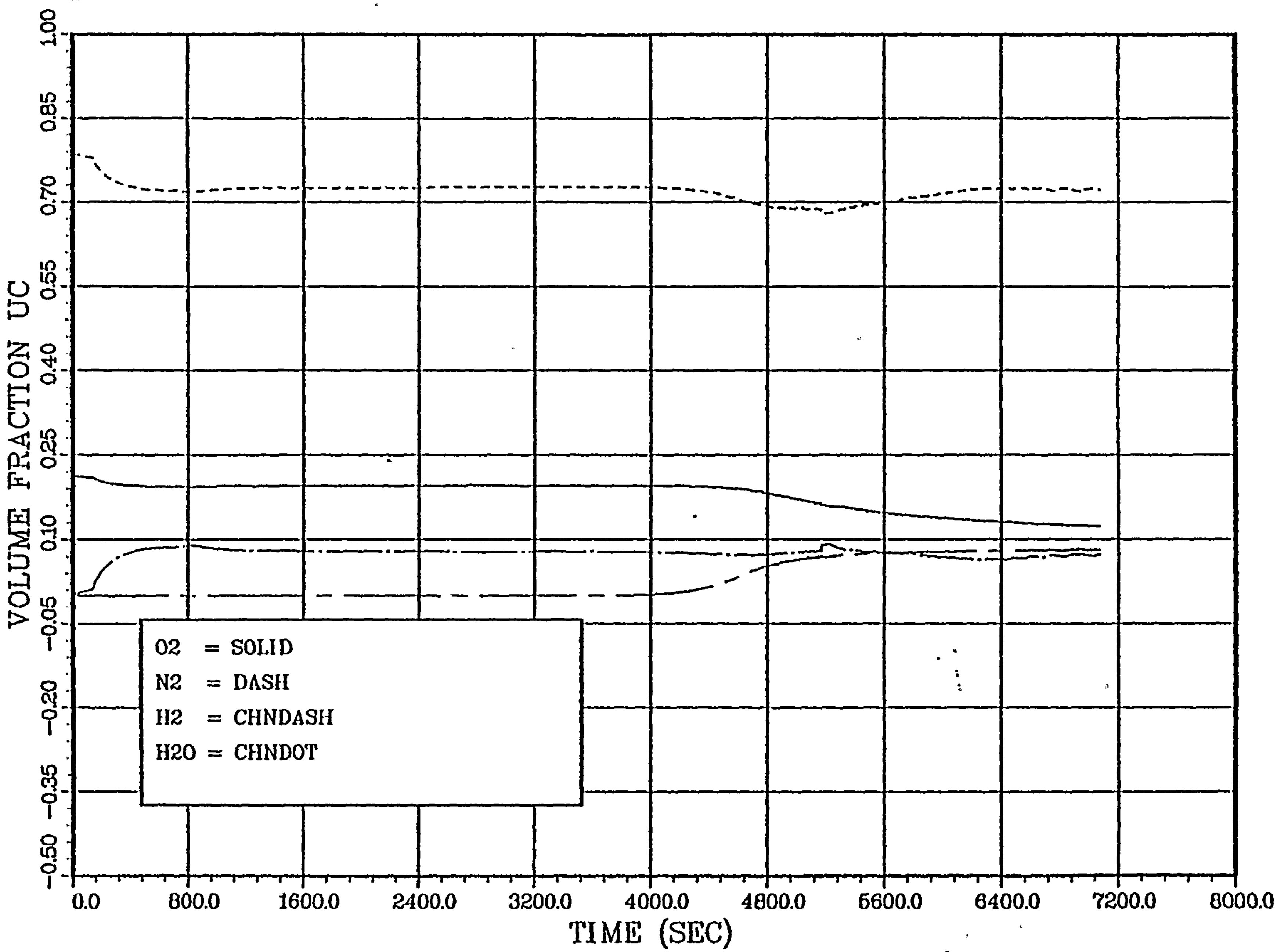
Case D Figure 4.0-15

CYBERNET NOS 1.0 DISSPLA-VER 8.2

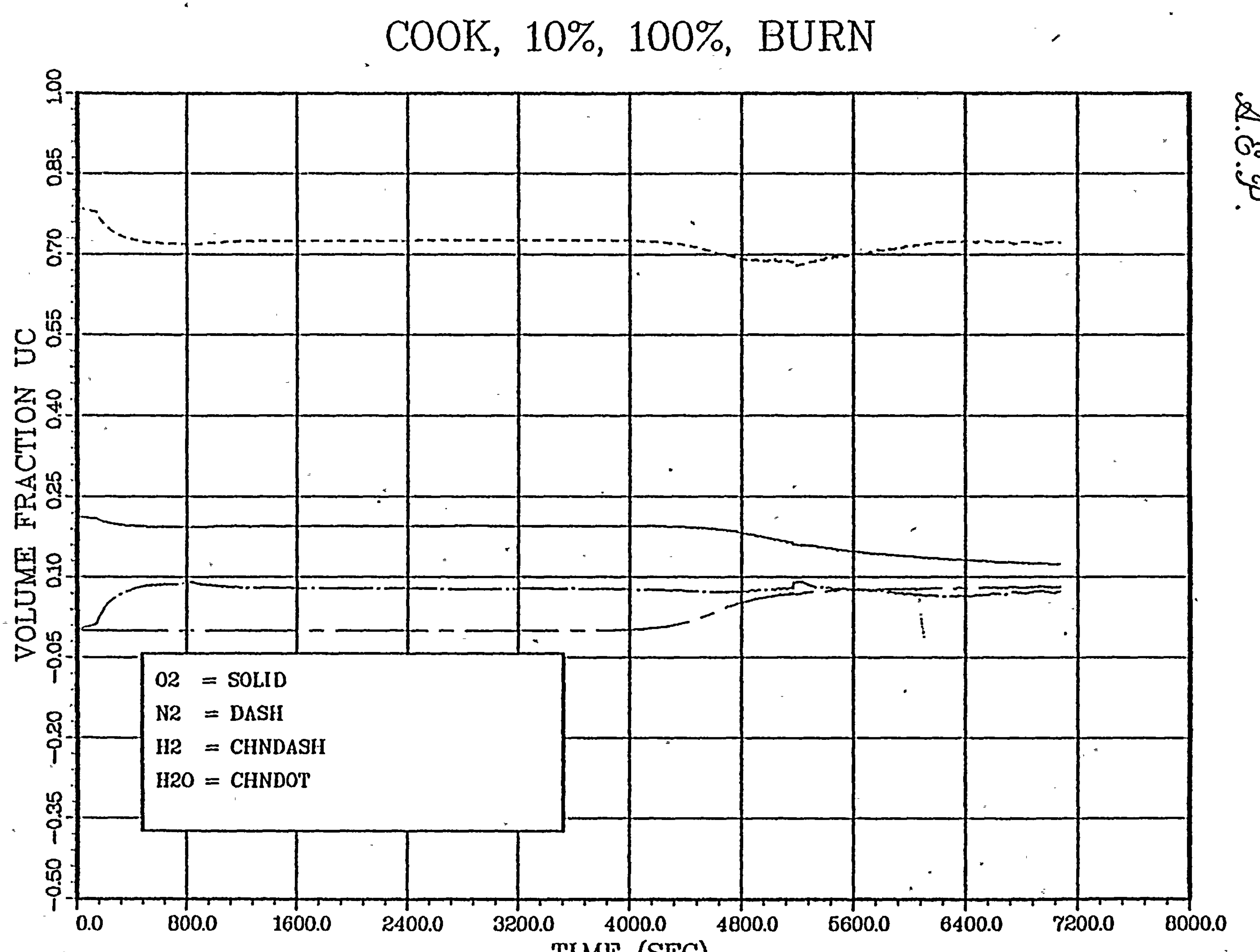


Case D Figure 4.0-16

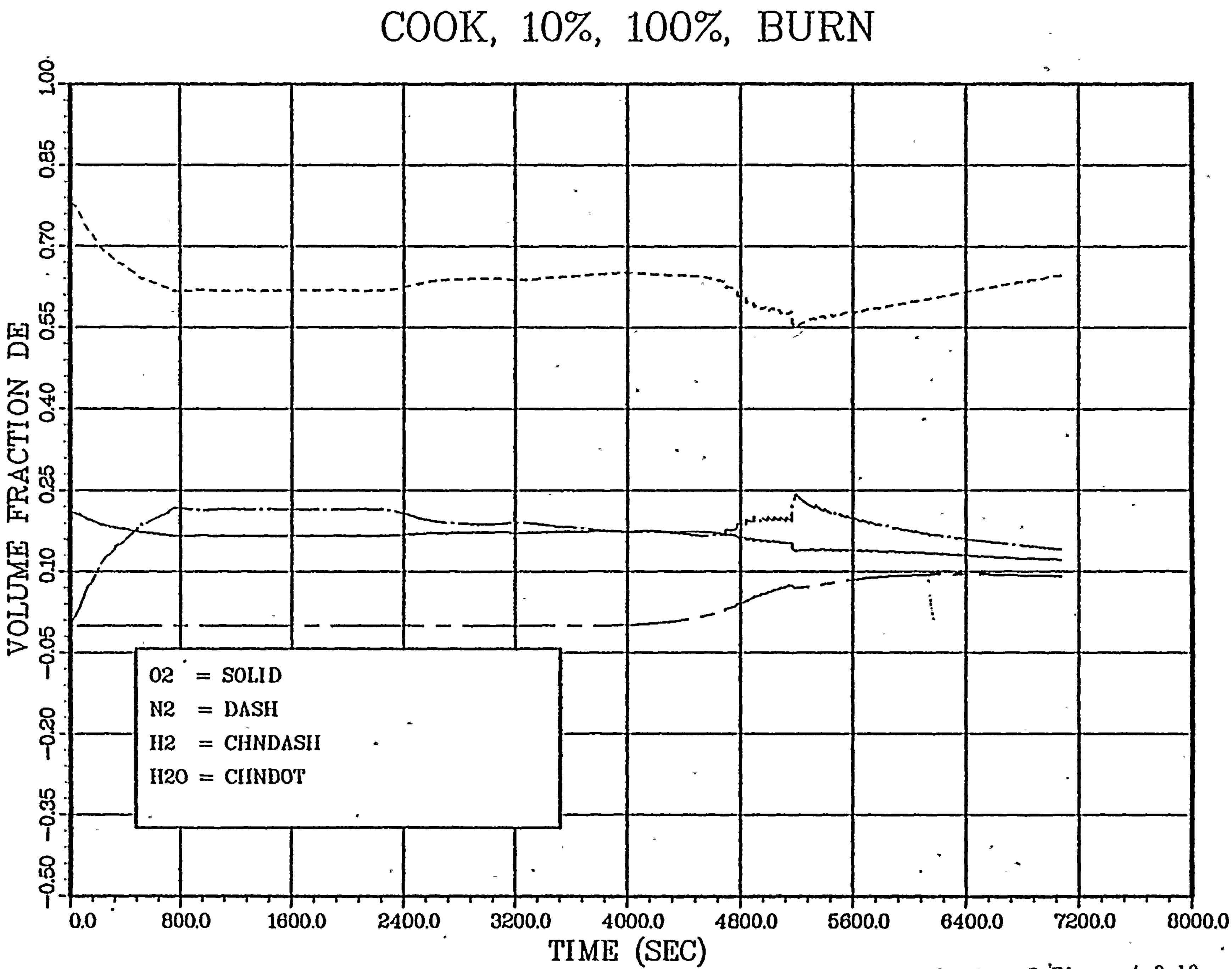
COOK, 10%, [illegible]0%, BURN



Case D Figure 4.0-17

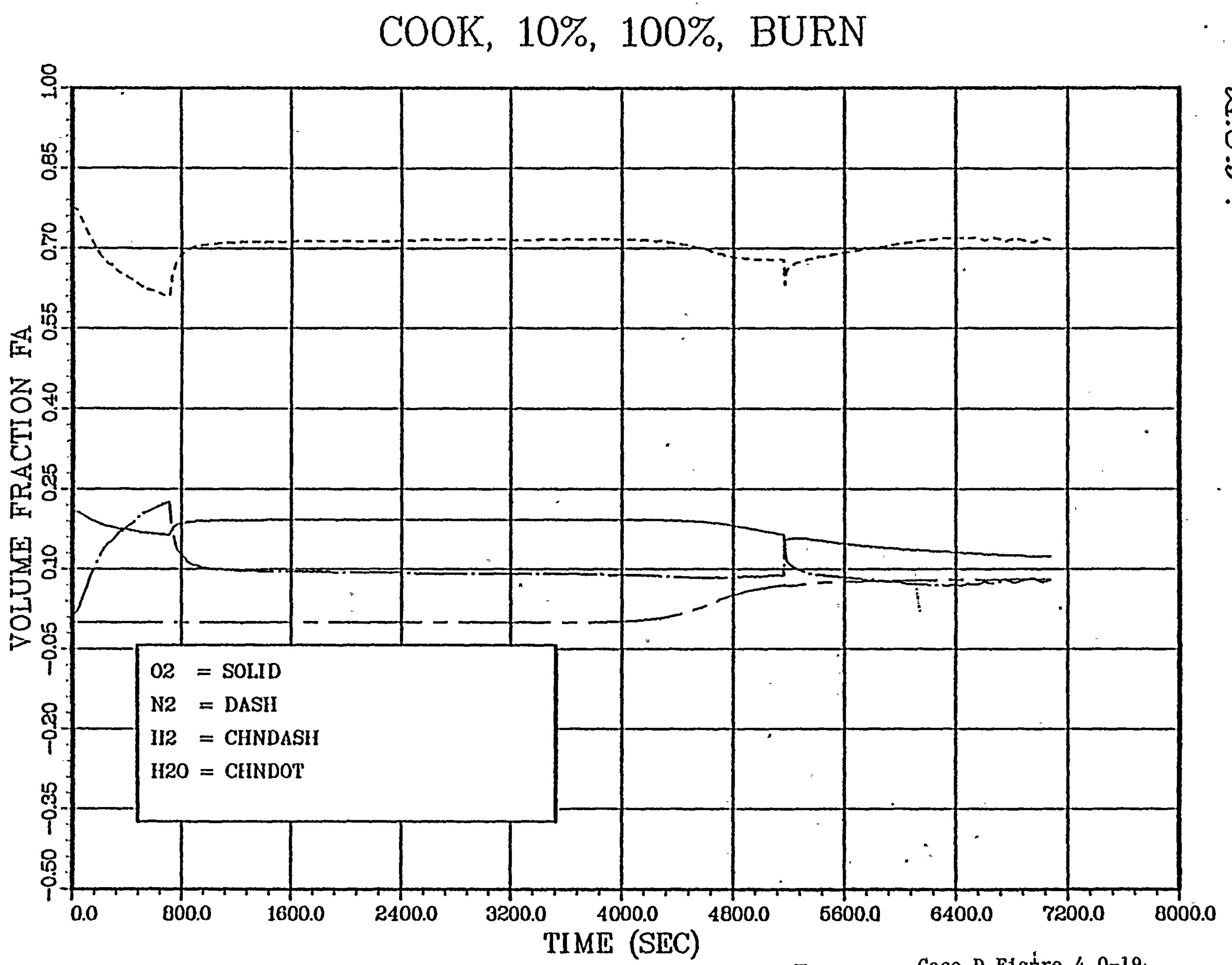


Case D Figure 4.0-17



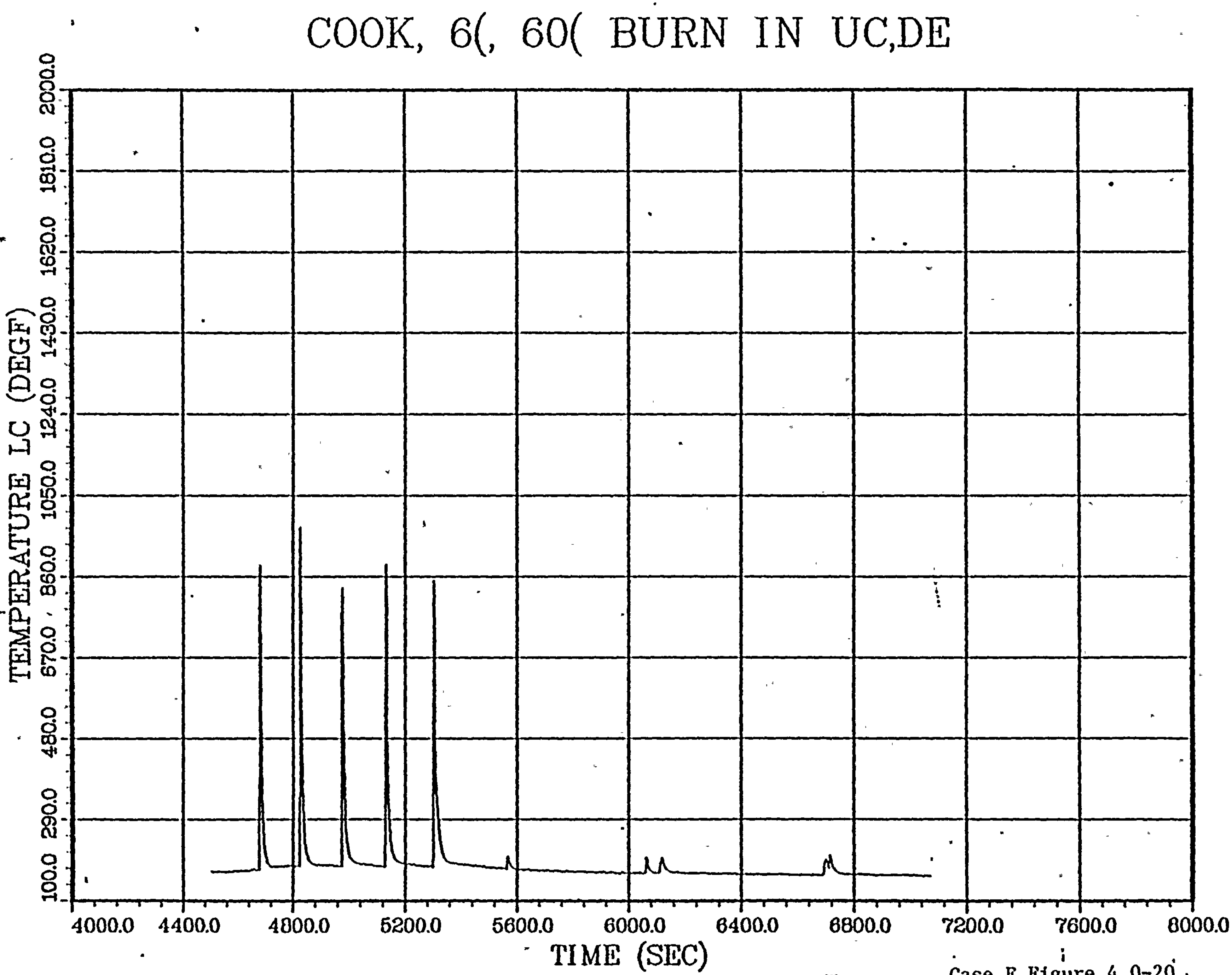
Case D Figure 4.0-18

PLOT 19 19 ..15 FRI 15 JAN, 1982 JOB-ANZRIZK , CYBERNET NOS 1.0 DISSPLA 8.2

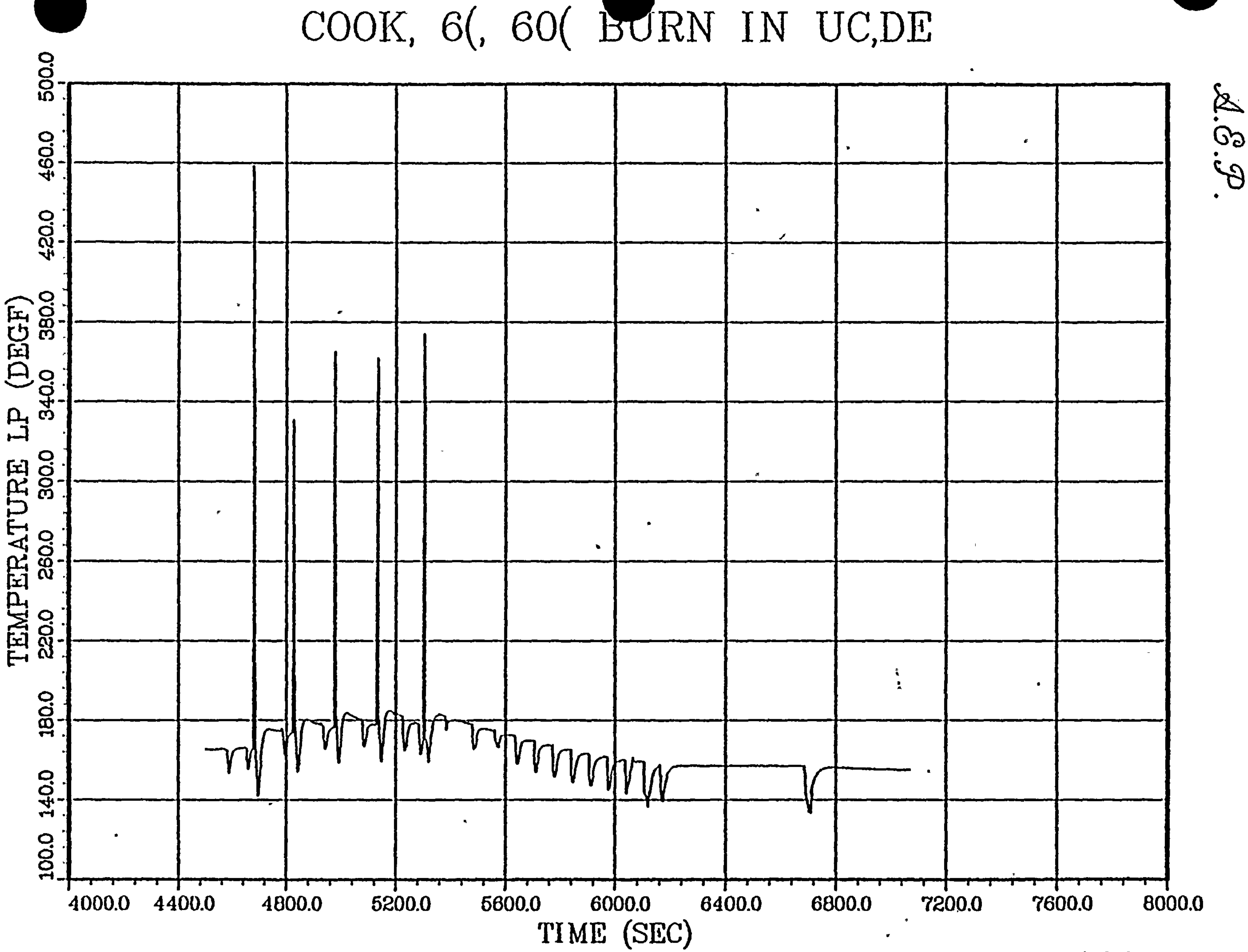


Case D Figure 4.0-19

CYBERNET NOS 1.0 BISSP 8.2

