EVALUATION OF AN IMPROVED

SAFETY INJECTION SYSTEM

WITH RETRAN-02/MOD 4

SONGS 1

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Approval

ME Motamed

Author

March 1988

1546j

<u>THERMAL HYDRAULICS</u>

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2. 2 - T/H-83-01 Yine-Ping Ting
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   RCS Flow Measurements

3. 2 - T/H-83-02 Yine-Ping Ting
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4. 2 - T/H-83-03 Charles Sayles
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6. 2&3 - T/H-84-02 Yine-Ping Ting
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SONGS 1

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1. SUMMARY

A proposed upgrade to the Safety Injection System of San Onofre Nuclear Generating Station Unit 1 (SONGS 1) is evaluated using the RETRAN-02/Mod 4 computer code . The upgrade consists of modifications to the charging system to allow high pressure injection of borated water by the two charging pumps during safety injection and bypass piping around the feedwater pumps. The limiting cold leg SBLOCA was simulated with the RETRAN model of SONGS 1 for the 3 inch, 4 inch, and 6 inch diameter break sizes. In each case the transient was simulated beyond the time of loop seal clearing, core uncovery, core recovery, and the point in time where SI flow exceeded the break flow. The proposed upgrade to the SI system was included in this simulation. It was assumed that the hydraulically actuated valves which realign the feedwater pumps to become a part of the SI system have failed, making the existing SI system inoperable.

The results of the SBLOCA simulation show that the core is adequately protected even with one SI line spilling out of the break. It is concluded that the upgraded Safety Injection System will protect the core in the event of the limiting SBLOCA.

2. INTRODUCTION

The Safety Injection System at SONGS 1 is different from most other PWR's since it depends on the main feedwater pumps to realign and inject borated water to the RCS. This involves automatic action of several hydraulically actuated valves. It is of interest to improve the SI system by reducing its reliance on the operation of these valves. Several upgrade options were considered. Based on SCE's evaluations (1) the recommended alternative consists of modifications to the charging system to allow high pressure injection of borated water by the two charging pumps during safety injection and bypass piping around the feedwater pumps.

The RETRAN model of SONGS 1 was used to evaluate this upgrade option for system response to a small break LOCA. The detailed model of the loop seal was included in the RETRAN model, since the process of loop seal clearing is very important in a limiting cold leg small break. The simulation was continued beyond the time of loop seal clearing, core uncovery, core recovery, and the point in time where the SI flow exceeds the break flow. As the RCS depressurizes, breakflow decreases and SI flow increases. After SI flow exceeds break flow the RCS begins to refill. It can be shown that the core is adequately protected prior to the time when SI flow exceeds break flow, then the core will remain covered beyond that time.

3. RETRAN MODEL

The RETRAN model of SONGS 1 used in the simulation of a cold leg SBLOCA consists of 48 control volumes and 76 junctions. Figure 1 shows a nodal diagram of the model. Primary Loops A and C are combined into an equivalent loop (right loop), and Loop B with the cold leg break (Junction 265) is modeled as a separate loop (left loop). Since the loop seal clearing process occurs in the SBLOCA's simulation, the detailed geometry and elevations of the loop seal including the crossover leg was included in the RETRAN model. The break sizes considered were 3, 4, and 6 inch diameter cold leg breaks located near the cold leg nozzle of loop B. These breaks cause voiding of large sections of the primary system. The loop flow becomes stagnant, and many volumes such as the reactor vessel upperhead and the pressurizer become completely voided of liquid. A bubble rise model was used in the primary system to model voiding of large sections of the RCS under low flow to fairly stagnant conditions. Control volumes were over-lapped by 0.02 feet to allow the mixture level to pass across volume boundaries. A detailed model of the steam generators including steam separator and recirculation was used to accurately represent the temperature distribution of the coolant in the secondary system. The pressure dependent Safety Injection flow is assumed to be the flow of two charging pumps with the proposed modifications, adjusted for charging pump mini-flow. Figure 2 shows the SI flow vs. pressure assuming one line is spilling, one line is blocked and one line is injecting. It is assumed that the main feedwater pumps have failed to realign to the SI system. Table 1 states the initial conditions and the assumptions made in this simulation. The RETRAN model of the SONGS 1 SBLOCA was benchmarked against the Westinghouse SBLOCA analysis performed with the WFLASH code for the current SI system of SONGS 1. The benchmark effort is discussed in Reference (2).