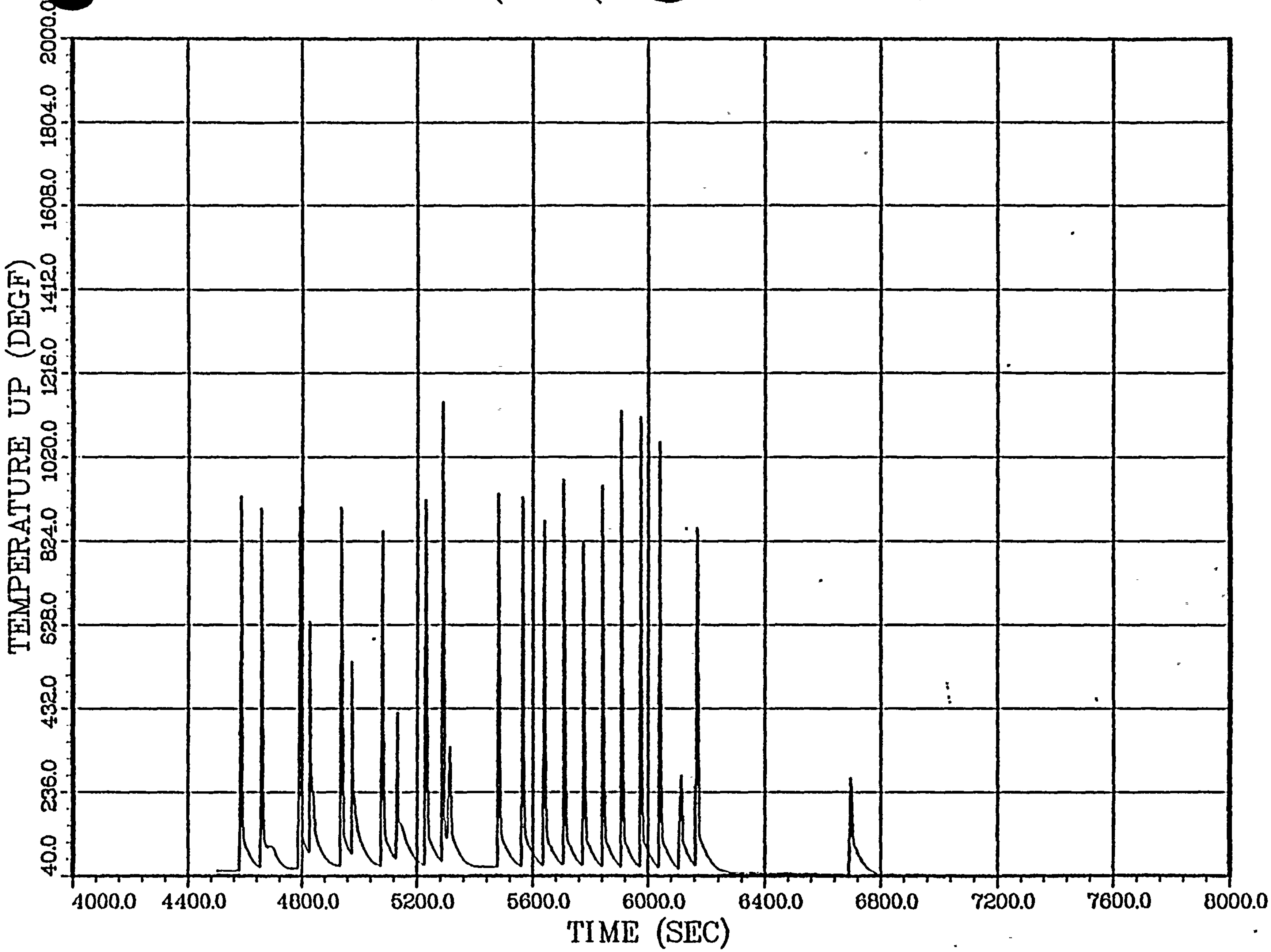


Case E Figure 4.0-20



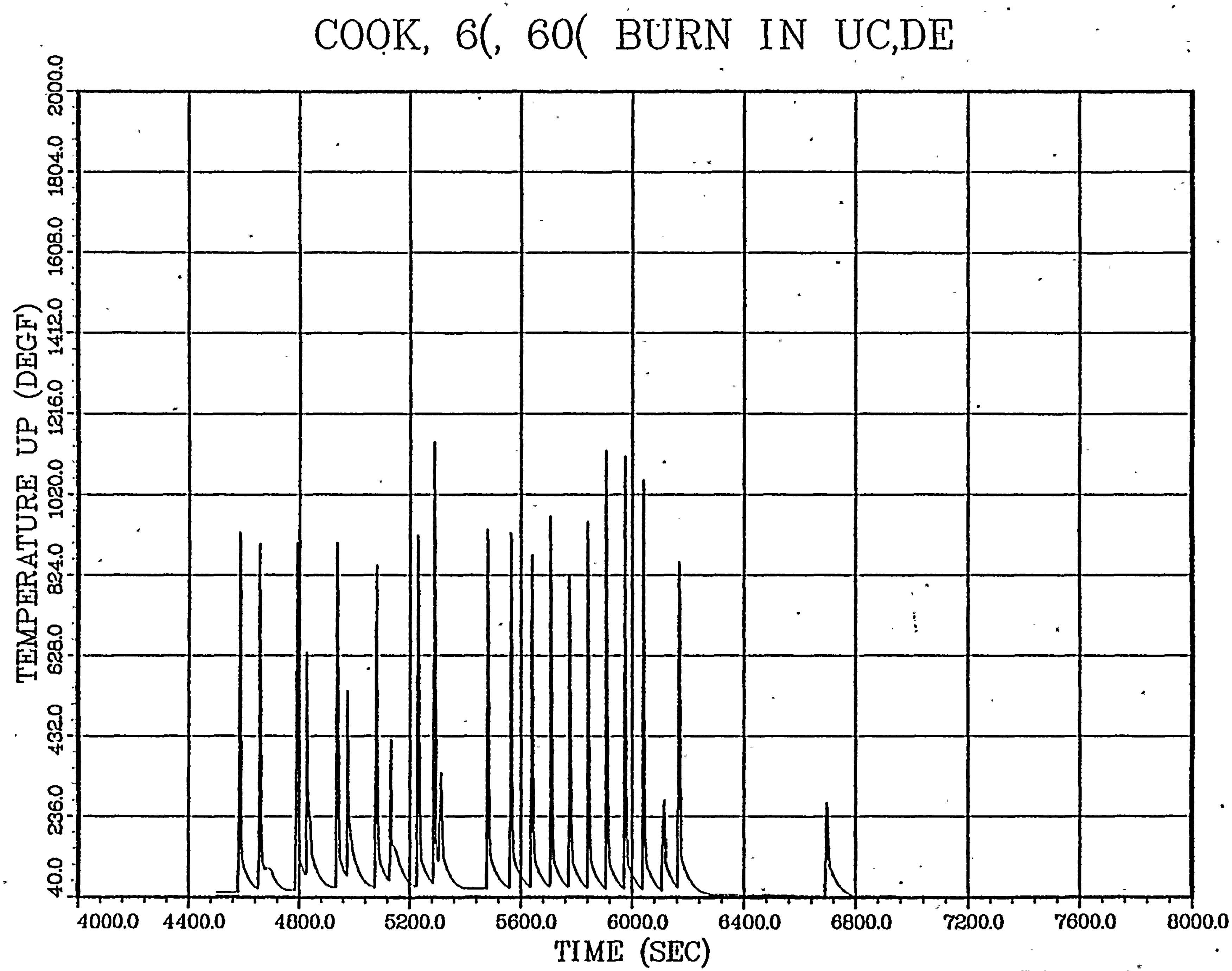
Case E Figure 4.0-21

COOK, 6(, 60([illegible]RN IN UC,DE



A.E.P.

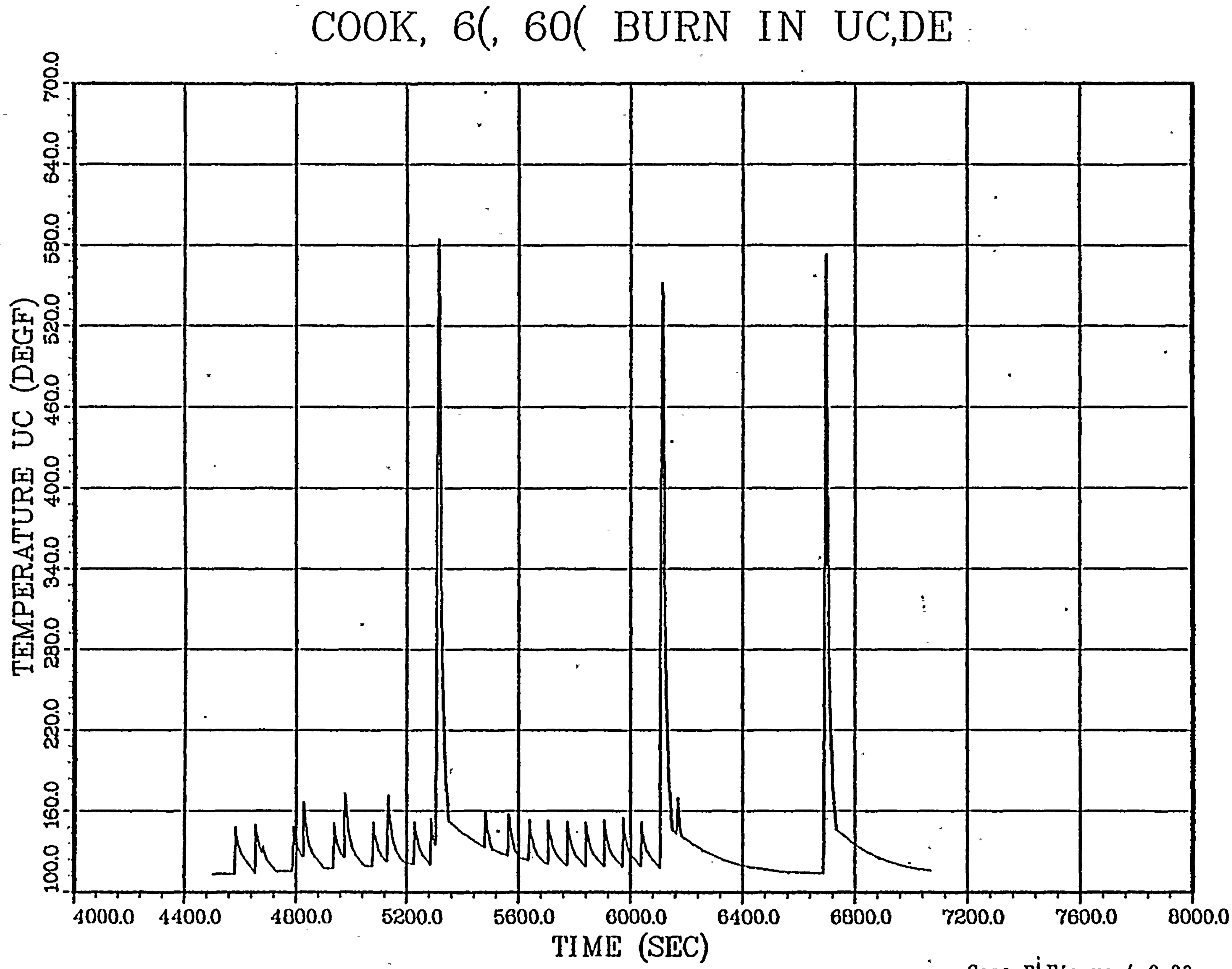
Case E Figure 4.0-22



A.E.P.

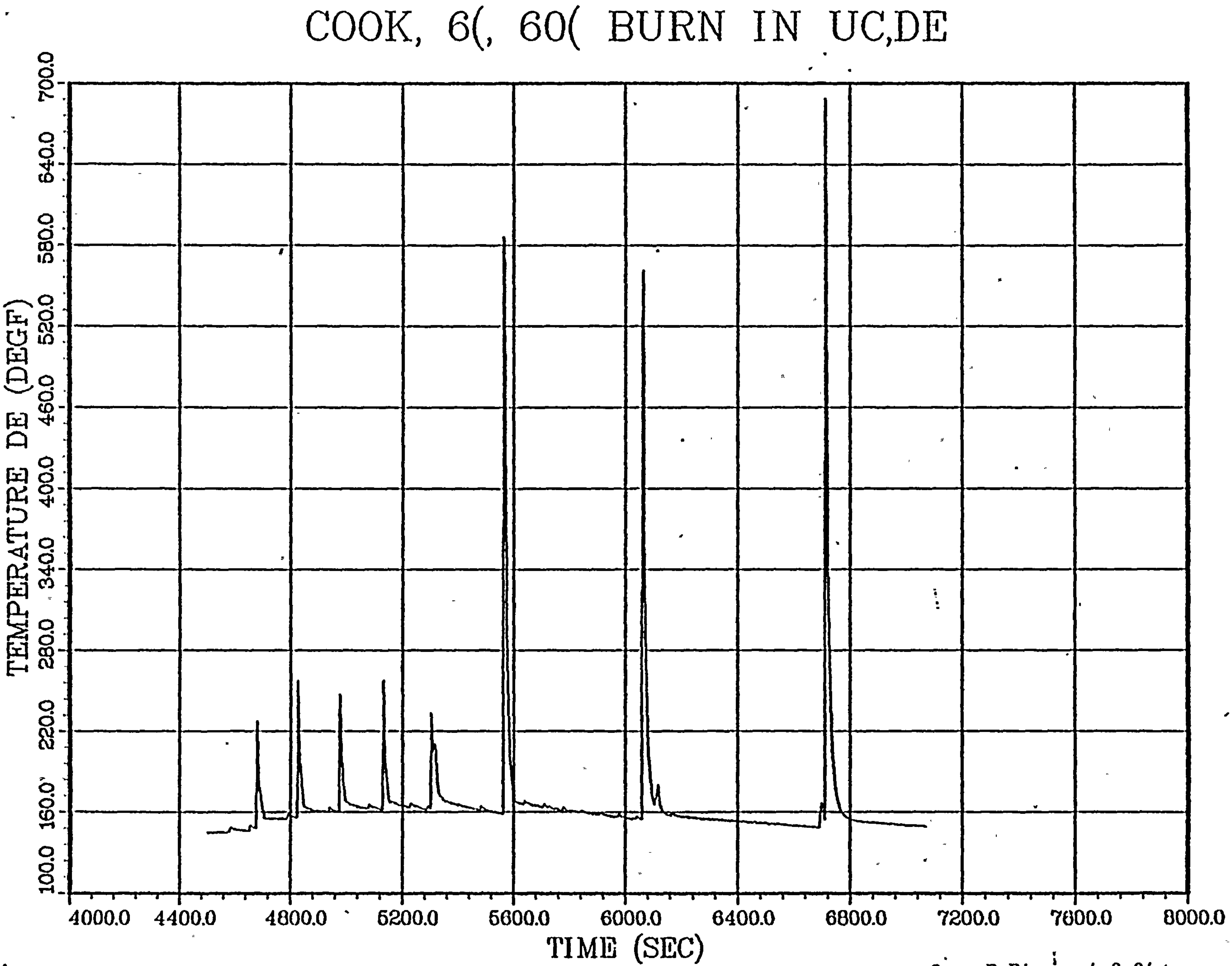
Case E Figure 4.0-22

PLOT 4 20[illegible]56 FRI 22 JAN, 1982 JOB-ANZRIYN , CYBERNET NOS 1.0 DISSPL[illegible] 8.2



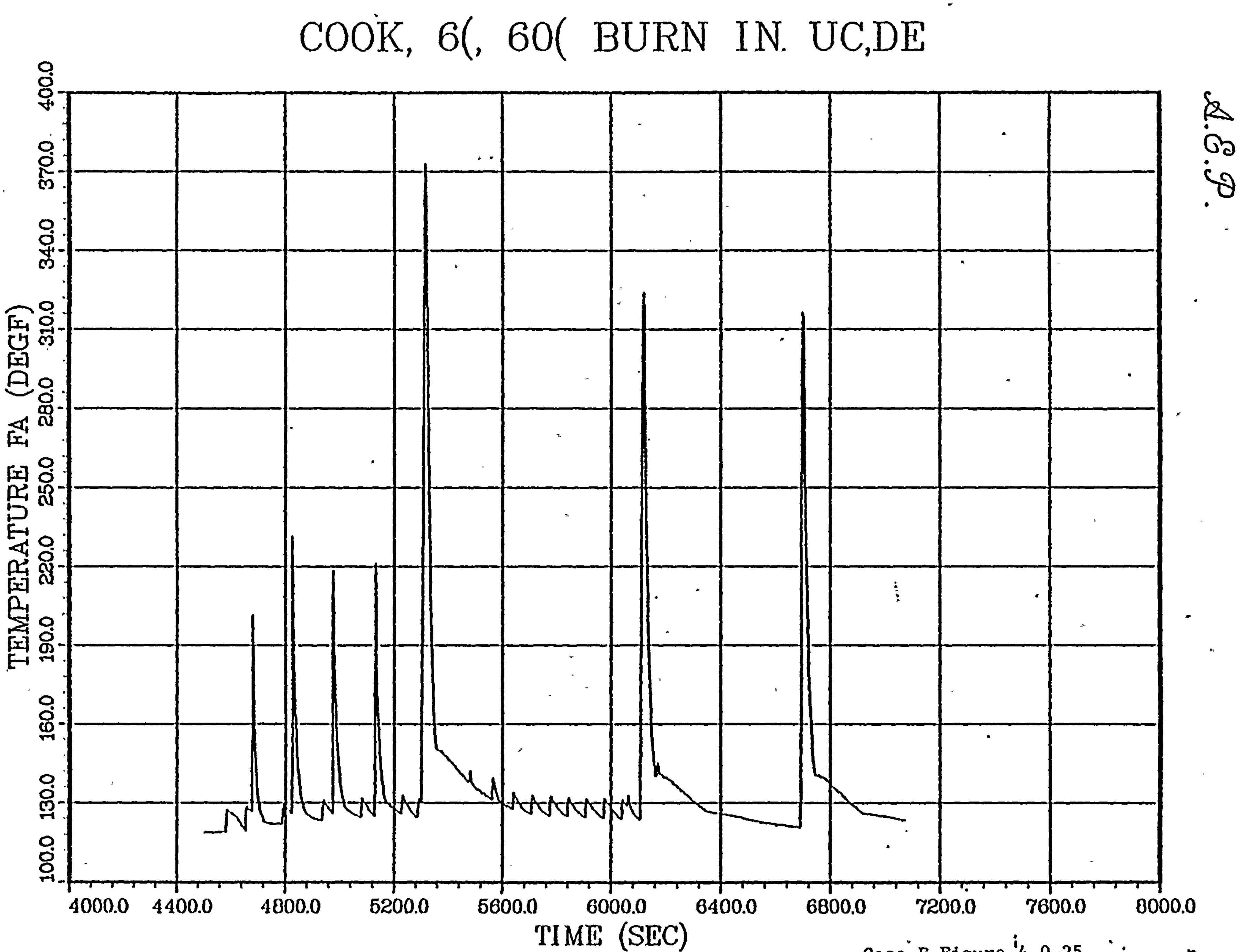
Case E Figure 4.0-23

PLOT 5 20.49.59 FRI 22 JAN, 1982 JOB-ANZRIYN , CYBERNET NOS 1.0 DISSPLA 8.2

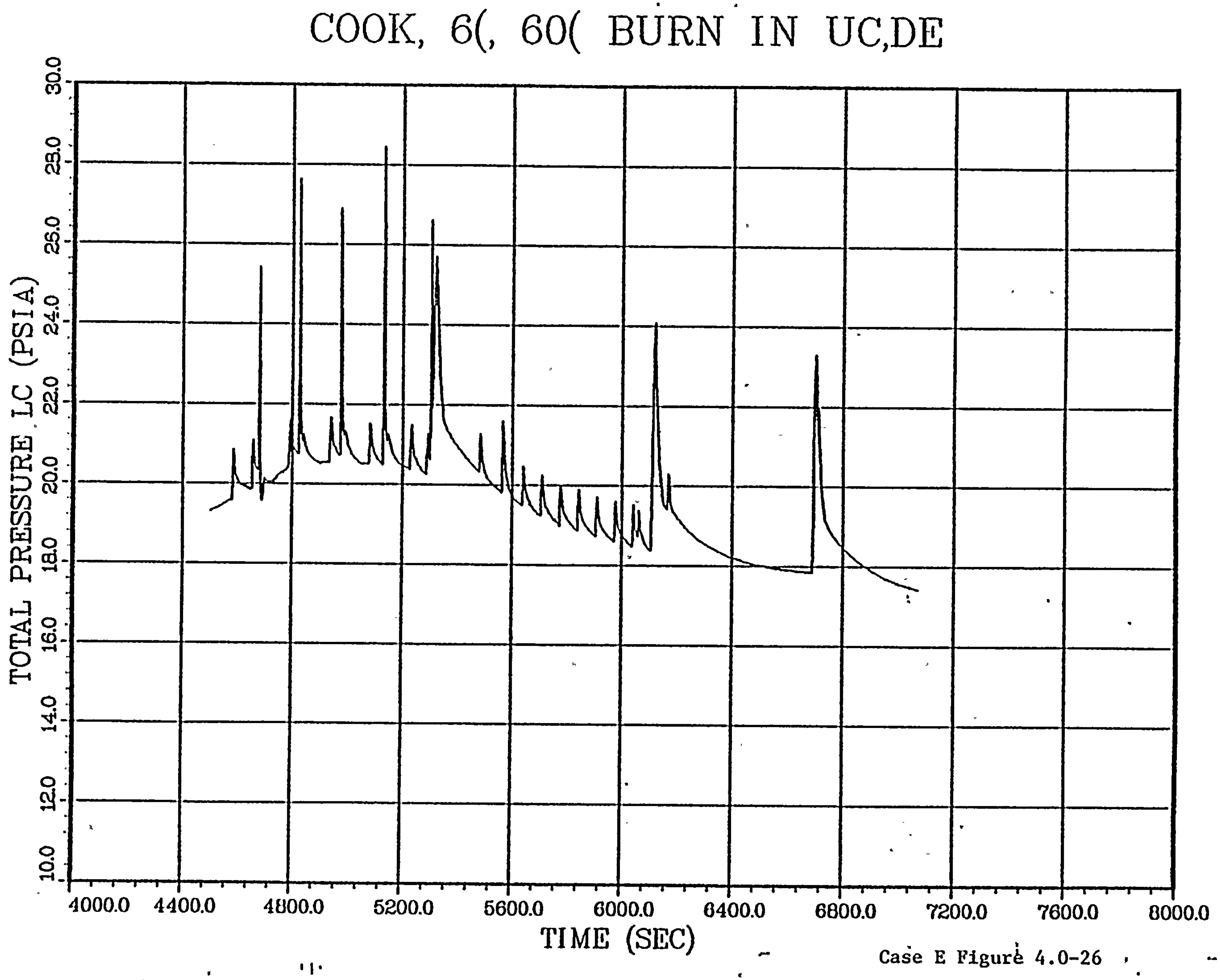


A.E.P.

Case E Figure 4.0-24



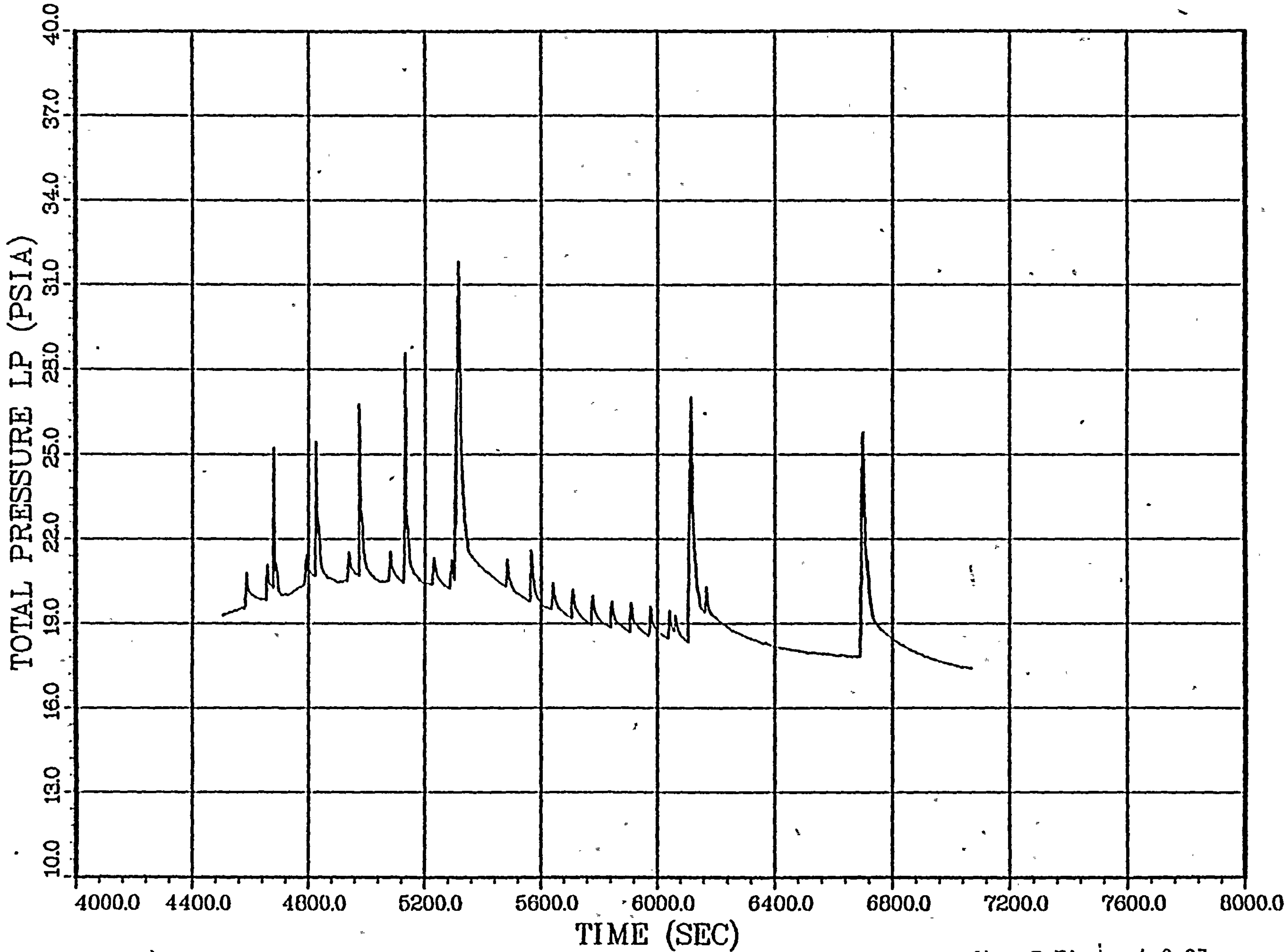
Case E Figure 4.0-25



A.E.P.

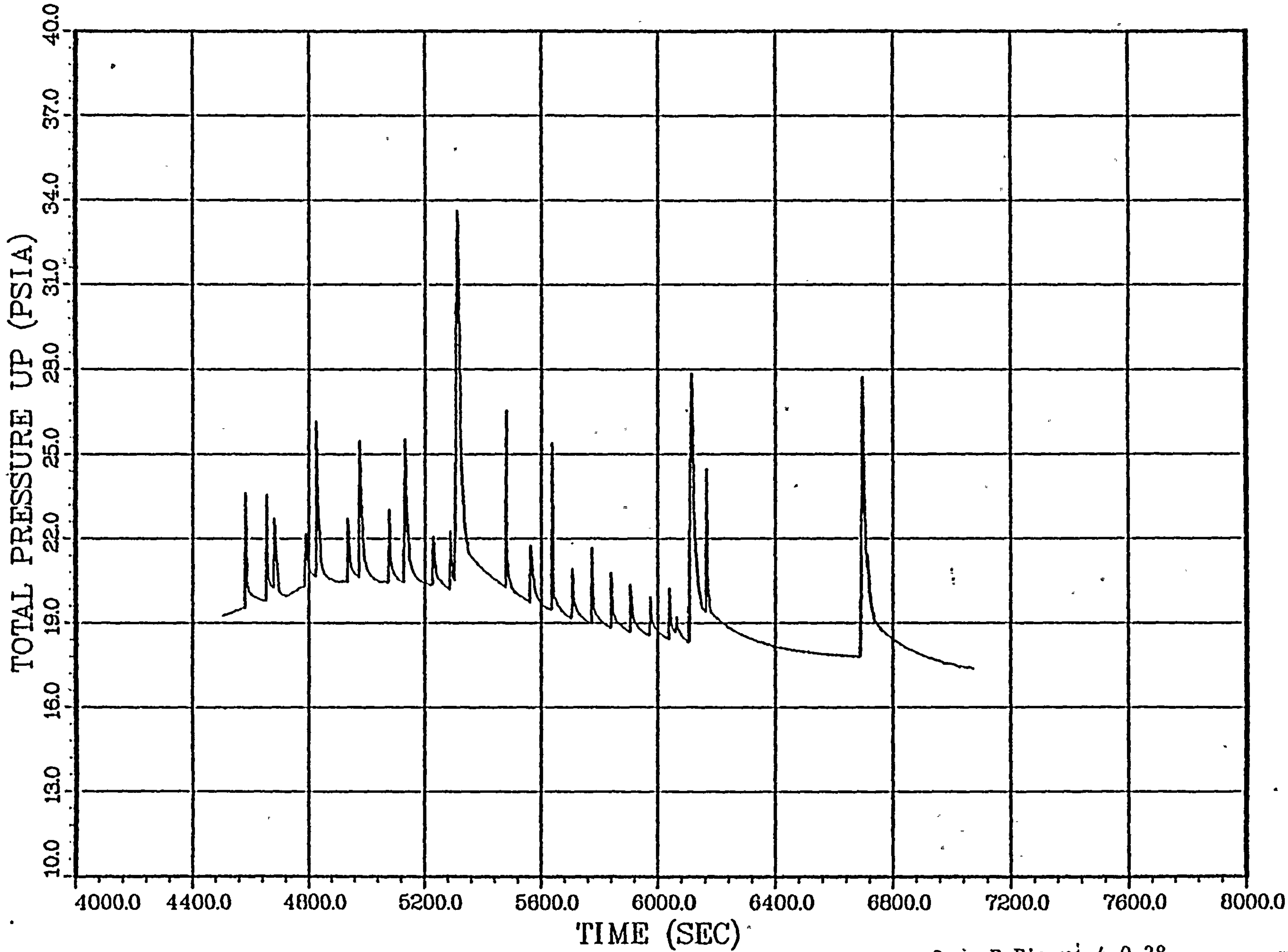
Case E Figure 4.0-26

COOK, 6(, 60(BURN IN UC,DE



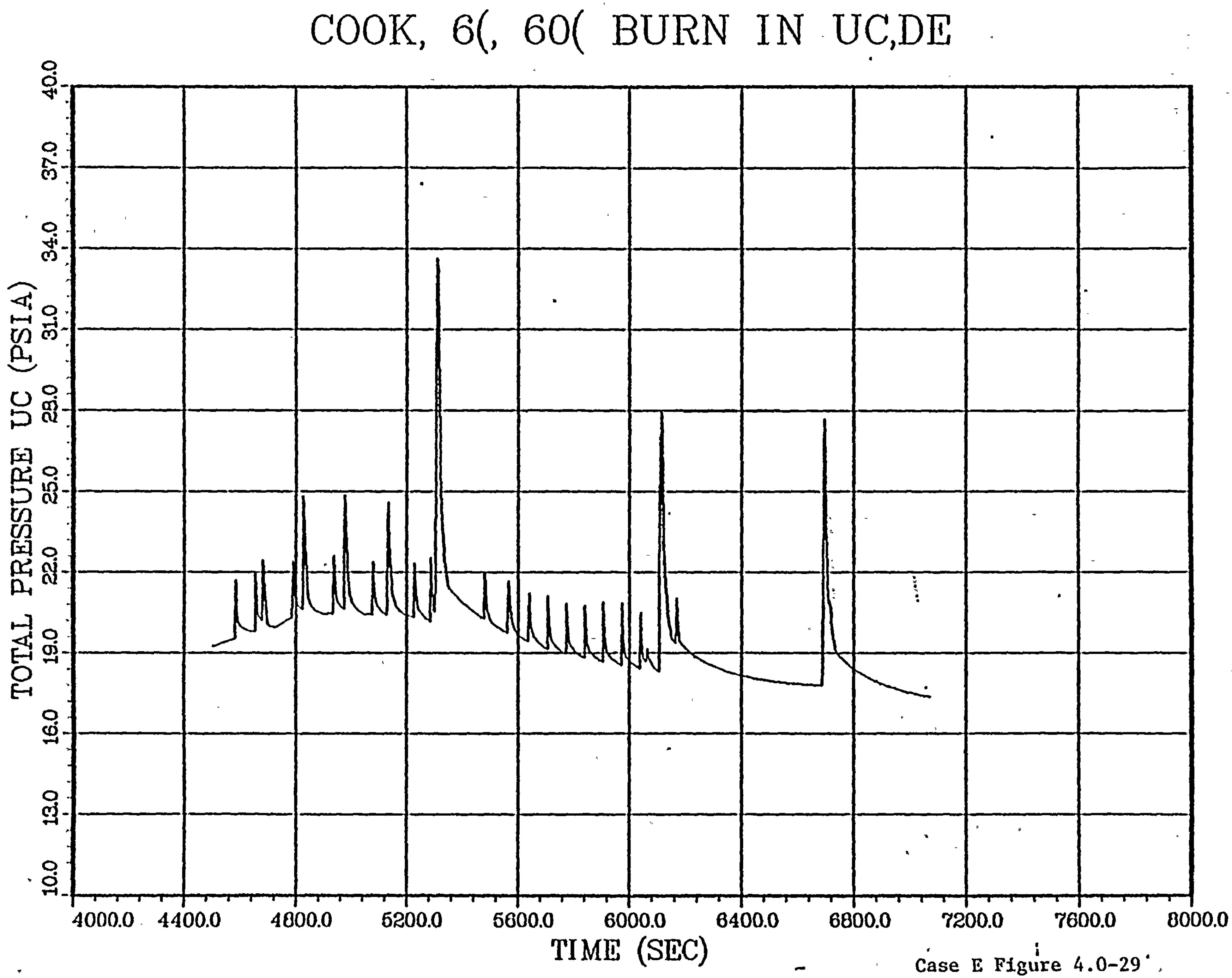
Case E Figure 4.0-27

COOK, 6(, 60(BURN IN UC,DE



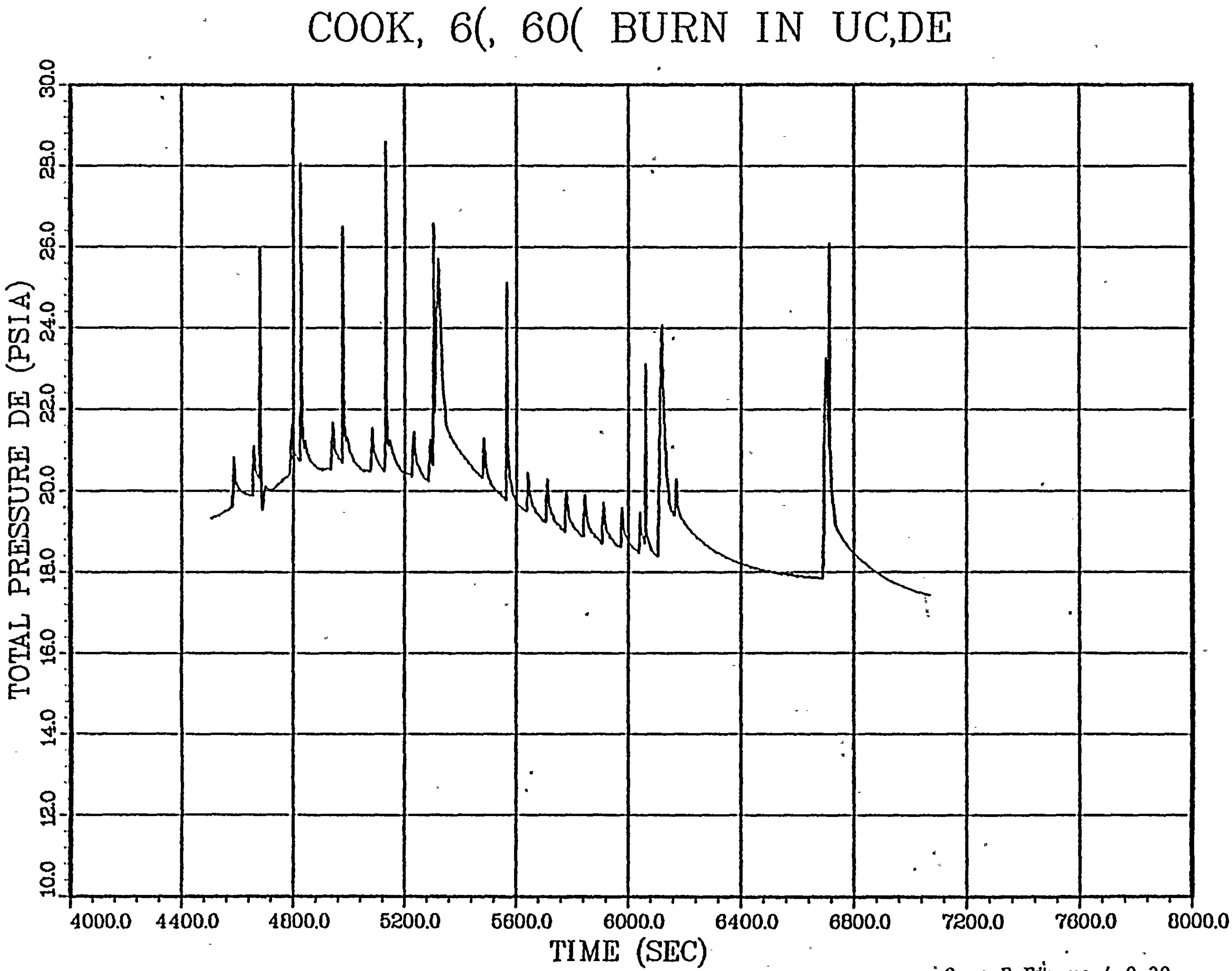
Case E Figure 4.0-28

PLOT 10 ...1.11 FRI 22 JAN, 1982 JOB-ANZRIYH , CYBERNET NOS 1.0 DIS... R 8.2



Case E Figure 4.0-29

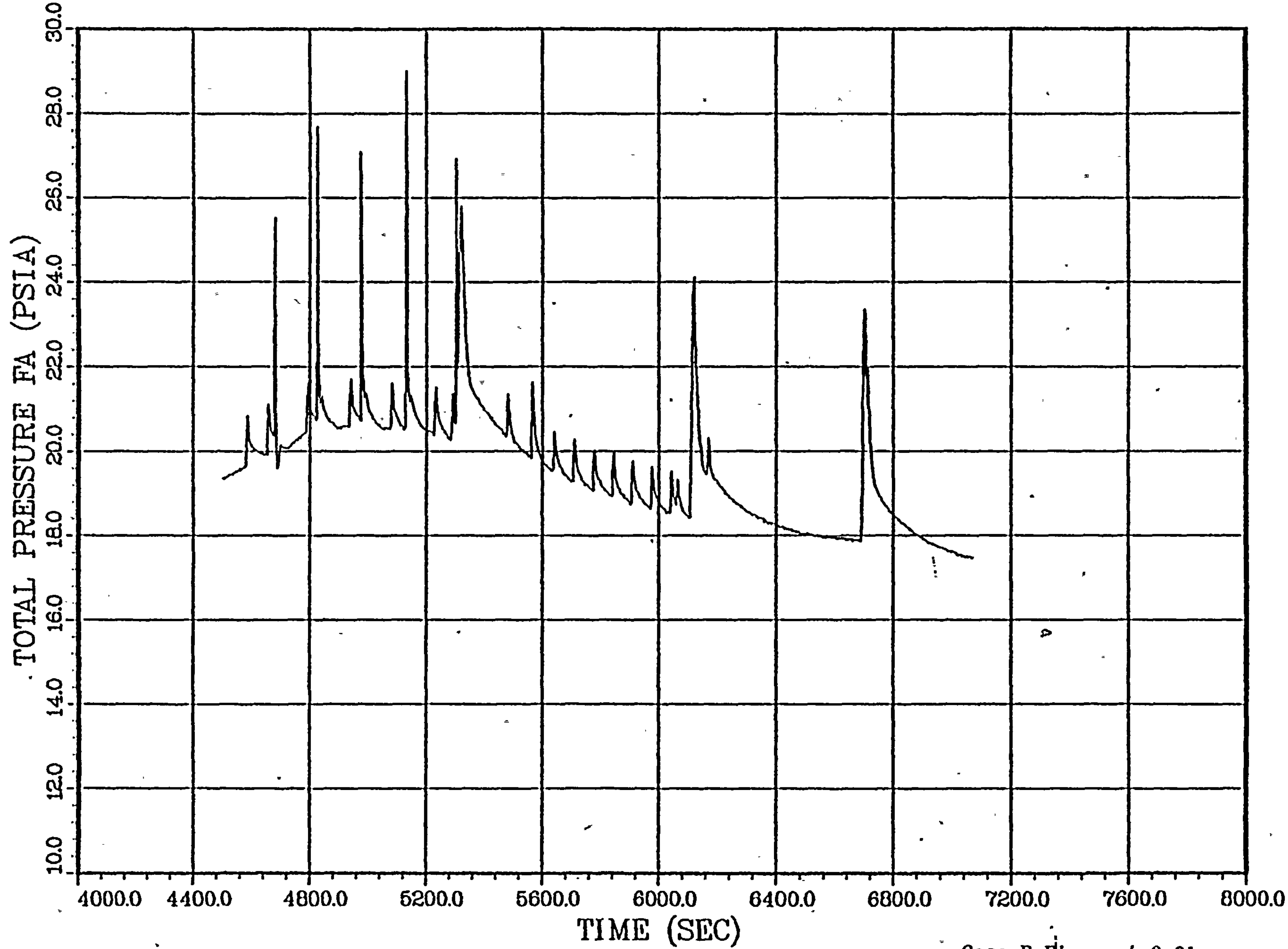
PLOT 11 20 1.15 FRI 22 JAN, 1982 JOB-ANZRIYN , CYBERNET NOS 1.0 DISSP 8.2