Table 1

Assumptions and Initial Conditions

1. Initial power: 100% (1347 MW_t)
2. Break occurs at the cold leg nozzle, loop B cold leg, discharge side of the pump.
3. Reactor trip on the low pressurizer pressure SI signal of 1750 psia with one second delay.
4. RCP's trip on SIS with 1 second delay (quick trip).
5. Turbine trip on reactor trip signal.
6. Feedwater trip on SIS.
7. Auxiliary feedwater is manually actuated with 10 minute delay.
8. The initial pressurizer level, hot leg and cold leg temperatures are consistent with the reduced temperature program (see figures).
9. Extended Henrey Fauske critical flow model was used for subcooled break flow, with a discharge coefficient of 1.
10. Moody's critical flow model was used for saturated break flow with a discharge coefficient of 1.
11. All control systems, especially the steam dump/bypass control system are inoperable.
12. SI flow enters the RCS with a 10 second delay after SIS actuation.
13. One SI train is operating with one line injecting, one line spilling, and one line blocked.

4. RESULTS

Three breaksizes were simulated 3, 4, and 6 inch diameter breaks. Simulation of the SBLOCA for all three break sizes was continued beyond the loop seal clearing, core uncovery/recovery, and beyond the point in time where SI flow exceeded the mass flow rate through the break. The overall system response for all three break sizes is quite similar. The reactor trip occurs due to low pressurizer pressure SI signal setpoint of 1750 psia. RCS pressure rapidly drops to approximately 1000 psia which is the steam generator safety valves setpoint. RCS pressure remains at 1000 psia until the loop seal clears at the broken loop. The turbine trips due to reactor trip (SIS) and the feedwater pumps are also tripped in the process of realigning to the safety injection system. The steam dump and bypass control system is assumed to be unavailable, which causes the steam generator pressure to increase to 1000 psia which is the setpoint of the safety valves with the lower settings. Steam generator pressure decreases after the loop seal clears and the primary system begins to cool down. The pressurizer and the upperhead void completely and the upper plenum and the reactor vessel downcomer partially void, and the primary loops void at elevations above the hot leg prior to loop seal clearing. Just before the loop seal clears the mixture level in the upper plenum drops to uncover part of the core for a short time. The mixture level returns above the top of the core when the loop seal clears. The RCS pressure continues to decrease and so does the break flow.

The SI flow increases as the system is depressurizing. The SI flow exceeds the breakflow at some point in time, beyond which the mixture level in the upper plenum will continue to increase. In the cases of the 3 inch and 4 inch breaks, RETRAN predicts a second core uncovery which is very brief and is due to the dynamics of the loop flow. The RCP's are tripped on the SI signal. Figures 3 through 13 show the system response for the 3 inch break, Figures 14 through 24 show the results for the 4 inch break and Figures 25 through 35 are for the 6 inch break.

5. CONCLUSIONS

The RETRAN model of SONGS 1 SBLOCA was used to evaluate a proposed upgrade to the Safety Injection System. The upgrade consists of modifications to the charging system to allow high pressure injection by two charging pumps. The break sizes considered were 3 inch, 4 inch, and 6 inch breaks at the cold leg nozzle of loop B. The simulation was continued to beyond a point in time where the SI flow exceeded the break mass flow rate. Results showed that certain sections of the primary system voided, the loop seal cleared, and the core was uncovered for a short time. However, the coolant mixture level quickly returned to above the top of the core. After reaching the point in time when SI flow exceeds break flow, the mixture level in the reactor vessel will begin to increase and the system will continue to depressurize.

It is concluded that in the event the feedwater pumps fail to realign to the SI system following a limiting cold leg SBLOCA, the SI system with the proposed upgrade will adequately protect the core during the ensuing depressurization event.