Case E Figure 4.0-30

PLOT 12 .41.19 FRI 22 JAN, 1982 JOD-AMZRIYN , CYBERNET NOS 1.0 D VER 8.2

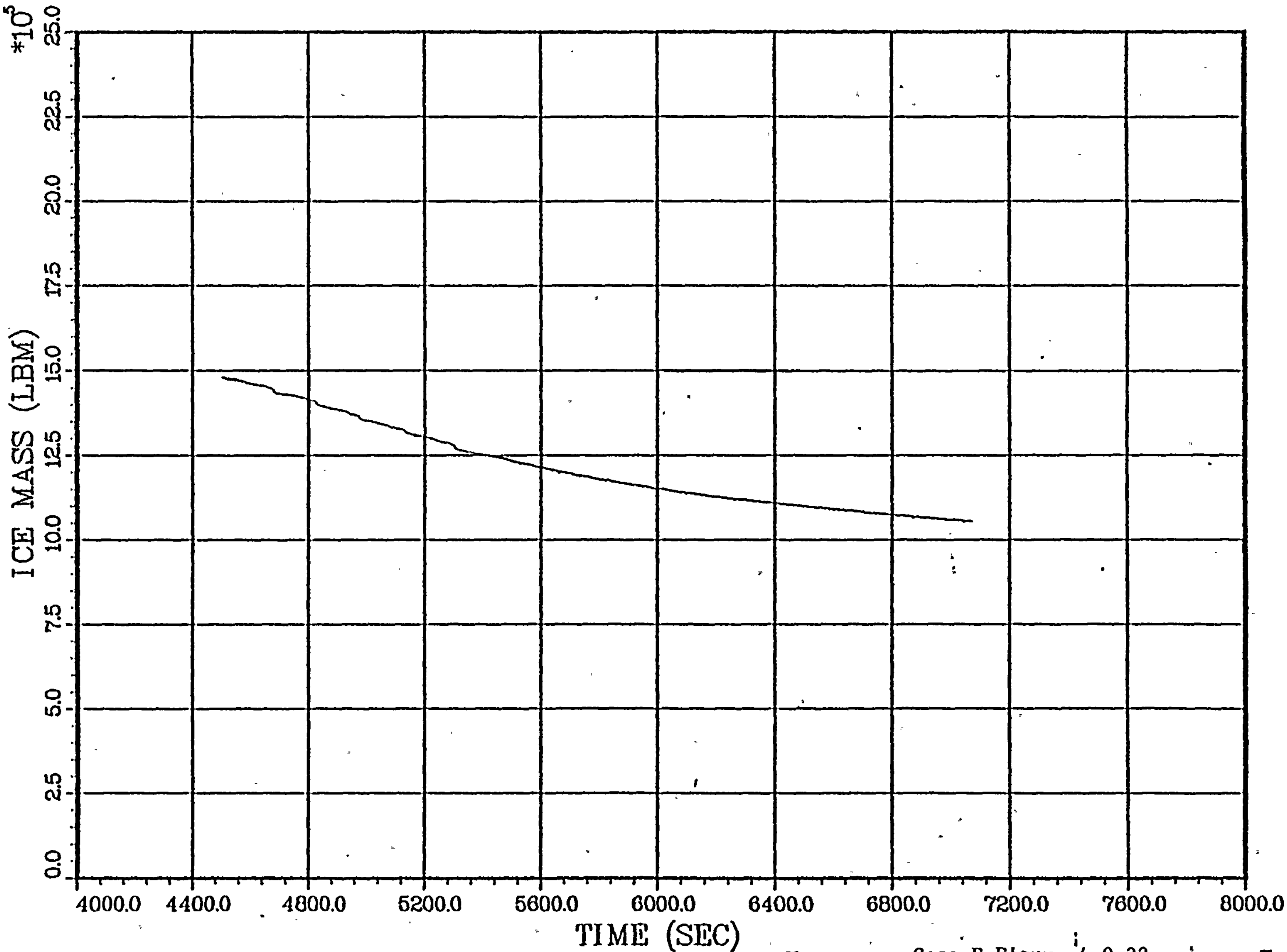
COOK, 6(, 60(BURN IN UC,DE



A.E.P.

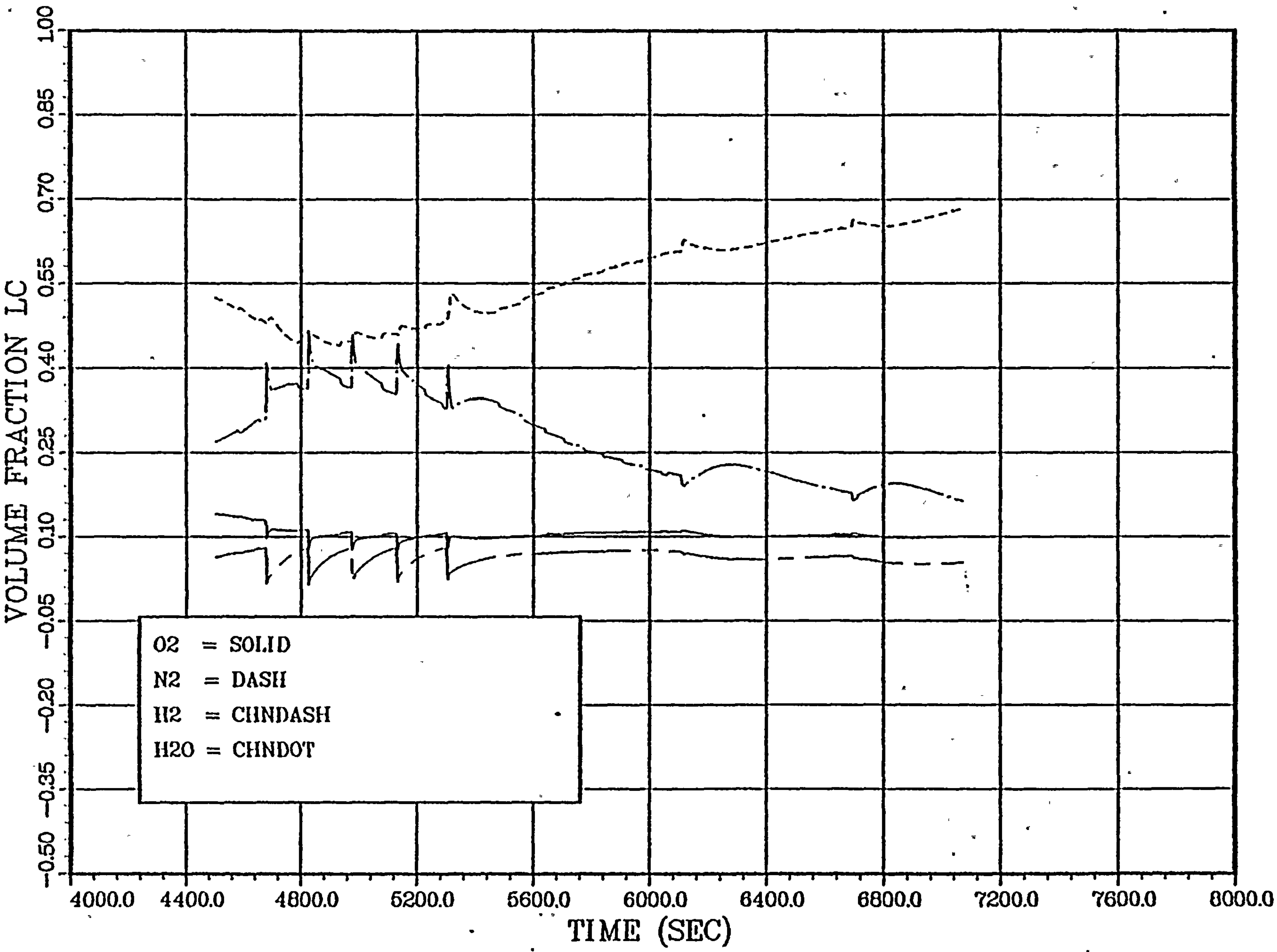
Case E Figure 4.0-31

COOK, 6(, 60(BURN IN UC,DE



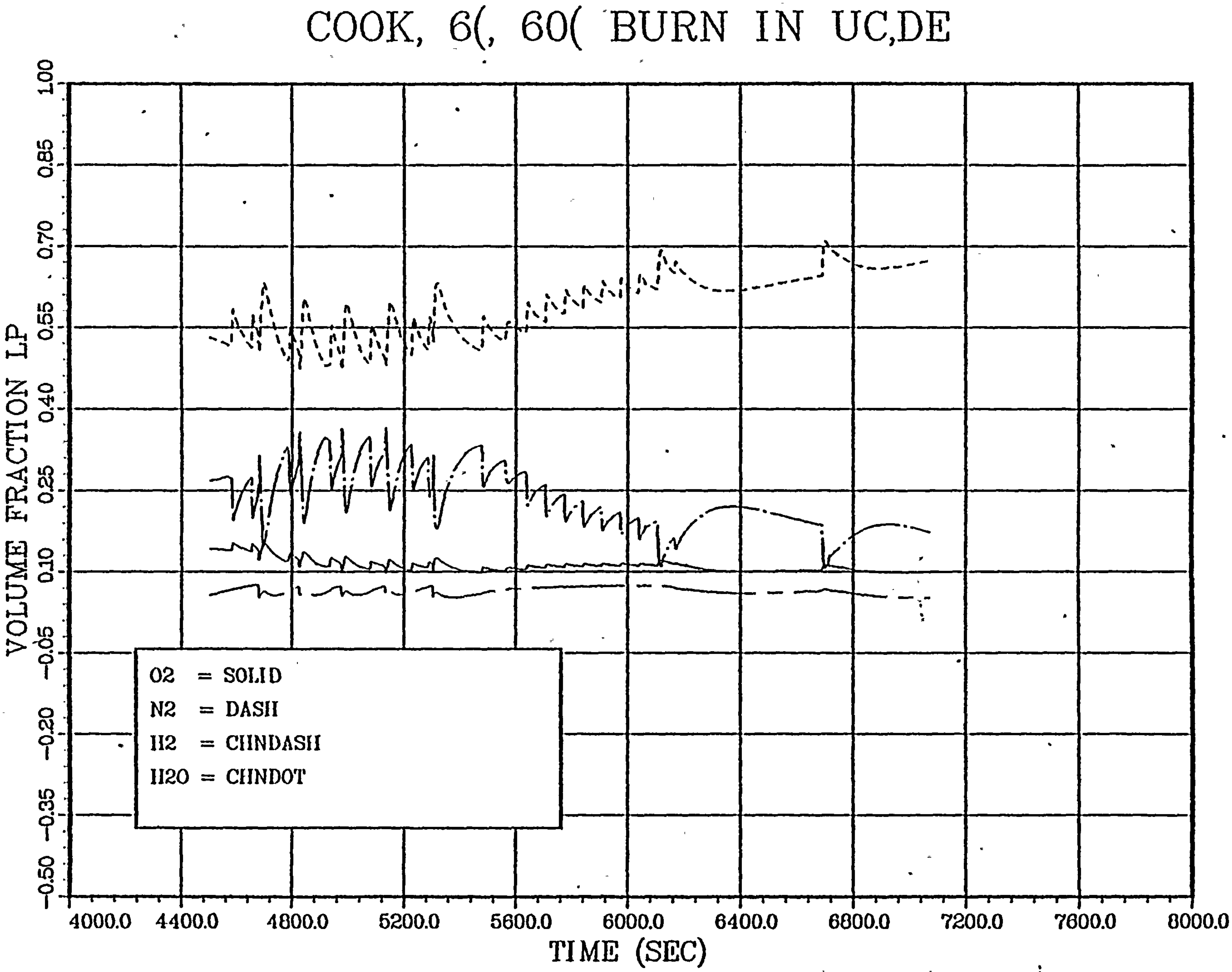
Case E Figure 4.0-32

COOK, 6(, 60(BURN IN UC,DE



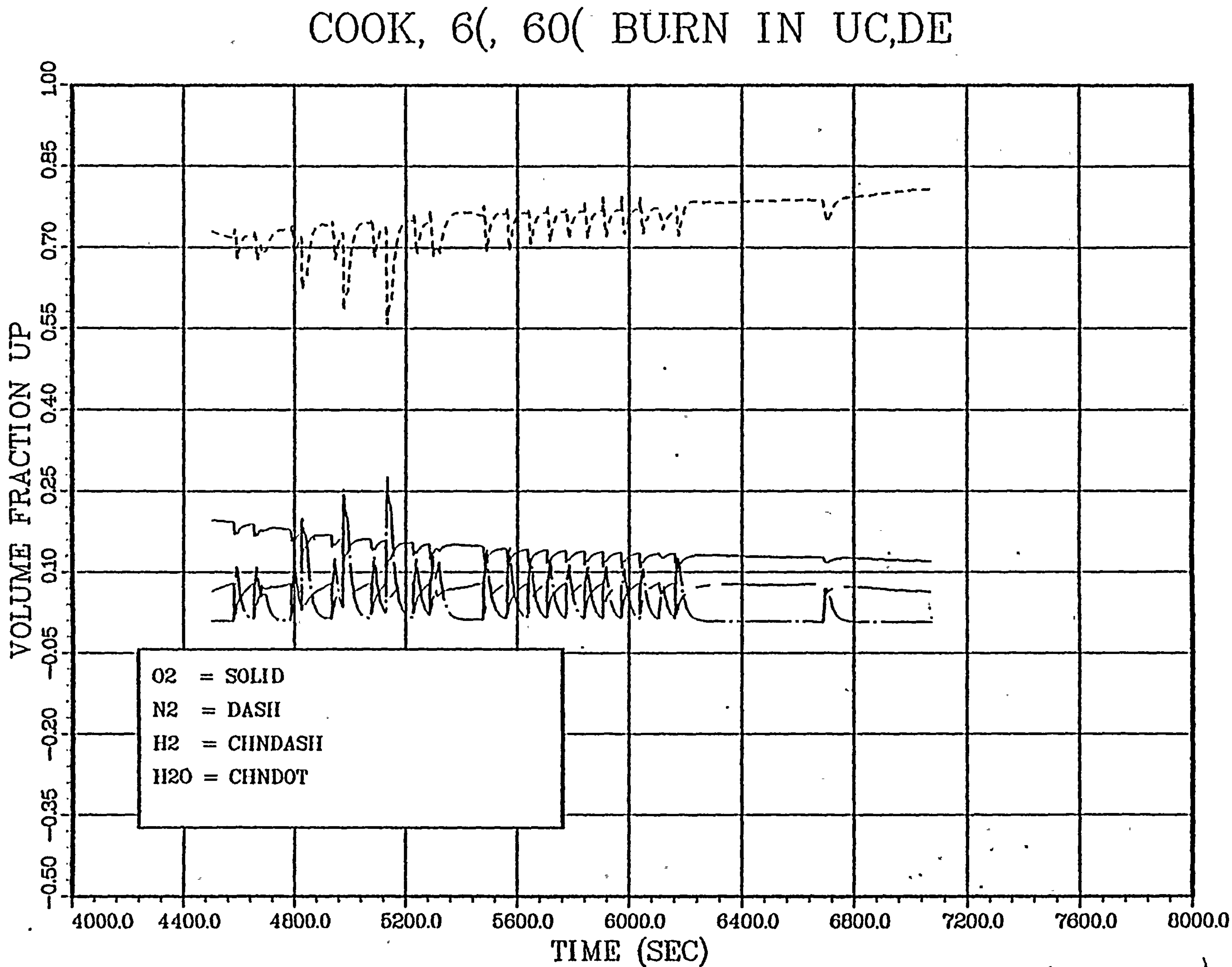
A.E.P.

Case E Figure 4.0-33



A.E.P.

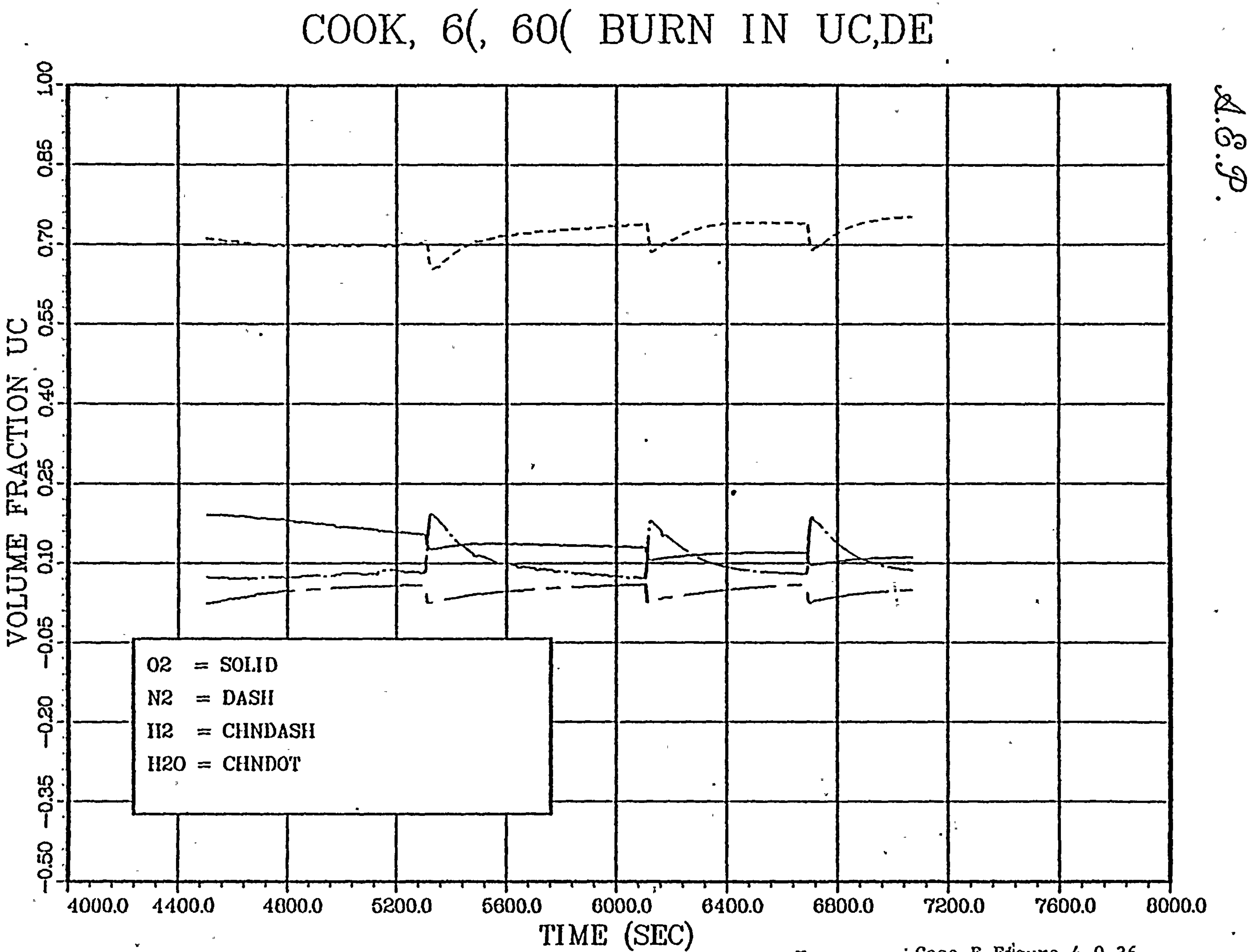
Case E Figure 4.0-34



A.E.P.

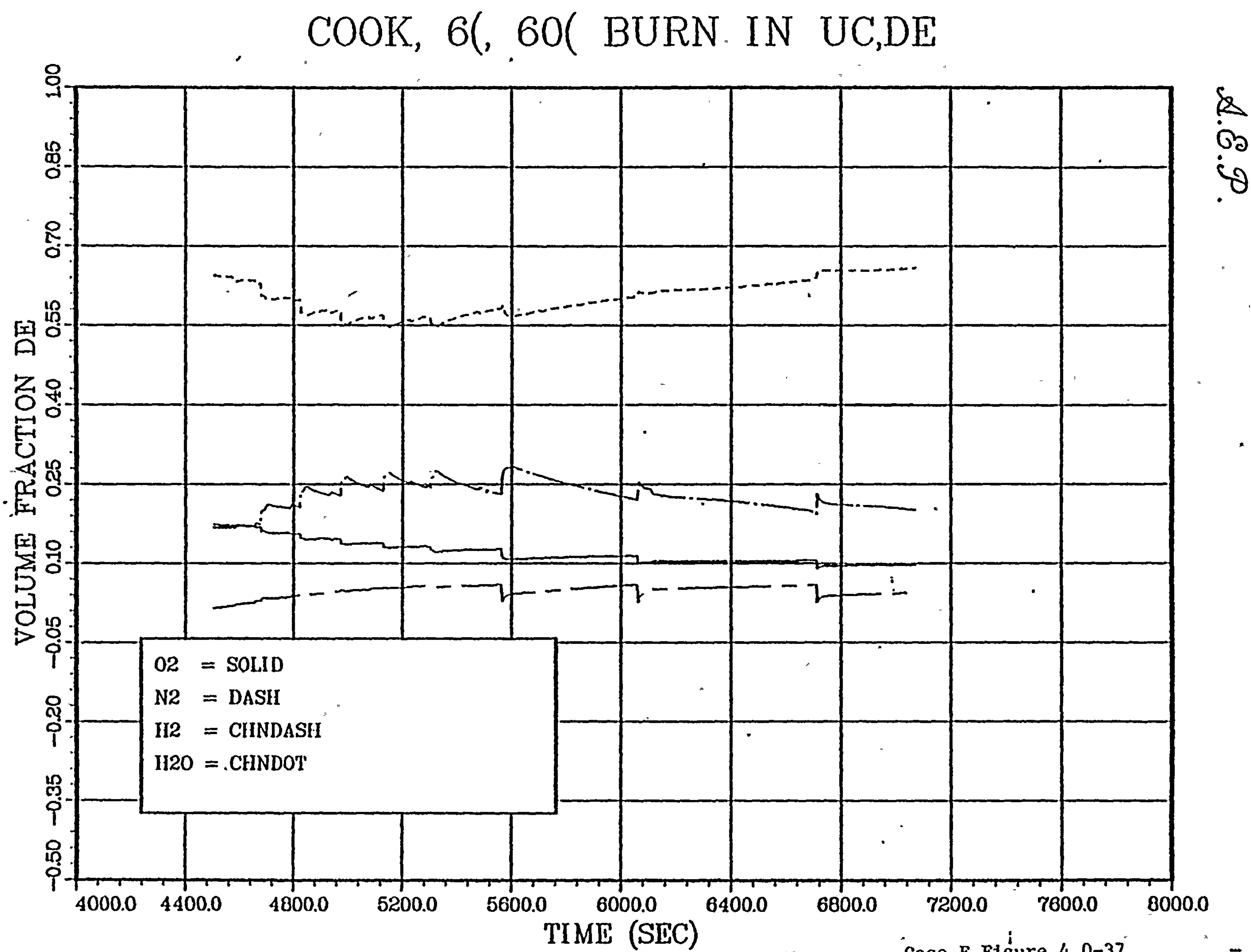
Case E Figure 4.0-35

PLOT 17 20.43.02 FRI 22 JAN, 1982 JOB-ANZRIYN , CYBERNET NOS 1.0 DISS[redacted]VER 8.2

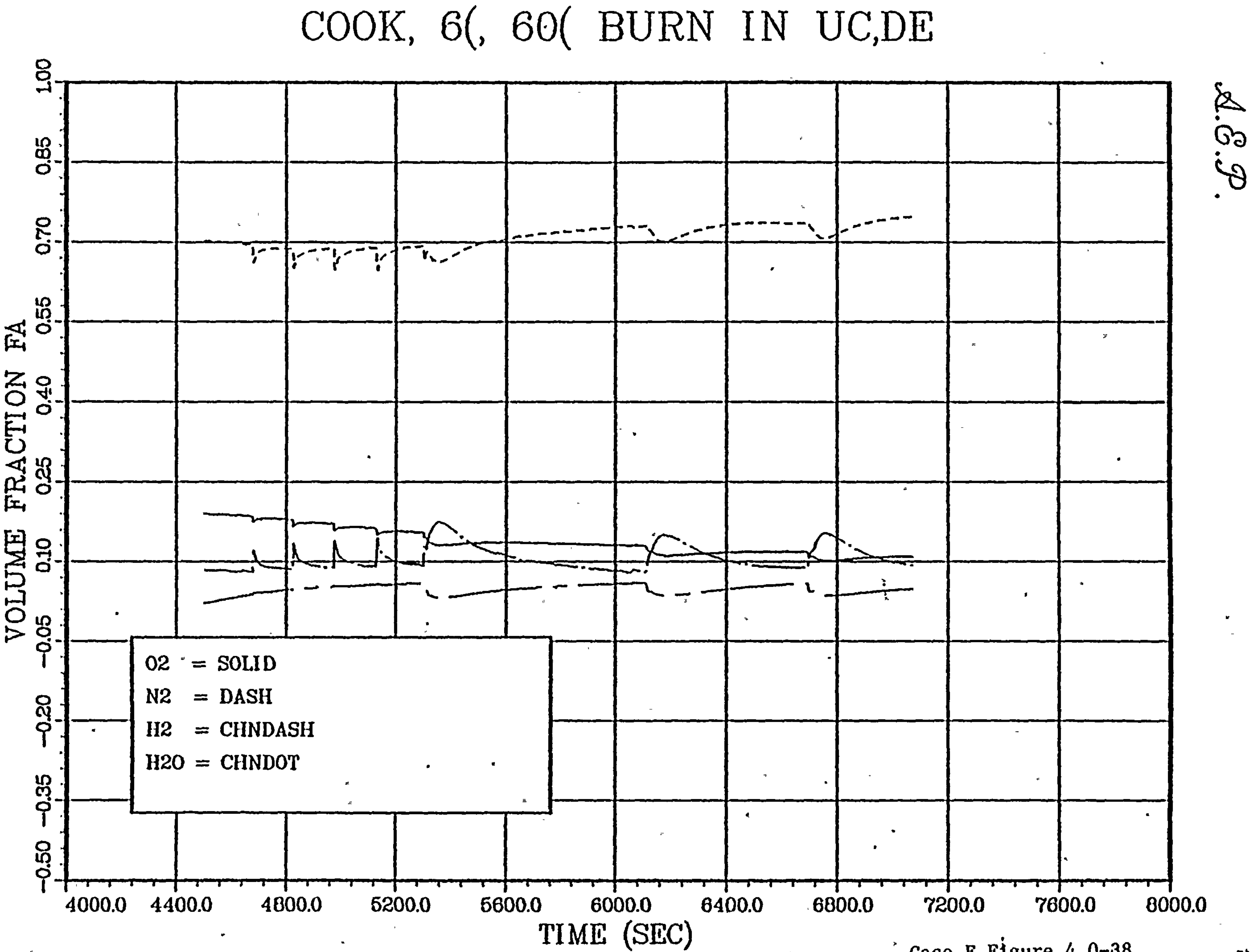


Case E Figure 4.0-36

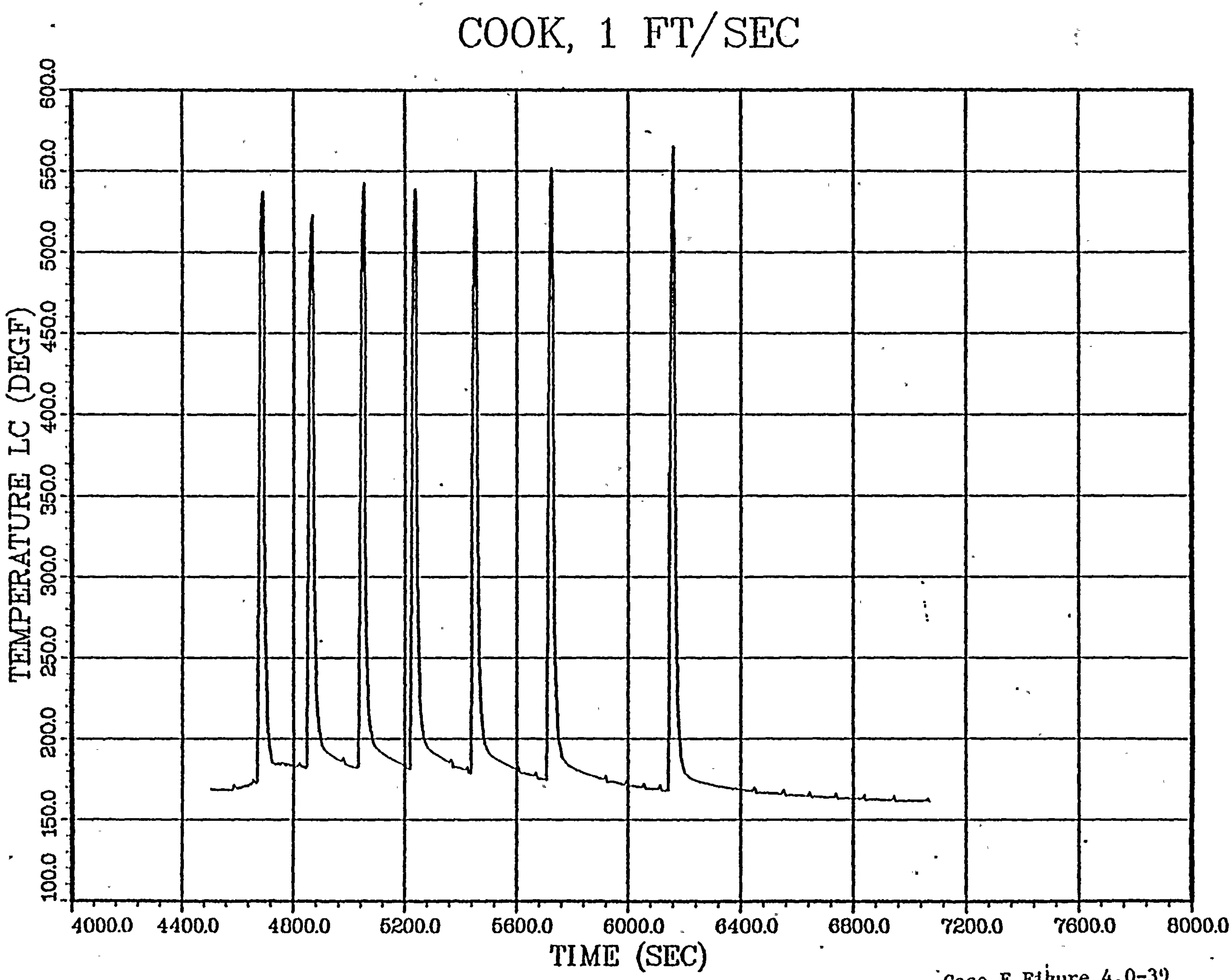
PLOT 18 ... 0.43.09 FRI 22 JAN, 1902 JOB-ANZRIYN , CYBERNET NOS 1.0 DI... VER 8.2



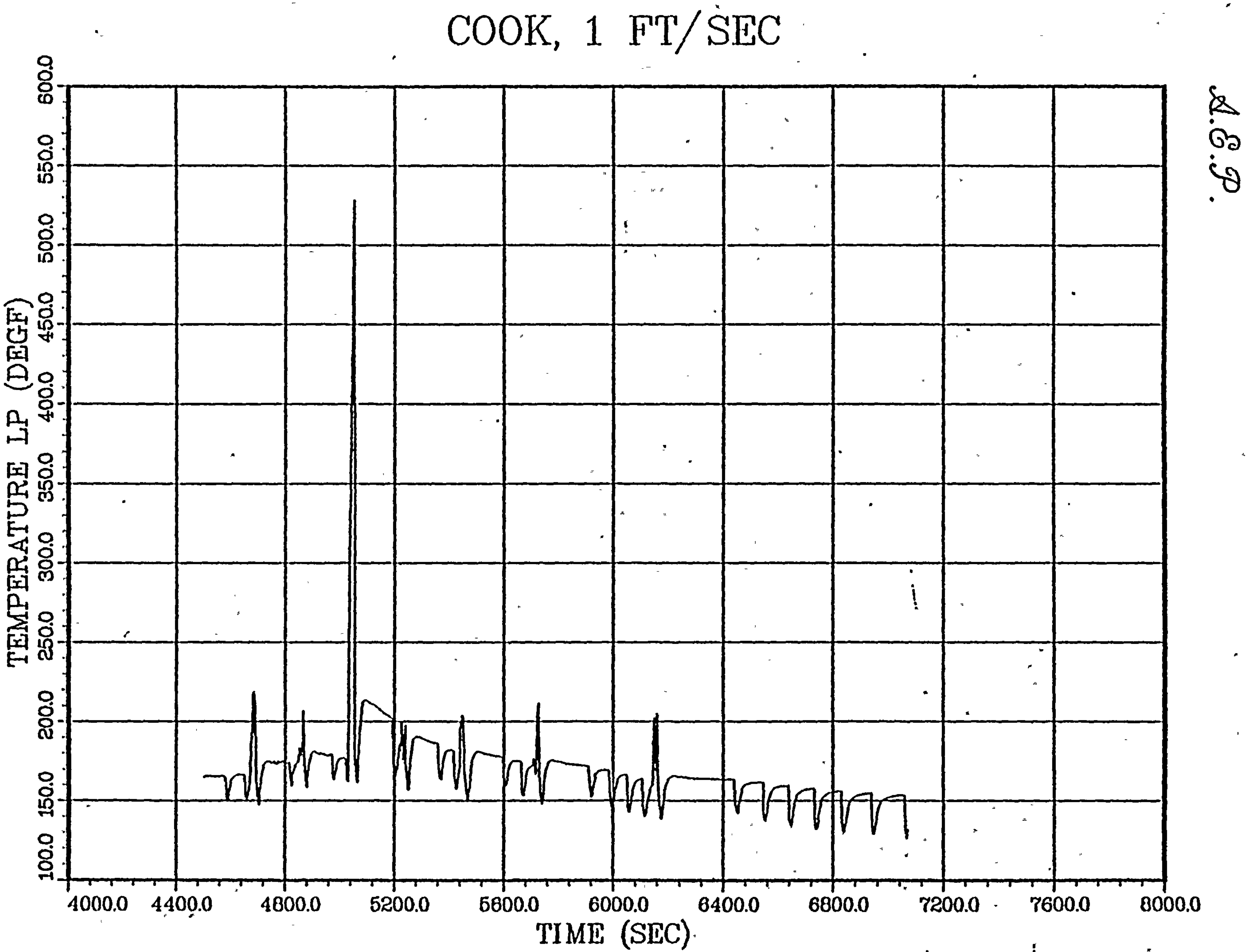
Case E Figure 4.0-37



Case E Figure 4.0-38

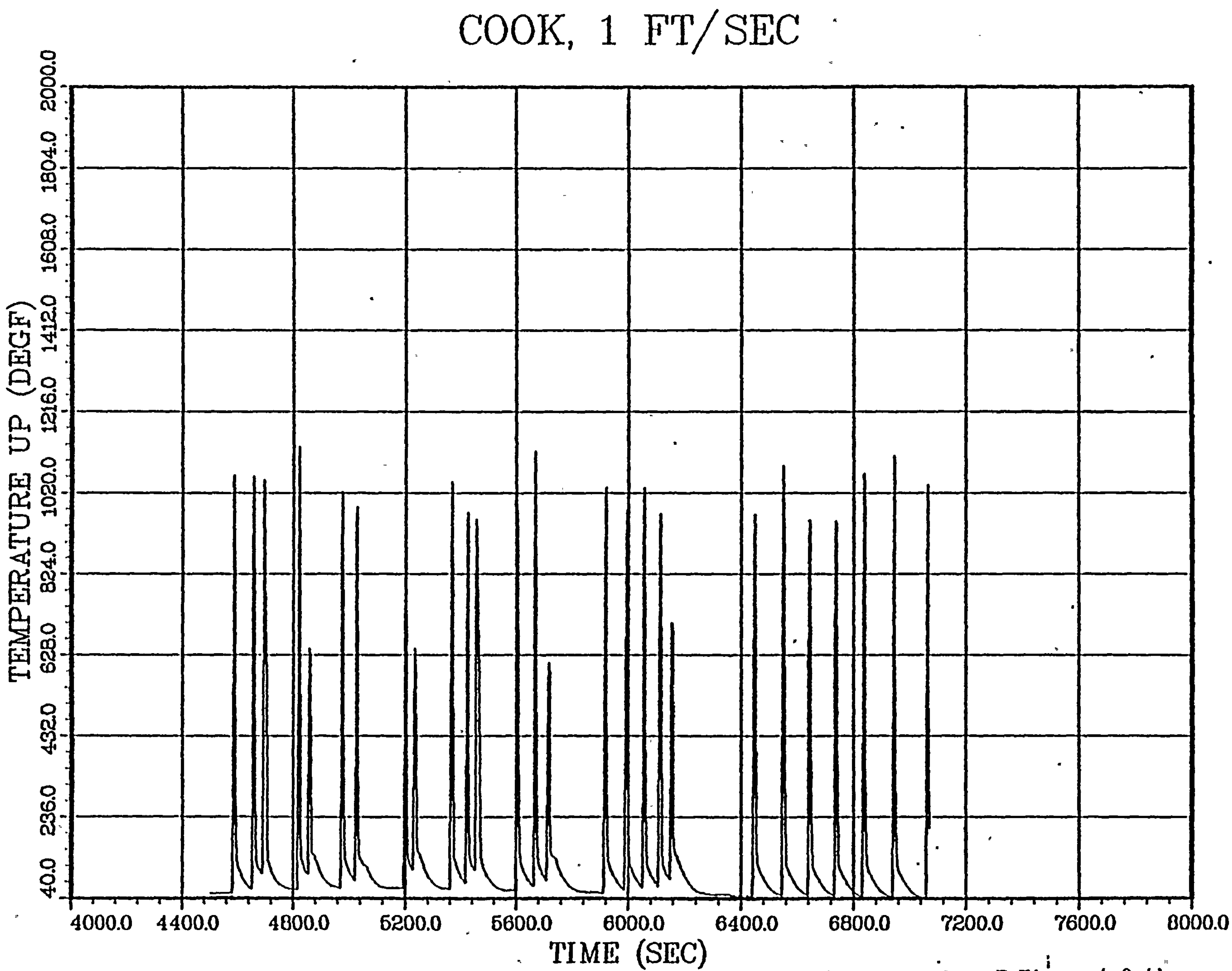


Case F Figure 4.0-39



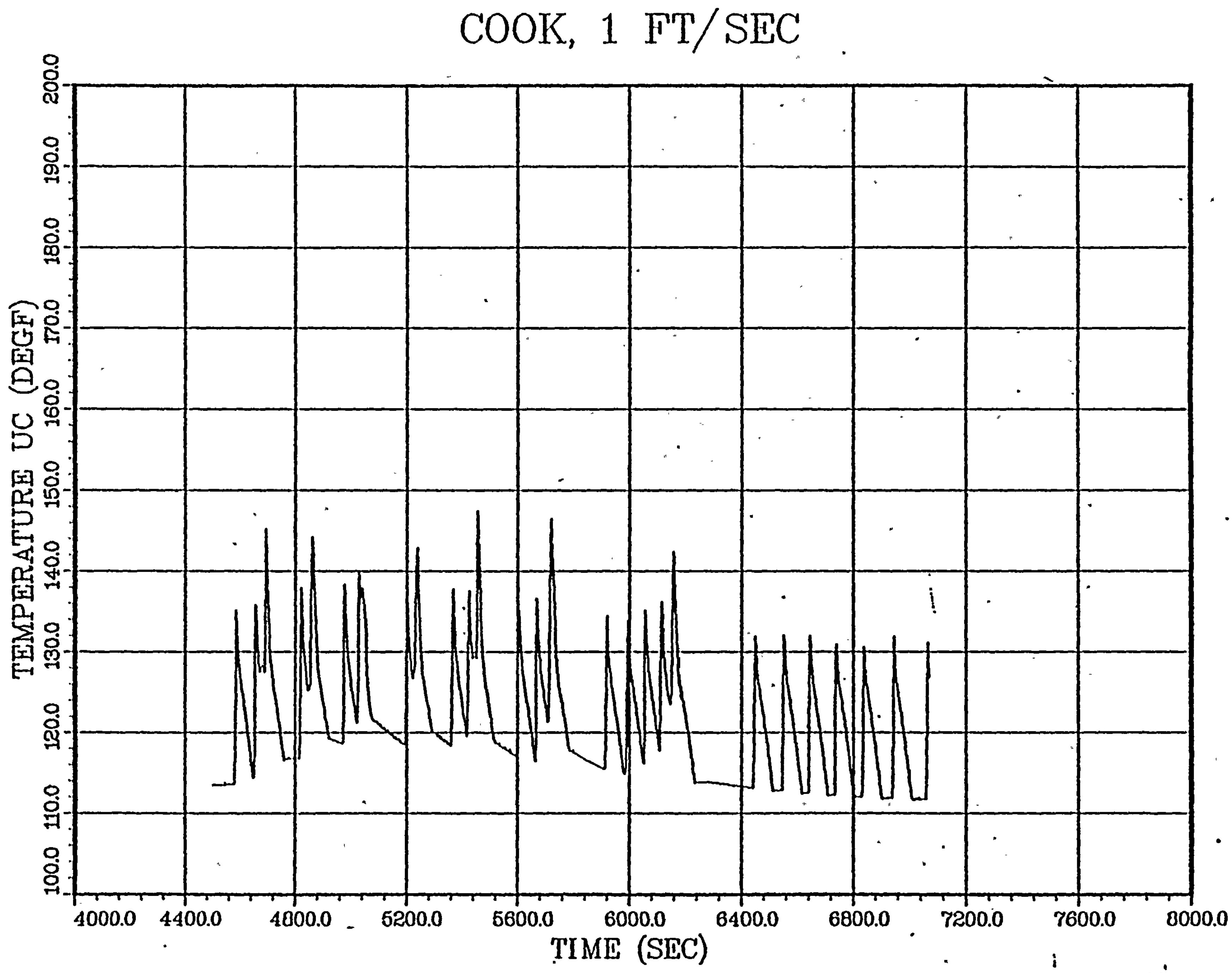
Case F Figure 4.0-40

PLOT 3 20[illegible]4.32 FRI 22 JAN, 1982 JOB-ANZRIHT , CYBERNET NOS 1.0 DISS[illegible] 8.2



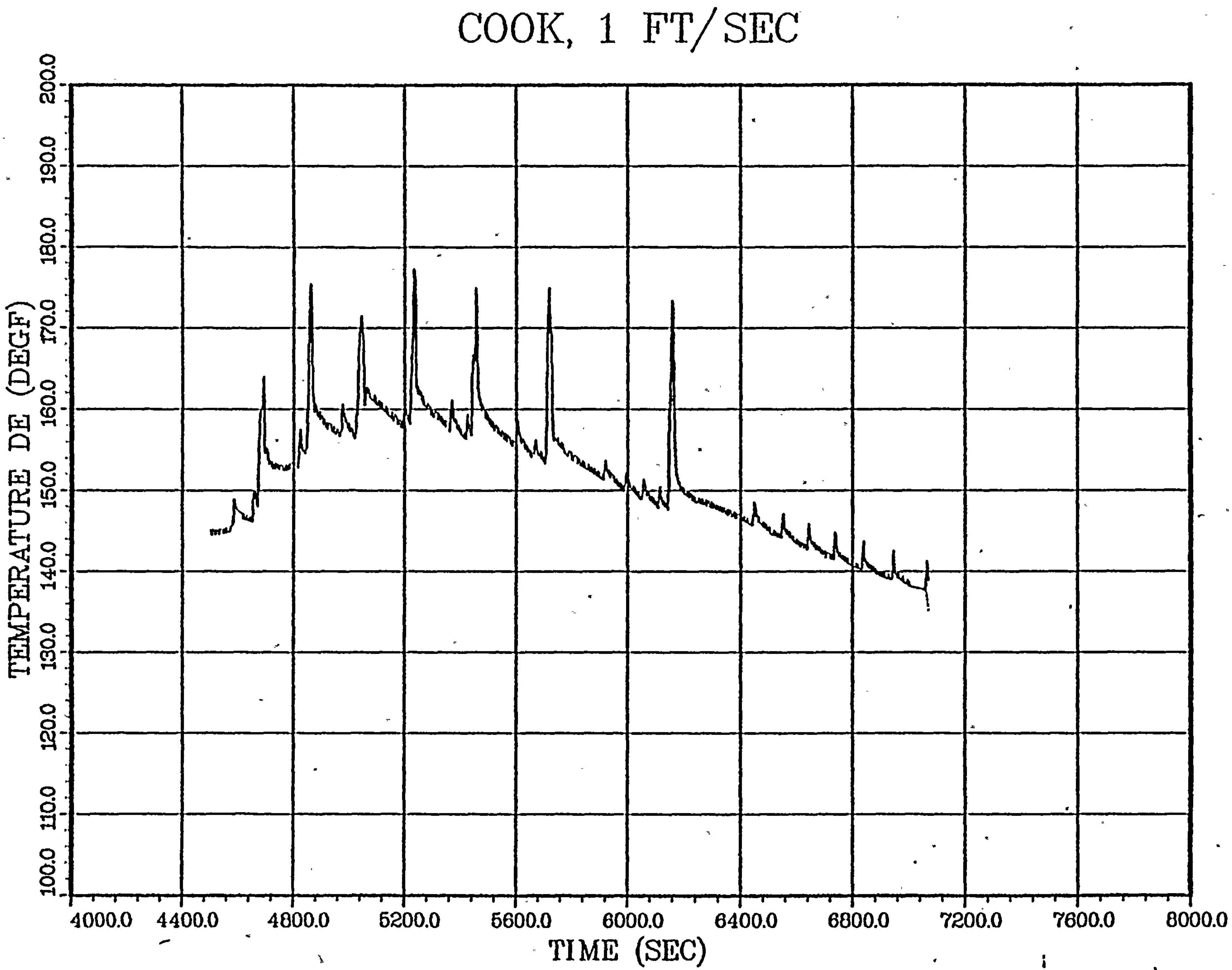
A.E.P.