6. REFERENCES

1. Letter from G. J. Stawniczy to J. L. Rainsberry, "Safety Injection Upgrade Alternatives, SONGS 1," November 16, 1987

2. Motamed, M., "RETRAN SBLOCA Model Benchmark (Comparison with WFLASH), SONGS 1," 1-T/H-88-02, March 1988

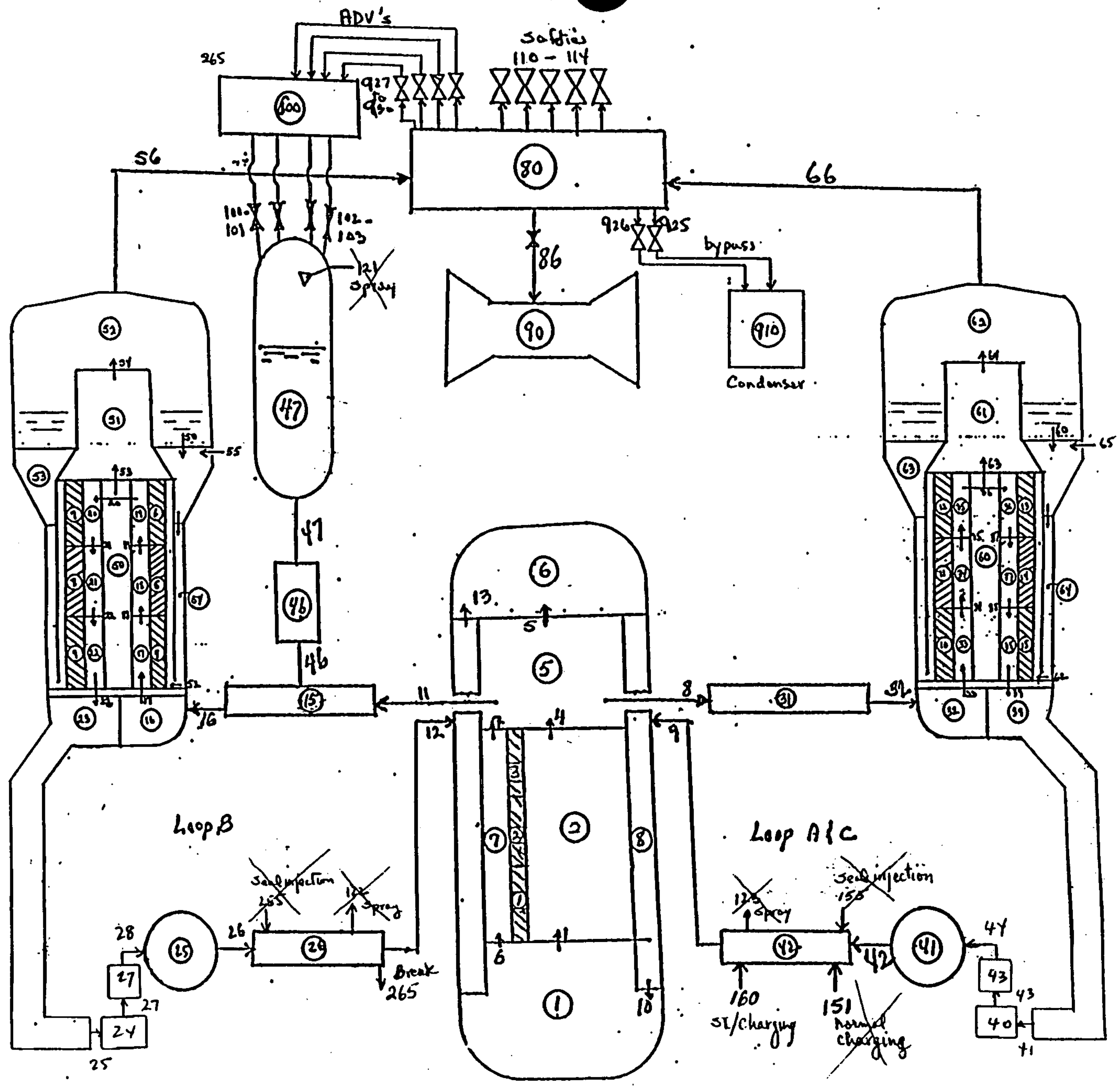
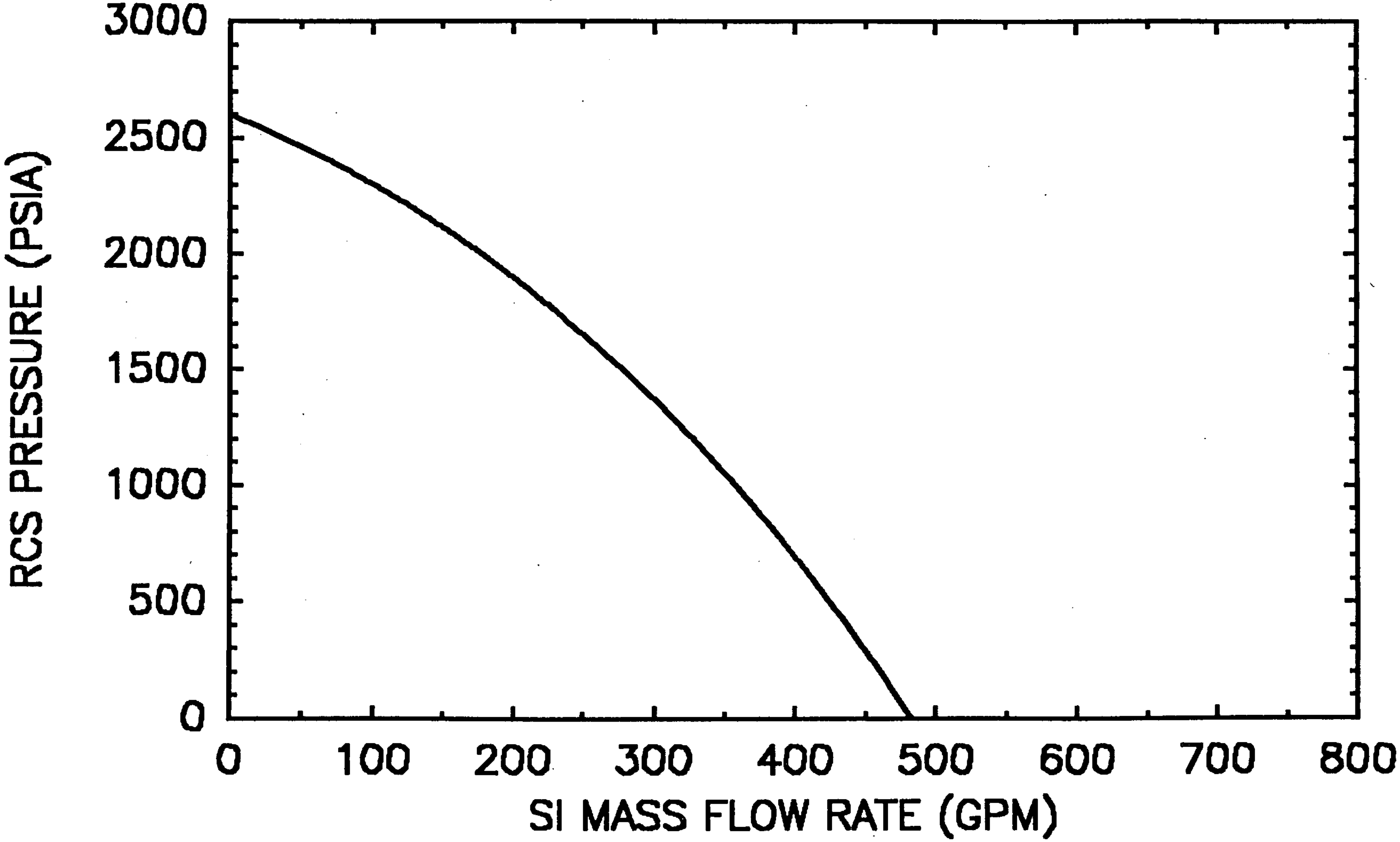