Case F Figure 4.0-41,

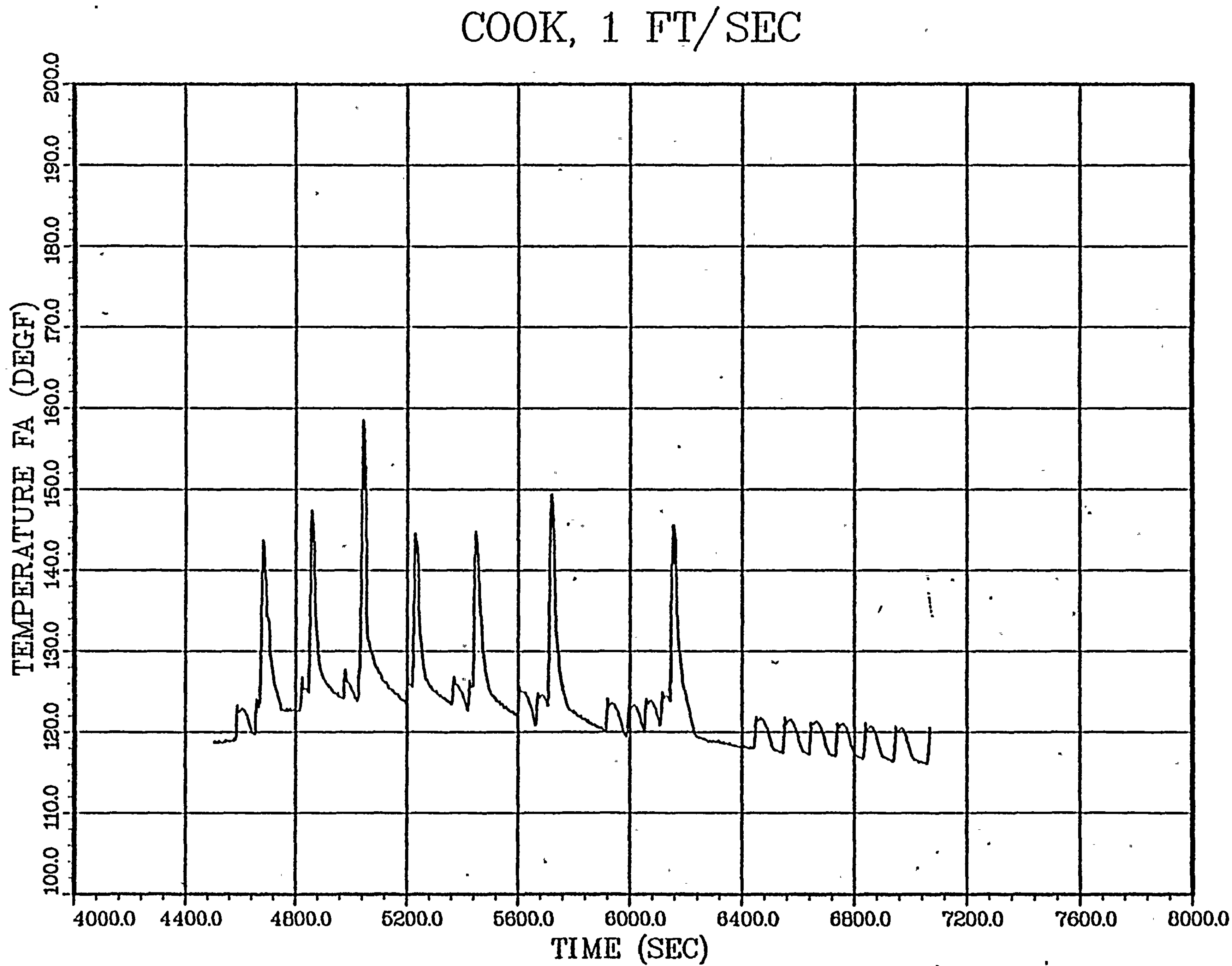


Case F Figure 4.0-42

PLOT 5 20 .39 FRI 22 JAN, 1982 JOB-ANZRIHT , CYBERNET NOS 1.0 DISSP 8.2

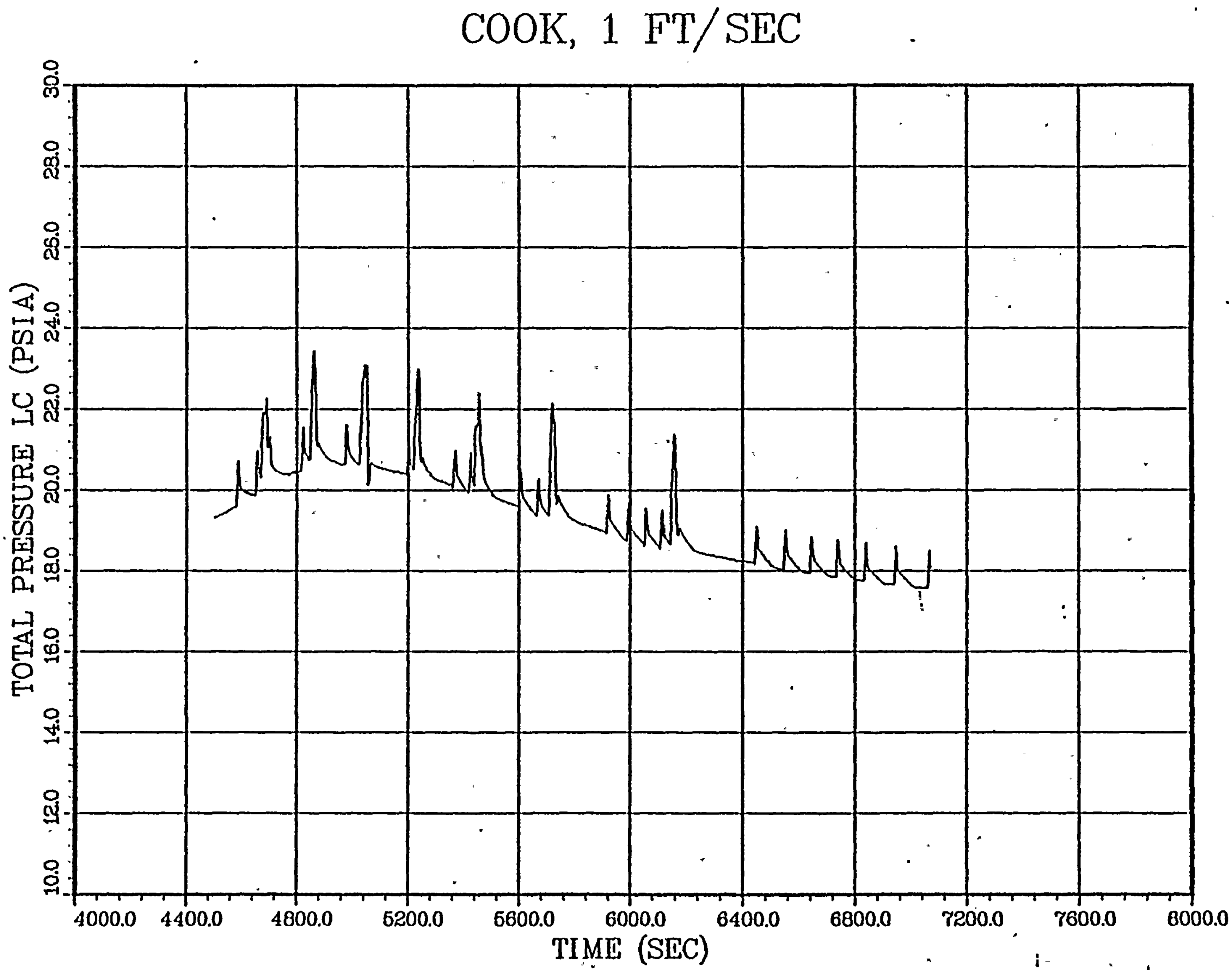


Case F Figure 4.0-43.



Case F Figure 4.0-44

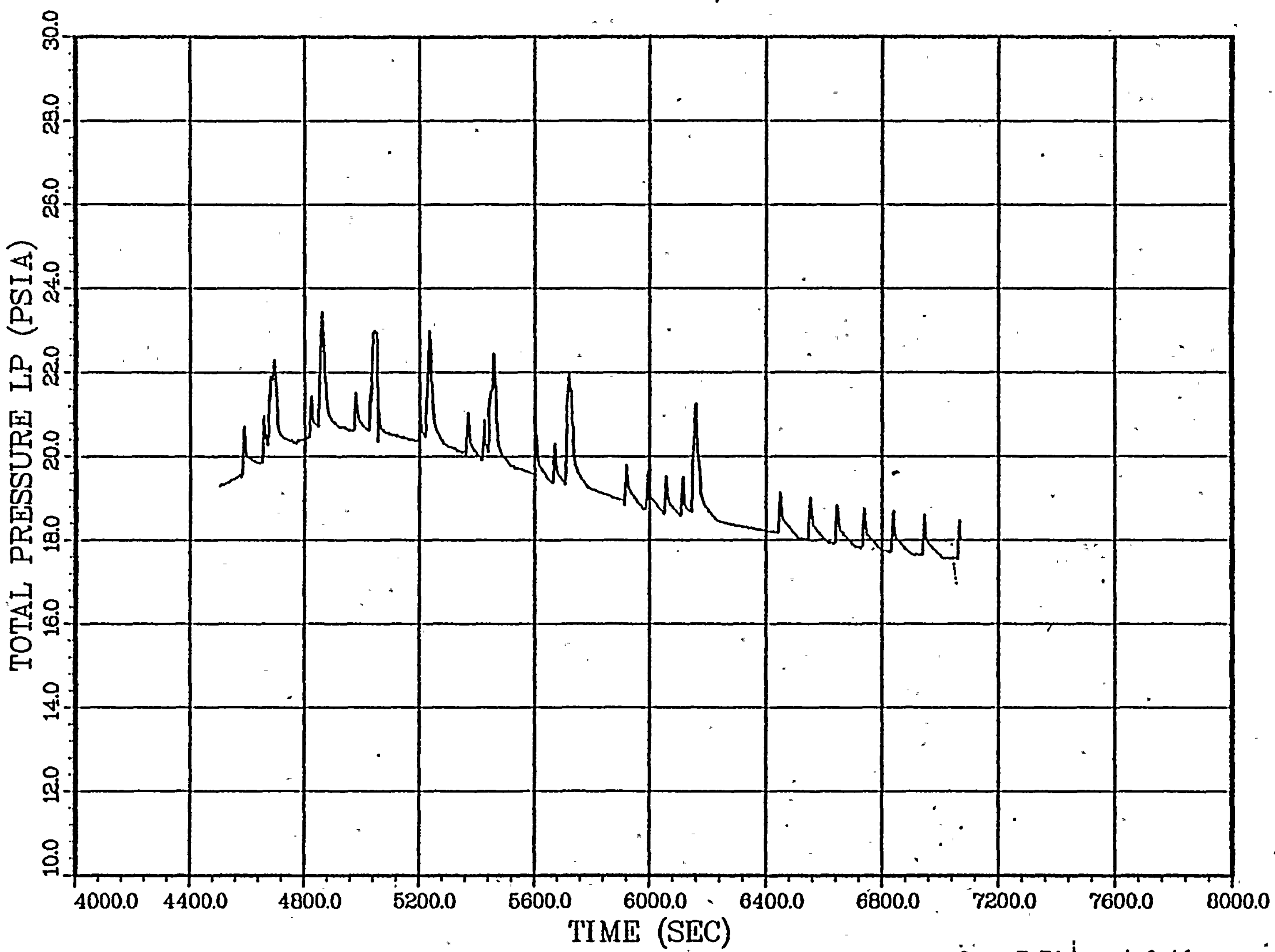
PLOT 7 ...4.46 FRI 22 JAN, 1982 JOB-ANZRINT , CYBERNET NOS 1.0 DISS... 8.2



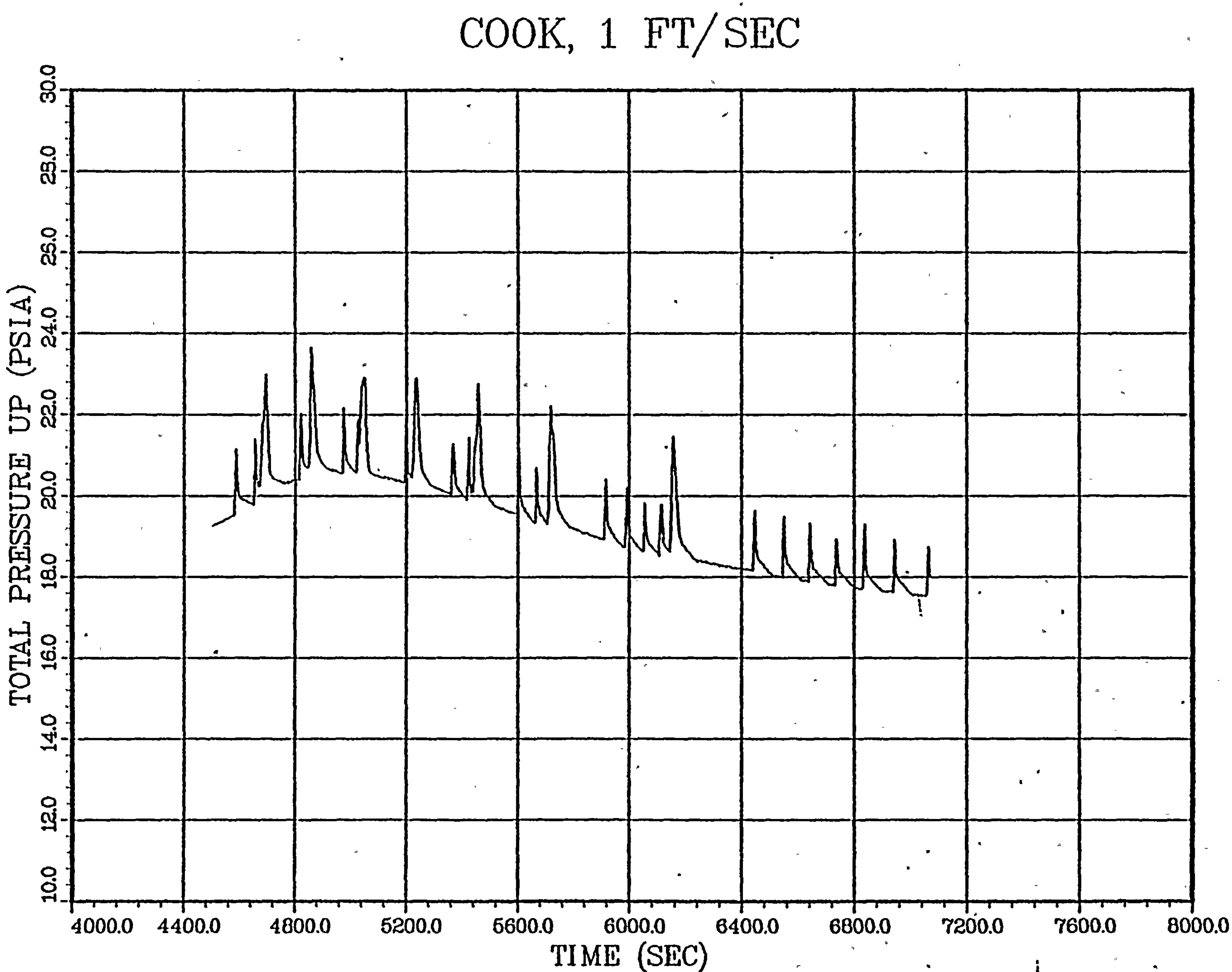
Case F Figure 4.0-45.