Figure 1
RETRAN Model Nodal Diagram

Figure 2
SONGS1 SBLOCA
UPGRADED SAFETY INJECTION SYSTEM
TWO CHARGING PUMP (ALT.D)
SI MASS FLOW RATE VS PRESSURE



FIGURES FOR 3 INCH BREAK

Figure 3

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
NORMALIZED REACTOR POWER

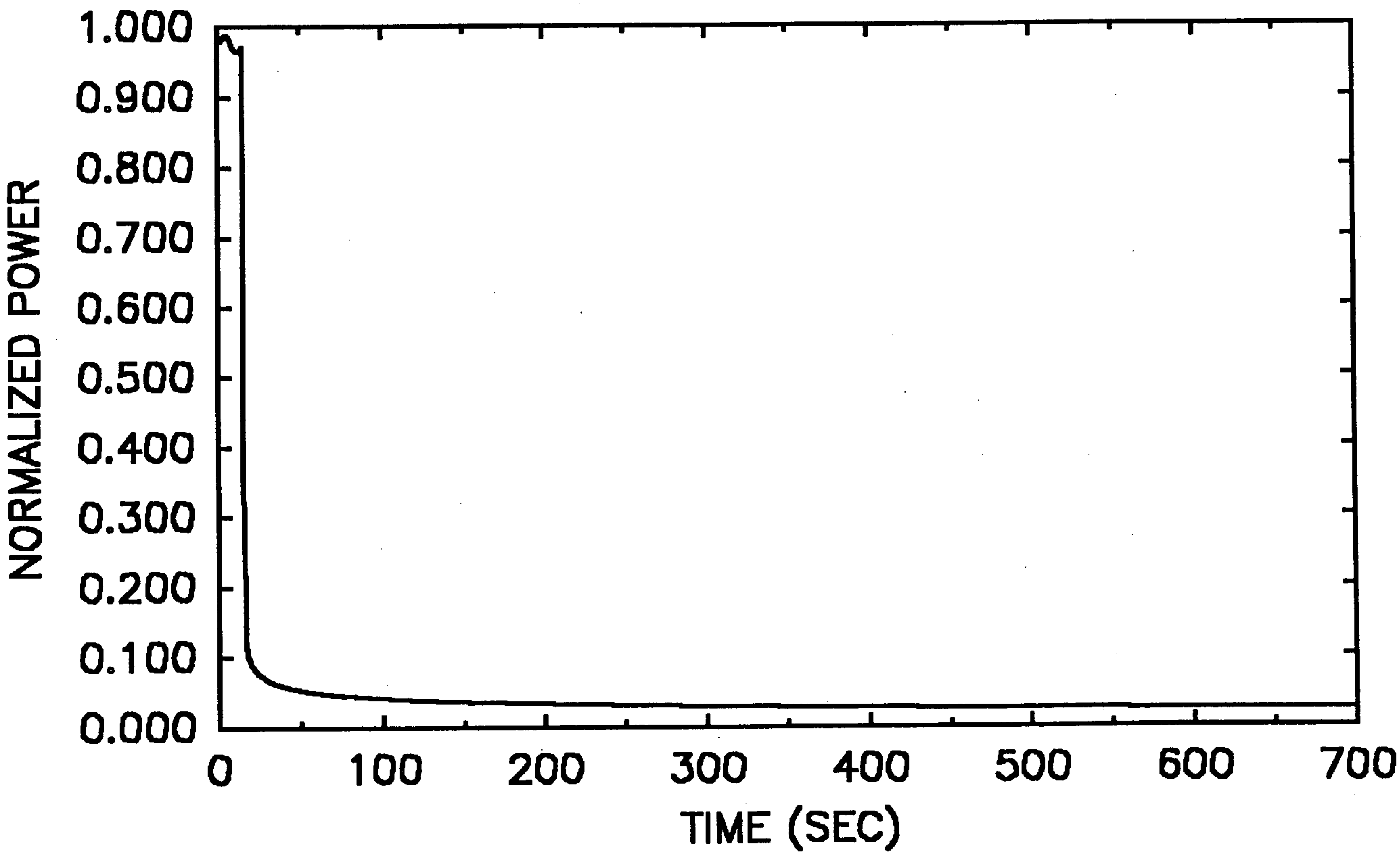


Figure 4

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
RCS PRESSURE

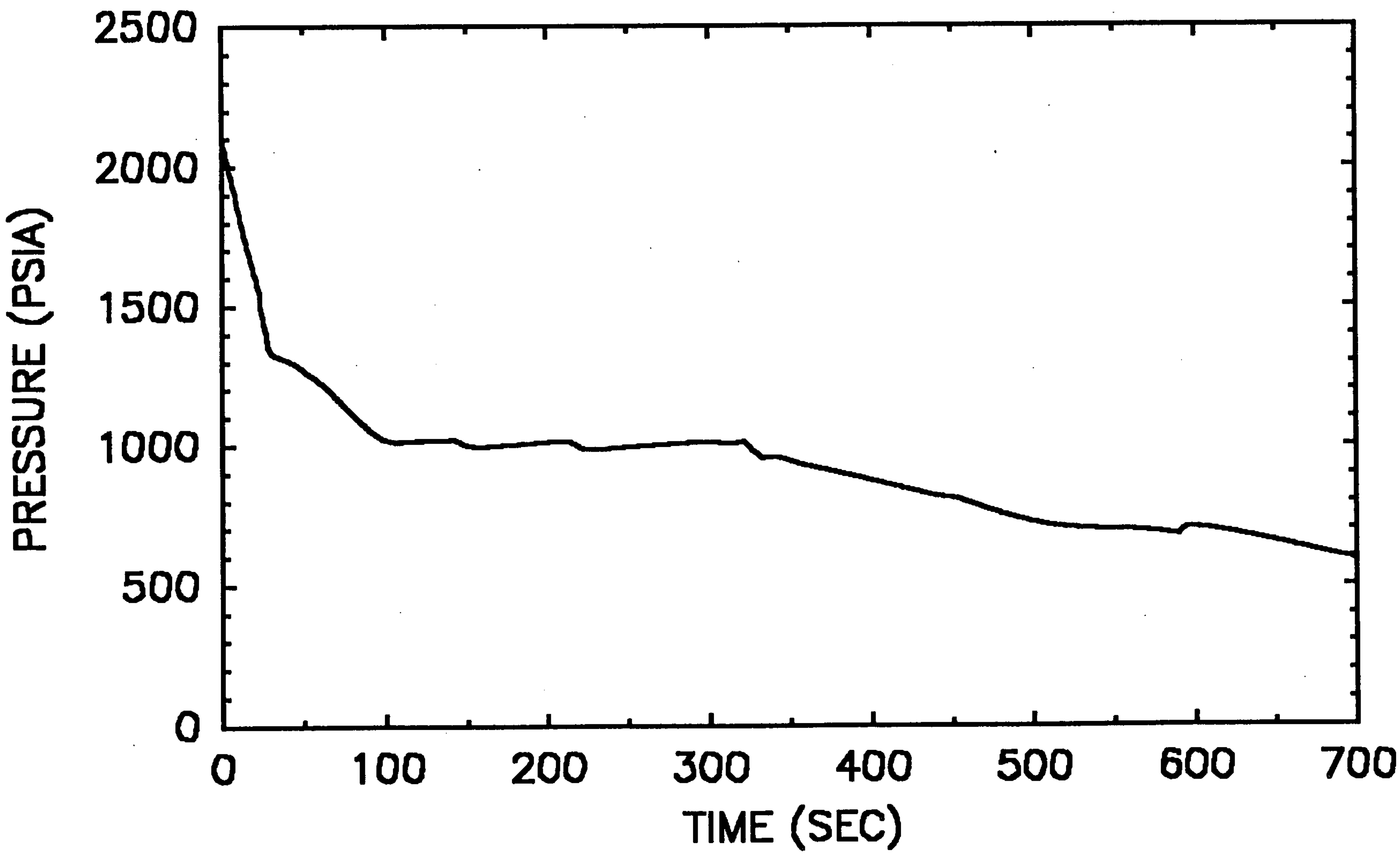


Figure 5

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
PRESSURIZER MIXTURE LEVEL