PLOT 8 50 FRI 22 JAN, 1982 JOB-ANZRINT , CYBERNET NOS 1.0 DISSP 8.2

COOK, 1 FT/SEC

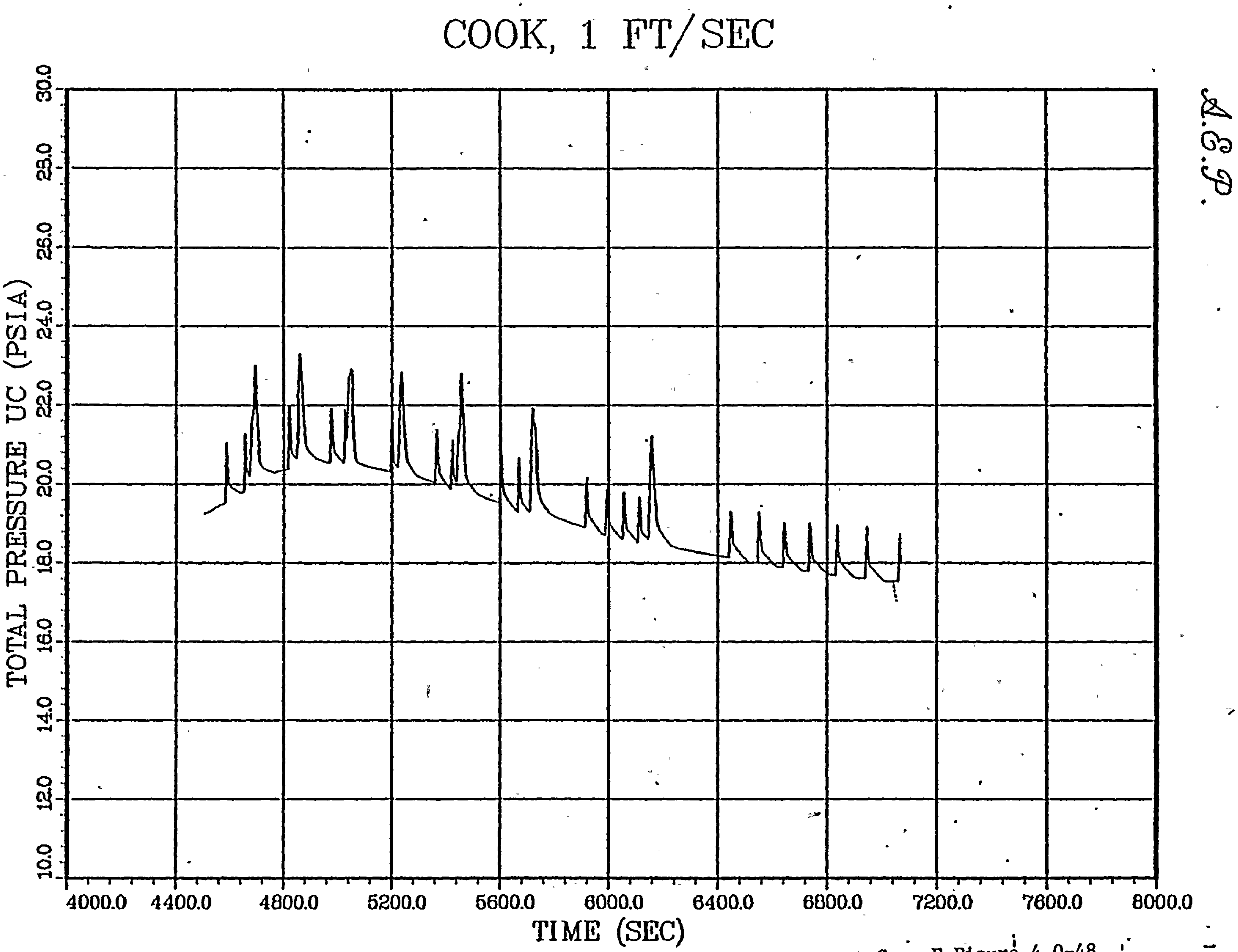


Case F Figure 4.0-46



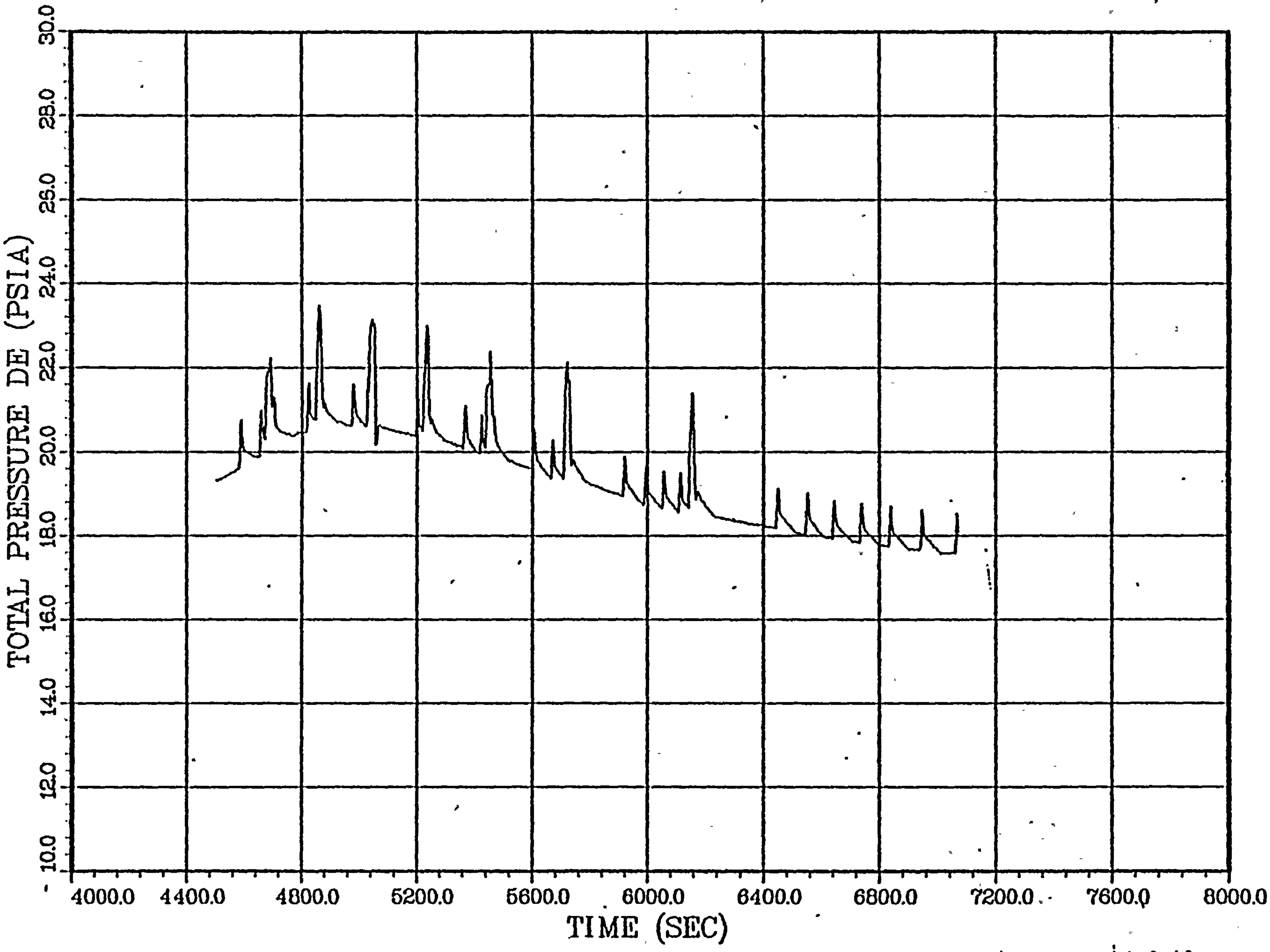
A.E.P.

Case F Figure 4.0-47



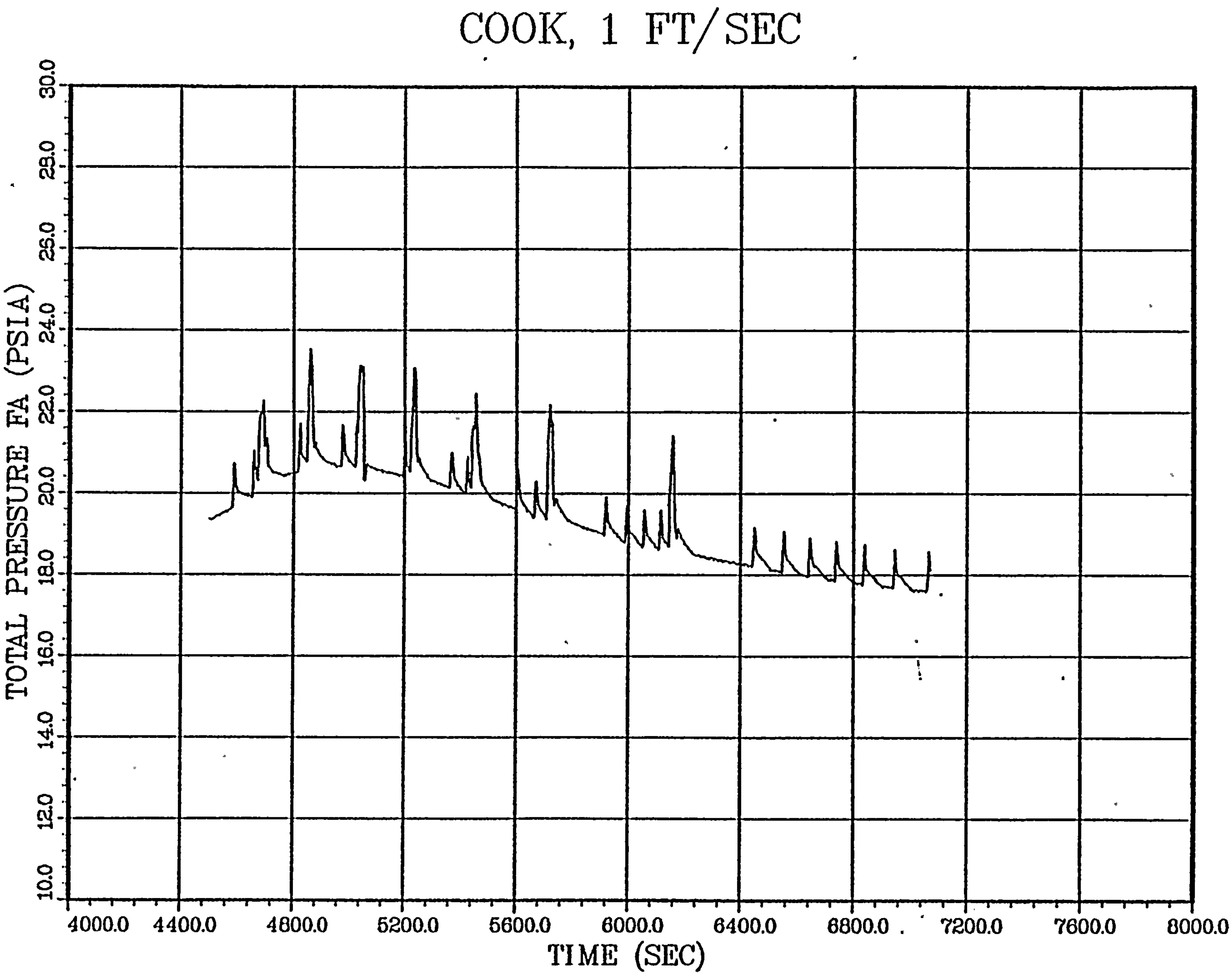
Case F Figure 4.0-48

COOK, 1 FT/SEC

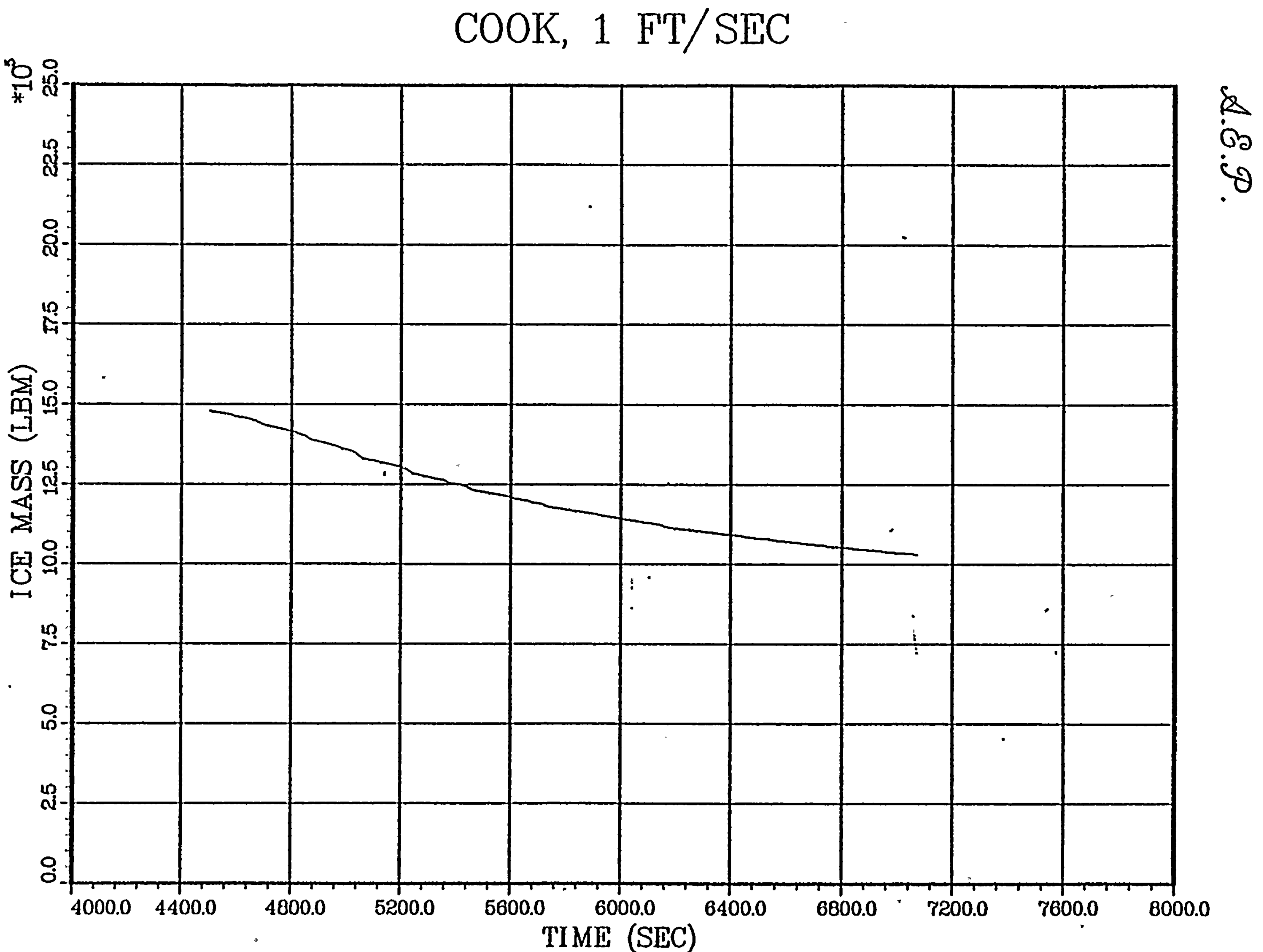


A.C.P.

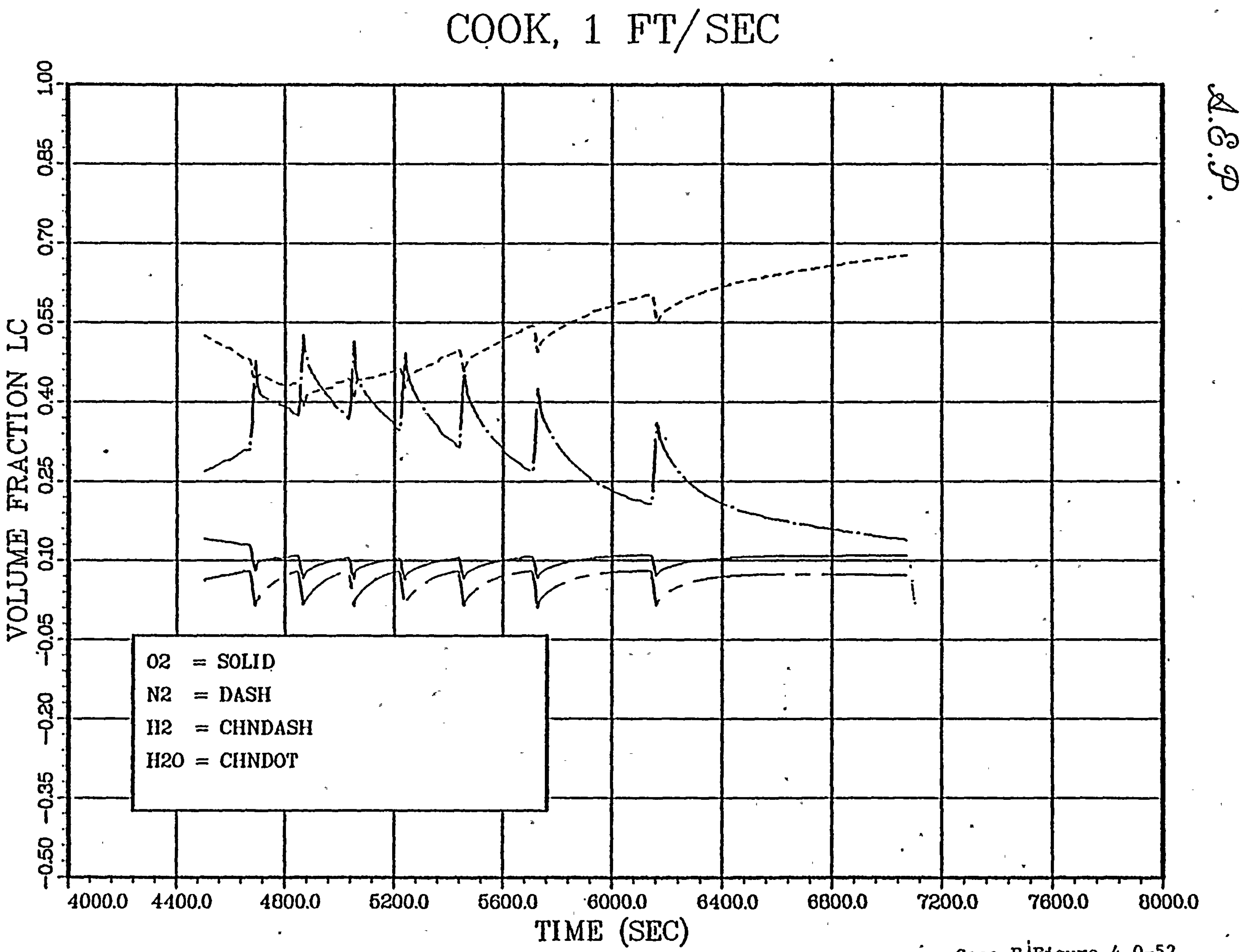
Case F Figure 4.0-49



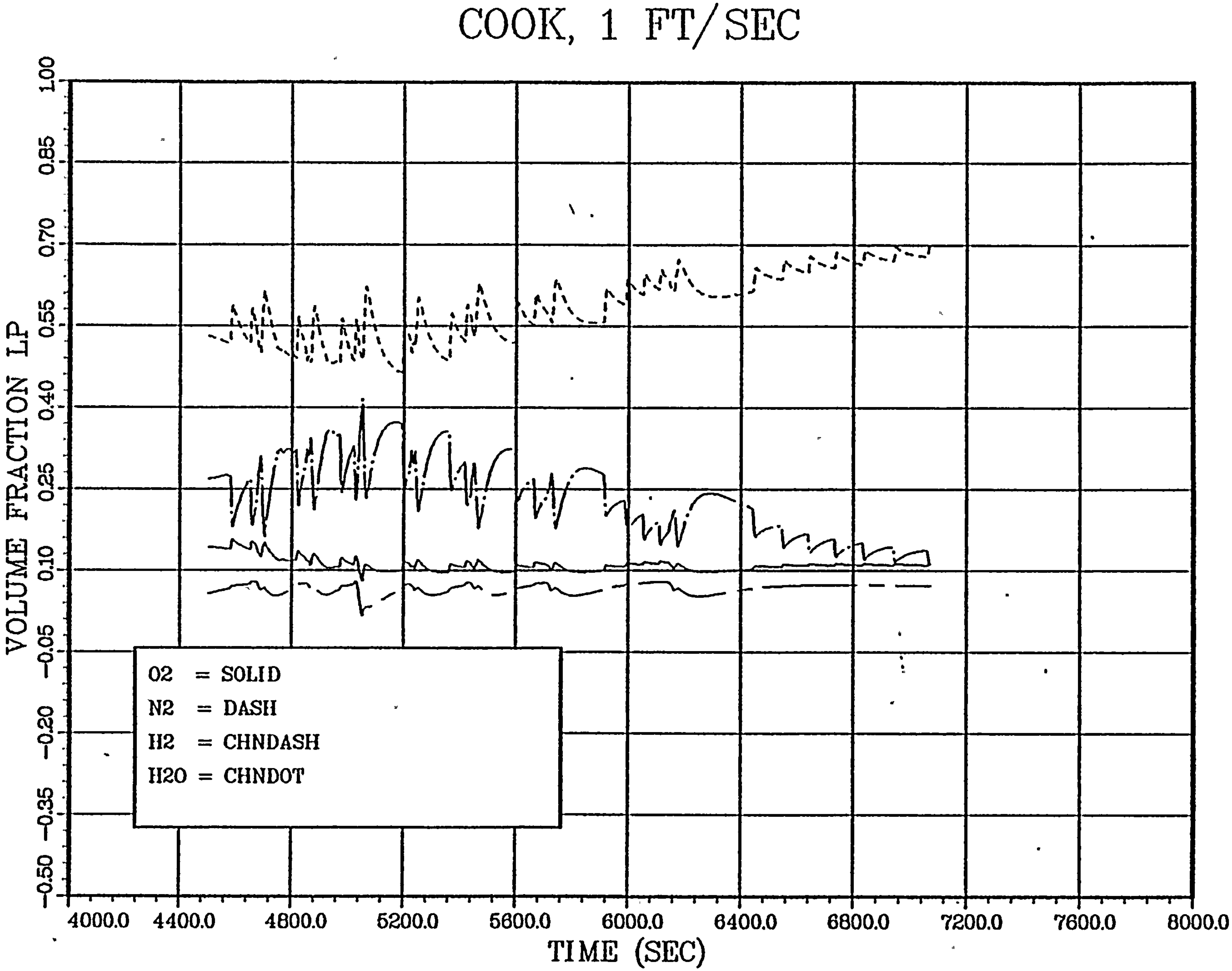
Case F Figure 4.0-50



Case F Figure 4.0-51

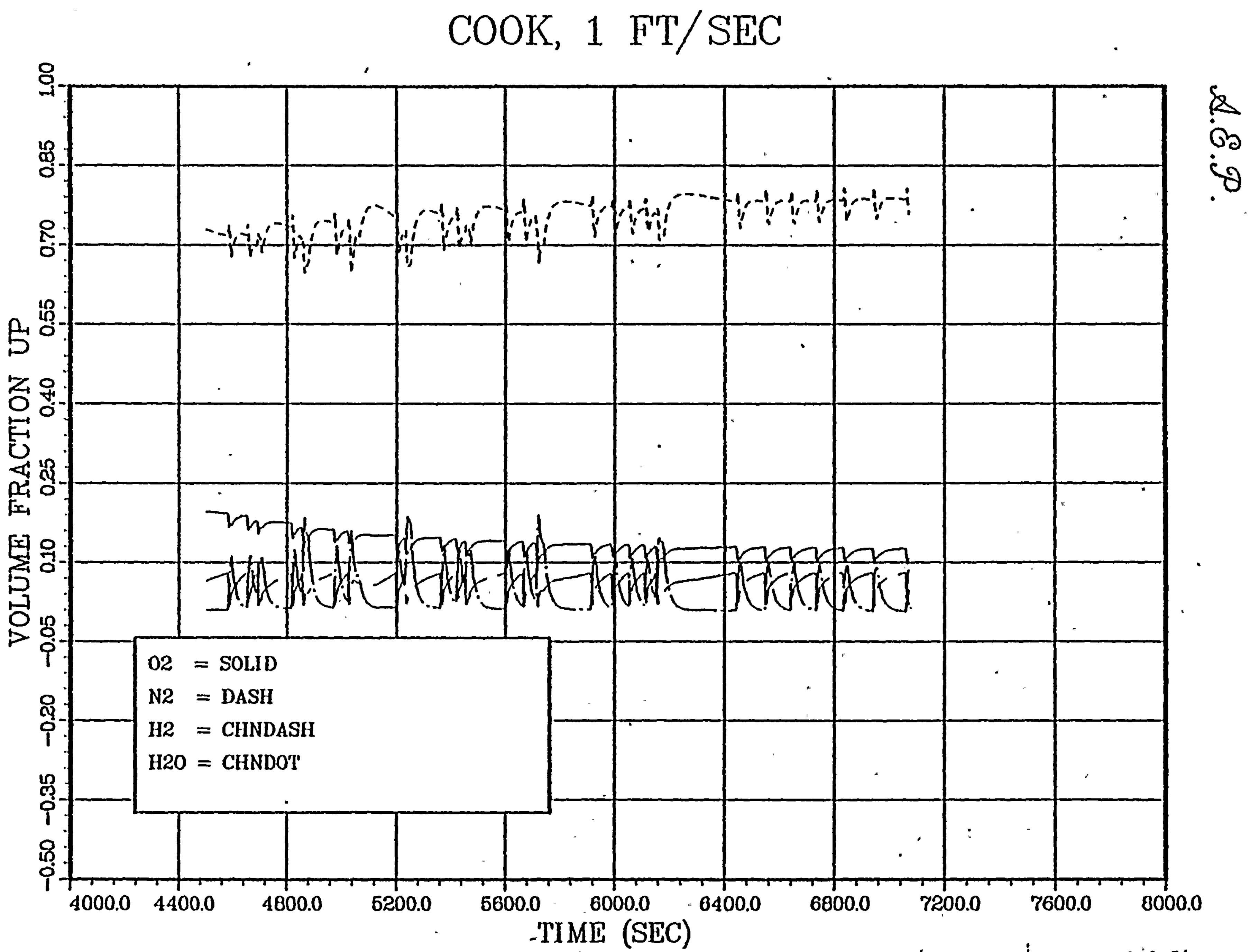


Case F Figure 4.0-52



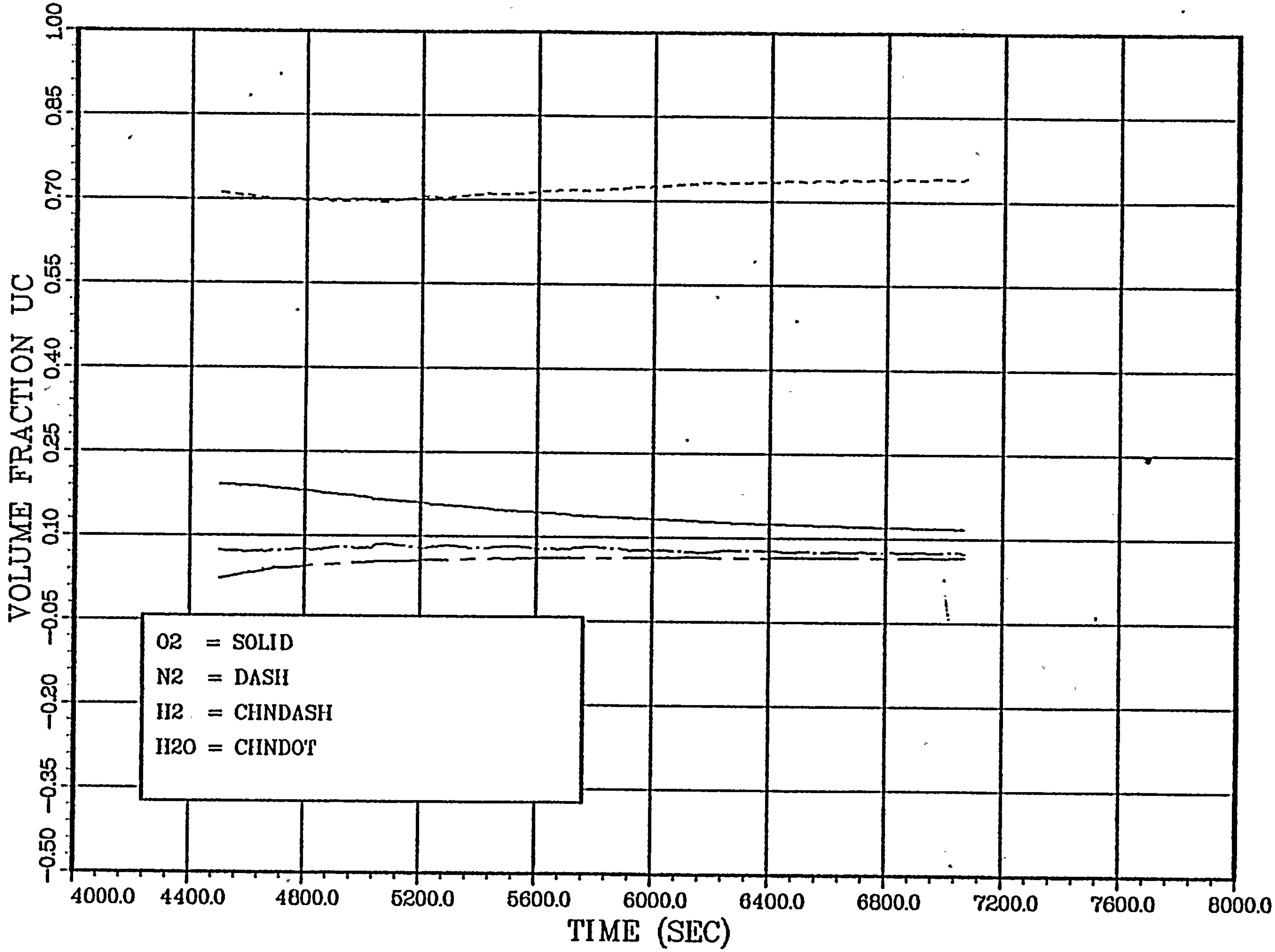
A.C.P.

Case F Figure 4.0-53



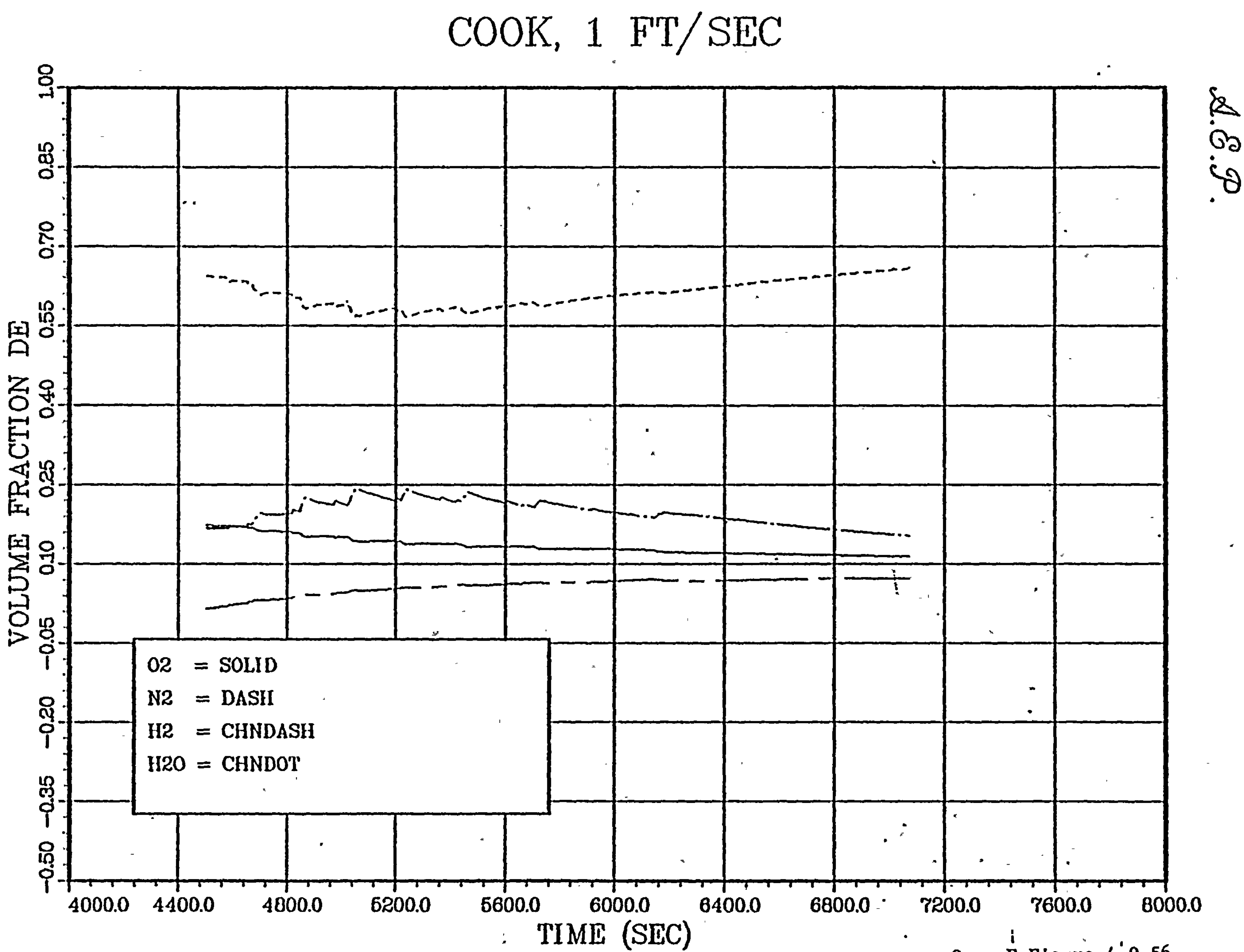
Case F Figure 4.0-54

COOK, 1 FT/SEC



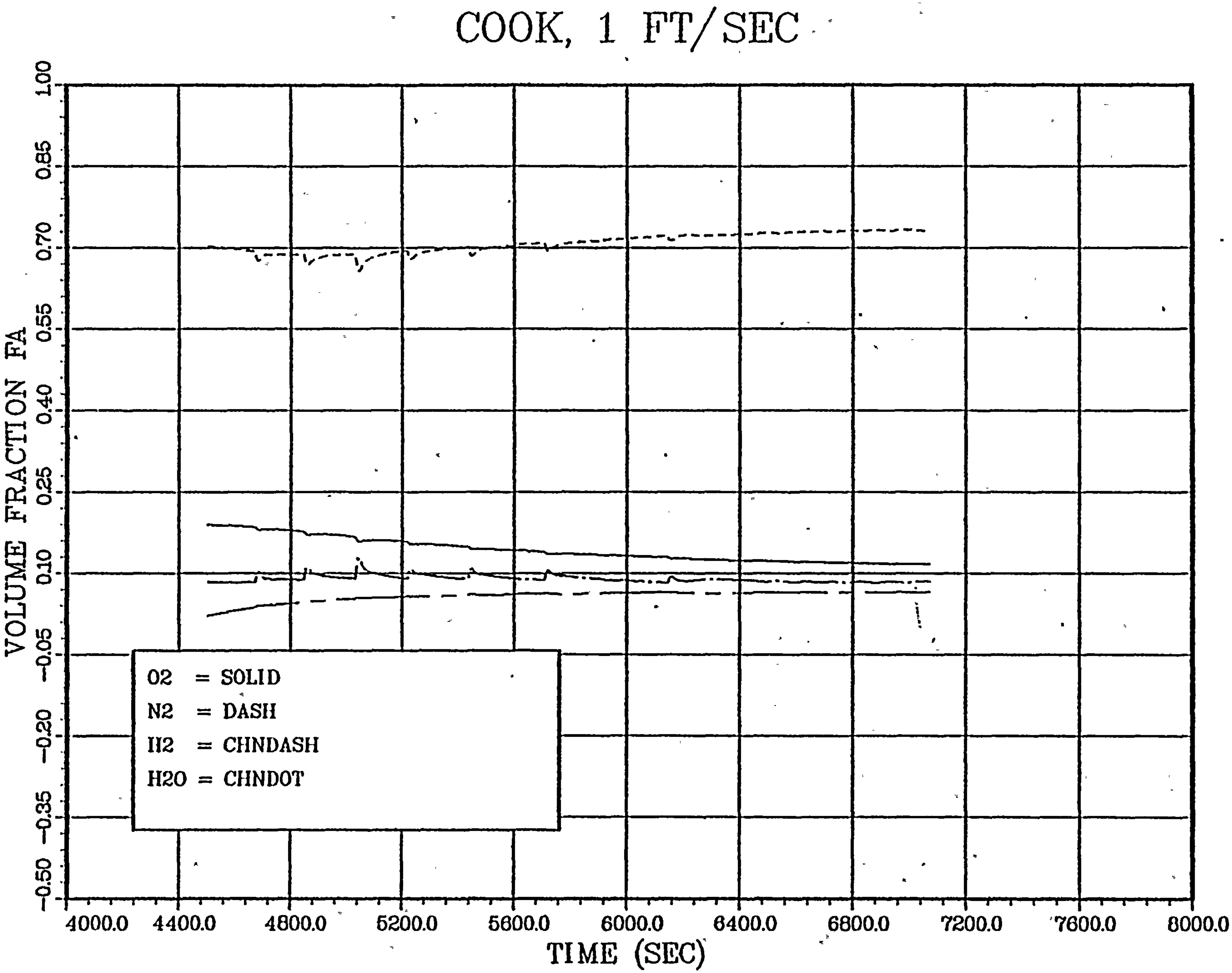
A.E.P.

Case F Figure 4.0-55



Case F Figure 4.0-56

PLOT 19 20.10.52 FRI 22 JAN, 1982 JOB-ANZRIHT, CYBERNET NOS 1.0 DISSPLA VER 8.2



A.E.P.

Case F Figure 4.0-57

5.0 Additional Parametric Studies and Evaluation of Event Sequences

Additional parametric analyses have been performed by TVA and Duke Power Company using the CLASIX computer code for the Sequoyah and McGuire Stations. These analyses included parametric variation of the flame speed, ignition limit, burn completion fraction, hydrogen source term, steam source term, equipment availability, ice inventory, and reduced igniter effectiveness. The results of these analyses are contained in the TVA "Containment Response to Degraded Core Events" report (Attachment No. 3 to Reference 5) and in Section 4.6 of Volume 3 of the McGuire "Red Books" (Reference 10). We have reviewed these analyses and have concluded that the results of the analyses are, in general, applicable to the Cook Plant, thus making performance of similar Cook-specific analyses unnecessary. These analyses provide further evidence in support of the distributed ignition system as a viable means of controlling post-accident hydrogen levels following a degraded core cooling accident. This approach is consistent with our response to Item 8 of Mr. S. A. Varga's letter of July 15, 1981 (see Attachment No. 1 Reference 11). The distributed ignition system has been effectively evaluated for a "spectrum of accidents" by performance of the above cited parametric studies.

References for Attachment No. 1 to AEP:NRC:00500H

(1) Offshore Power Systems Document No. OPS-07A35, "The CLASIX Computer Program for the Analysis of Reactor Plant Containment Response to Hydrogen Release and Deflagration", Revision 1, January 1982, G. M. Fuls.

(2) AEP:NRC:00500E, dated July 12, 1981.

(3) Reactor Safety Study - An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants; WASH-1400 (NUREG-75/014), USNRC, October 1975.

(4) Reactor Safety Study Methodology Applications Program: Sequoyah Unit No. 1 PWR Power Plant, NUREG/CR-1659/1 of 4, Sandia National Laboratories.

(5) Letter dated December 1, 1981, L. M. Mils (TVA) to E. Adensam (NRC).

(6) "Determination of Ignition Performance Characteristics of Glow Plug Hydrogen Ignitor", Fenwal Inc., Report No. PSR-914, November 10, 1980 - Submitted by Duke Power Company as Appendix 2A to Reference 10 below.

(7) "Determination of Ignition Performance Characteristics of a Glow Plug Hydrogen Ignitor and the Effect of Exposure of Equipment to Hydrogen Burns", Fenwal Inc., Report No. PSR-918, December 3, 1980 - Submitted by Duke Power Company as Appendix 2B to Reference 10 below.

(8) "Combustion Behavior Study of Glow Plug Ignitor in Hydrogen-Air-Steam Mixtures: Interim Progress Report"- December 1981, K. K. Shiu, et al. - Submitted as Attachment No. 4 to Reference 11 below.

(9) "Final Results of the Hydrogen Igniter Experimental Program", Lawrence Livermore Laboratory, NUREG/CR-2486, W. E. Lowry, et al., February 1982.

(10) "An Analysis of Hydrogen Control Measures at McGuire Nuclear Station", Duke Power Company, 3 volumes - October 1981, as amended and supplemented (The "Red Books").

(11) AEP:NRC:00500G, dated February 17, 1982.

ATTACHMENT NO. 2 TO AEP:NRC:00500H
DONALD C. COOK NUCLEAR PLANT UNIT NOS. 1 AND 2
HYDROGEN MITIGATION AND CONTROL STUDIES
CORE RECOVERY ANALYSIS SUMMARY

CORE RECOVERY ANALYSIS

In response to Question (7h) of the Attachment to Mr. S. A. Varga's letter of July 15, 1981, Westinghouse Electric Corporation (W) has performed an analysis to investigate the effects of core recovery on hydrogen and steam production rates. The W analysis, conducted with the WFLASH and LOCTA computer codes, serves to verify the conservatisms inherent in the hydrogen and steam production time histories used for containment response analyses and to verify that the hydrogen and steam generation rates do not "spike" during the core recovery phase of the accident.

The accident analyzed was a break in the pressurizer vapor space of a size equivalent to a pressurizer safety valve. Following a reactor trip, the accident is modeled to include no active emergency core cooling (ECC) injection and no auxiliary feedwater. The accumulators, while modeled in the analysis, did not inject during the course of the transient. Approximately ten minutes into the accident the auxiliary feedwater system is assumed to begin delivery of water to the steam generators. However, ECC injection is not restored until the core mixture level is at or below the bottom of the active core region. Shortly after activation of the ECCS, the core mixture level begins a steady rise until the core is completely covered.

The results of the analysis indicate that if the ECCS is initiated shortly after the core mixture level drops below the active core region, the total zircaloy-water reaction is limited to less than 40% of the total core zircaloy. Additionally, the rate of hydrogen generation is less than approximately 112 lb/min at its peak generation point. The maximum steam generation rate during the period of hydrogen production is less than 30 lb/sec.

ATTACHMENT NO. 3 TO AEP:NRC:00500H
DONALD C. COOK NUCLEAR PLANT UNIT NOS. 1 AND 2
HYDROGEN MITIGATION AND CONTROL STUDIES
UPPER PLENUM IGNITER SPACING EVALUATION
AND SUMMARY OF IGNITER TESTING

1. Ice Condenser Upper Plenum Igniter Coverage

In response to Question (14) of the Attachment to Mr. S. A. Varga's letter of July 15, 1981, an evaluation has been performed of the adequacy of the igniter coverage provided in the ice condenser upper plenum. The evaluation was based on a single train of seven igniters assumed to be uniformly spaced in the upper plenum. As stated in Question (14), the intent of the evaluation was to verify that the amount of hydrogen exiting the upper plenum into the containment upper compartment is conservatively less than that amount predicted by analysis using the CLASIX computer code. The evaluation has indeed verified the conservatism of the CLASIX analysis insofar as hydrogen introduction into the upper compartment is concerned.

In order to be consistent with the assumptions used in the base case CLASIX analyses presented as Cases A, B, and C in Attachment No. 1 of this submittal, the evaluation focused on a range of upper plenum hydrogen concentrations prior to the onset of ignition, between 7.5 and 8.5 volume percent (v/o). An upper limit condition of 10 v/o hydrogen in the upper plenum, corresponding to the Case D CLASIX analysis presented in Attachment No. 1, was also performed.

Ignition at upper plenum hydrogen concentrations below 7.5 v/o were not considered due to the lower burn fractions and temperature and pressure transients associated with combustion of such lean mixtures. In addition, Table 2 of this attachment clearly shows that the average concentration of hydrogen in the mixture leaving the upper plenum increases as the hydrogen concentration required for ignition increases, thus making analysis of ignition levels below 7.5 v/o unnecessary.

The key factors in the analysis were the flame speed, burn time, combustion model, and the assumed level of mixing within the upper plenum. The flame speed was varied monotonically from approximately 2 ft/sec to approximately 14 ft/sec for hydrogen concentrations between 7.5 and 10 v/o in the upper plenum. Burn times were computed based on the maximum distance traversed by two independent flames initiating from adjacent igniters on the same train using both buoyant bubble rise and spherical propagation combustion models. As expected, the buoyant bubble rise model consistently predicted a greater burn time at a given hydrogen concentration and thus conservatively predicted higher input rates into the upper compartment than were predicted using the spherical flame propagation model. Two types of mixing were considered within the upper plenum, a homogeneous mixing model and a model considering distinct burnt and unburnt gas regions. Comparison of the results indicates a minimal effect of the mixing model on the average value of the hydrogen concentration in the gas entering the upper compartment following an upper plenum burn. The results of the analysis, summarized in the attached tables, clearly indicate that seven igniters provide adequate igniter coverage in the ice condenser upper plenum.

TABLE 1
UPPER PLENUM IGNITER EVALUATION
COMPARISON OF BURN TIMES FOR BUOYANT BUBBLE
AND SPHERICAL DEFLAGRATION COMBUSTION MODELS*

Volume Percent H_2 For Ignition	Burn Fraction	Flame Speed (ft/sec)	Burn Time: Buoyant Bubble Model (sec.)	Burn Time: Spherical Deflagration Model (sec.)
7.5	76	2.11	16.4	8.68
8	80	3.23	9.45	5.67
8.5	81	4.38	6.53	4.18
10	100	14.1	1.79	1.30

* Assuming Seven Igniters Operable

TABLE 2

UPPER PLENUM IGNITER EVALUATION
SUMMARY OF BUOYANT BUBBLE MODEL
RESULTS AND EFFECTS OF MIXING ASSUMPTIONS*

Volume Percent H_2 For Ignition	Calculated Time Between Burns (sec)	Average H_2 Concentration of Upper Plenum Exhaust Gases Between Burns	
		Uniform Mixing Model (v/o)	Non-Uniform Mixing Model (v/o)
7.5	66.3	5.2	5.4
8	69.6	5.8	5.7
8.5	70.5	6.3	6.1
10	52	6.5	6.1

* Assuming Seven Igniters Operable

2. <u>In Situ Igniter Testing Results</u>

The glow plug igniters installed in Unit No. 1 were recently tested to verify system operability. All igniters were verified operable in accordance with proposed Technical Specification Surveillance Requirements contained in Attachment No. 2 to our AEP:NRC:00500C letter dated May 29, 1981. In addition, igniter temperature measurements were taken using a portable radiometer. The average igniter temperature measured was approximately 1980°F.