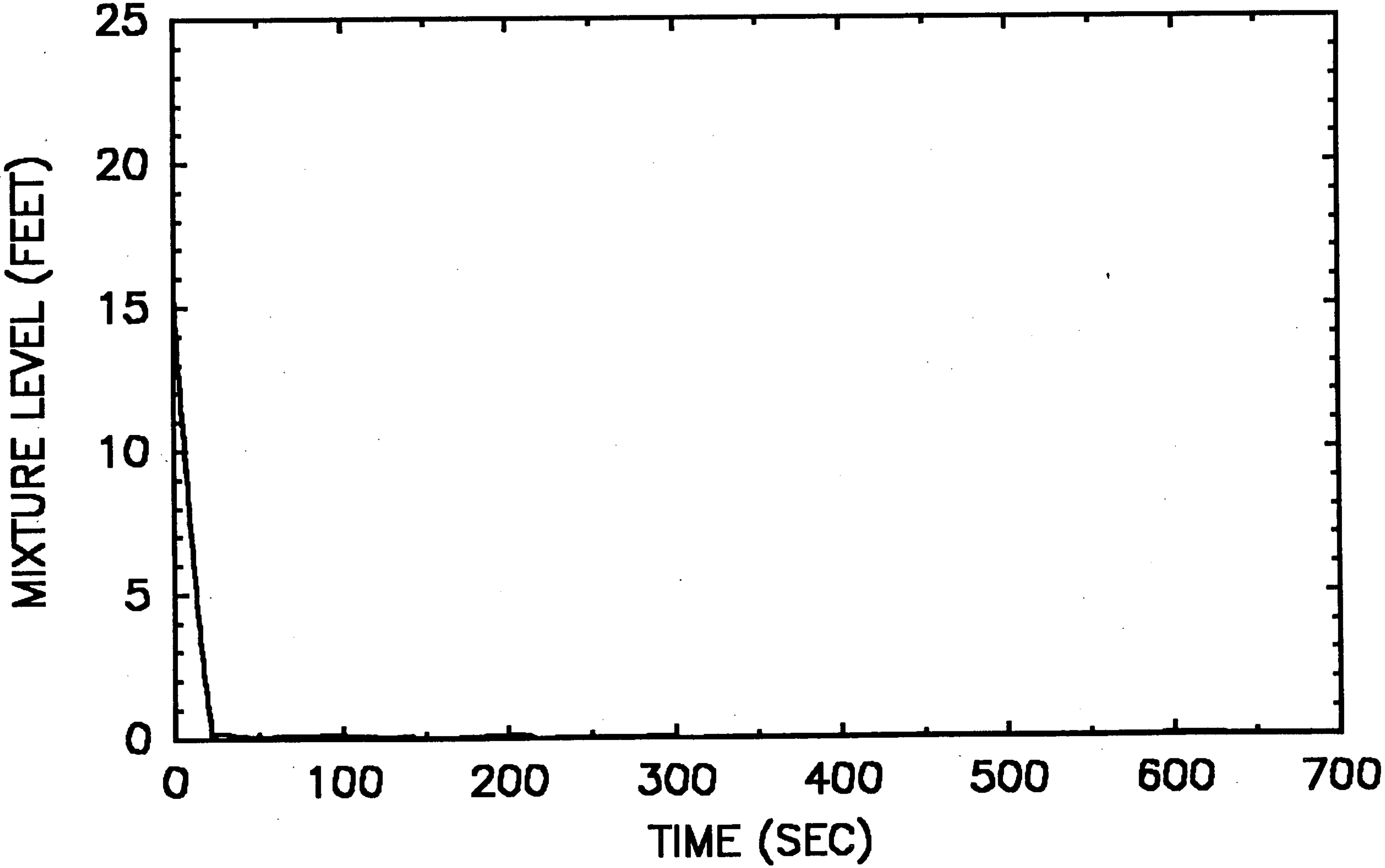


Figure 6

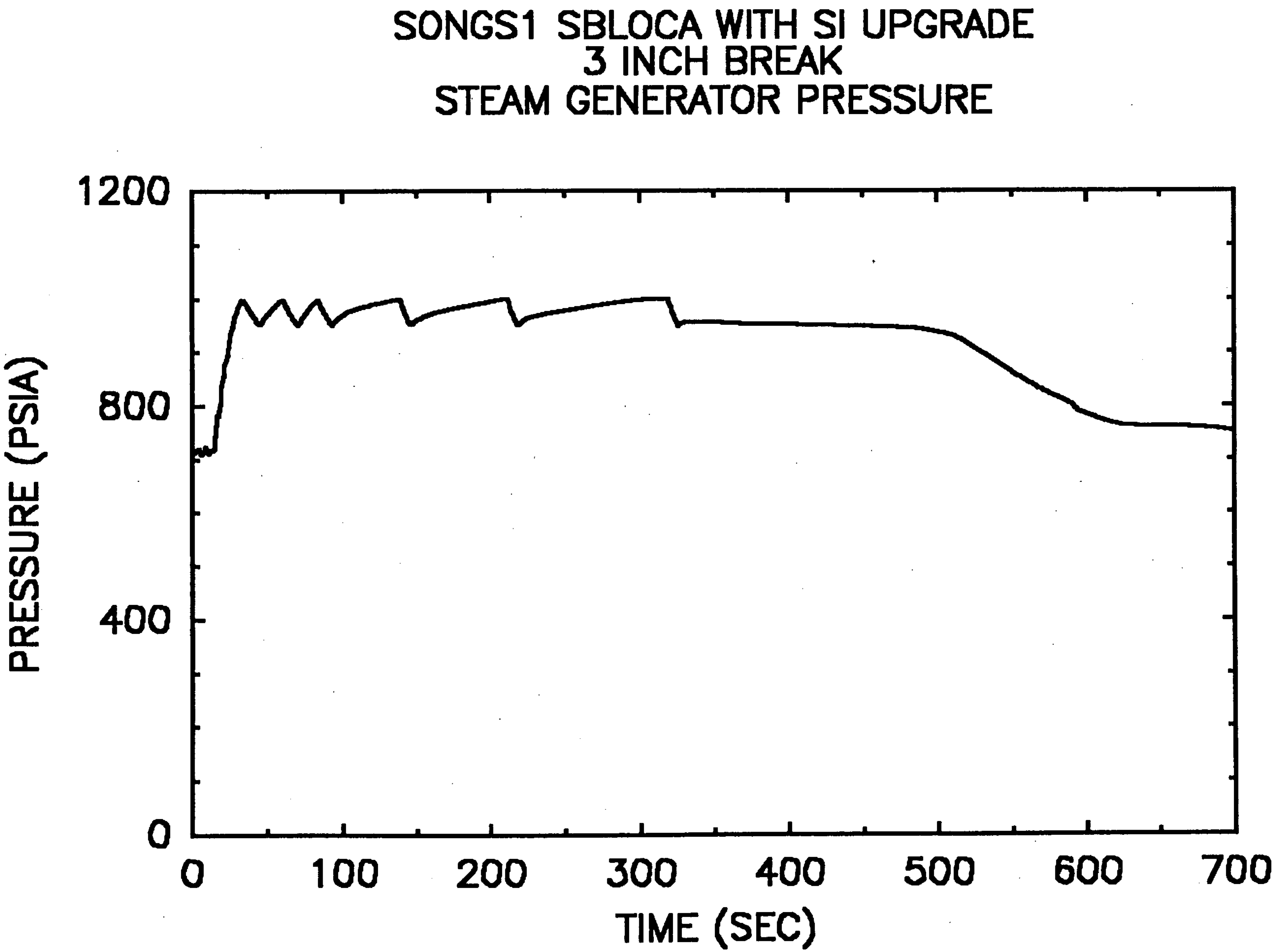

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
STEAM GENERATOR PRESSURE
1200
800
400
0
PRESSURE (PSIA)
0
100
200
300
400
500
600
700
TIME (SEC)

Figure 7

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
RX VESSEL DOWNCOMER MIXTURE LEVEL

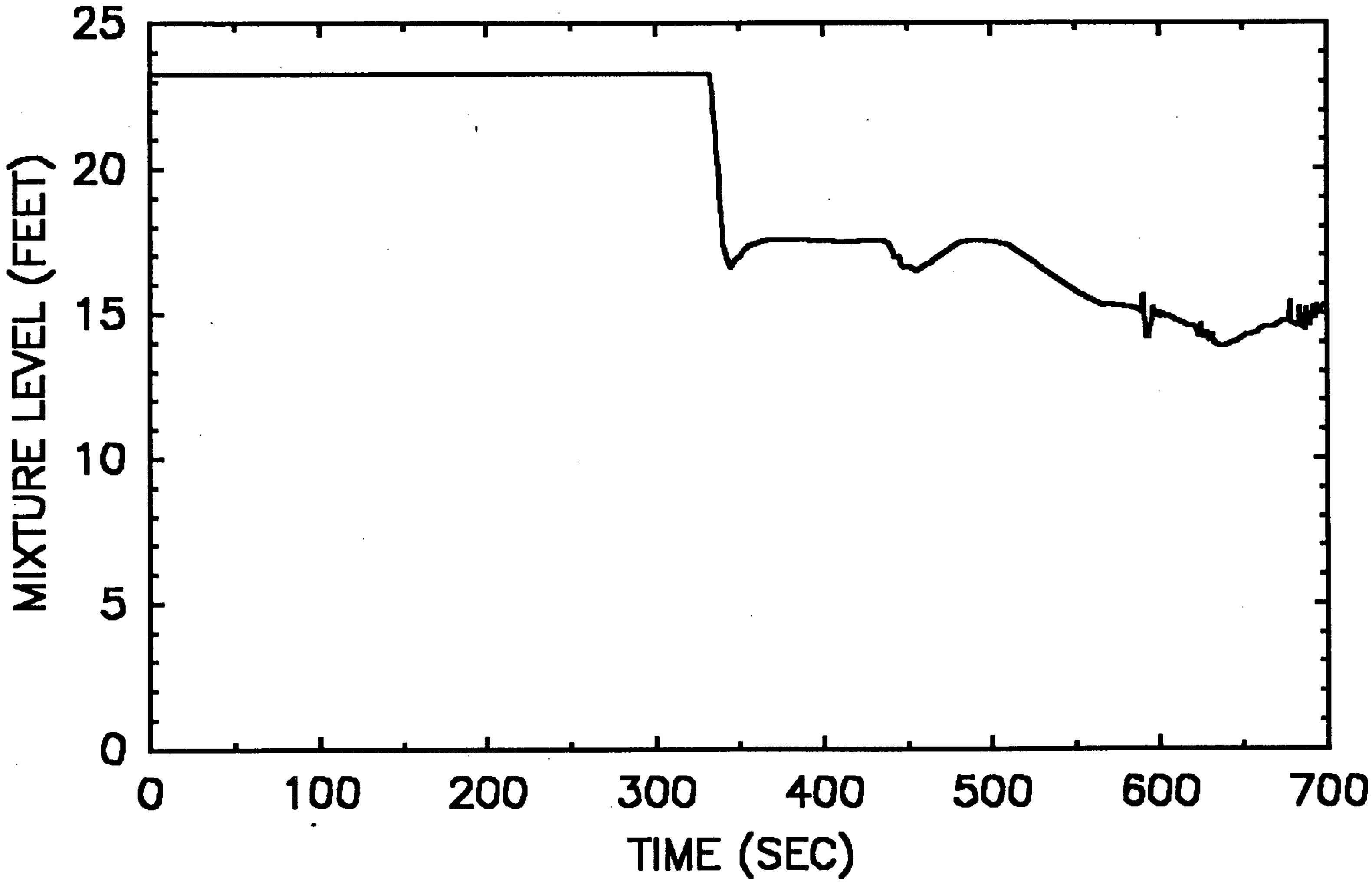


Figure 8

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
RX VESSEL UPPER HEAD MIXTURE LEVEL

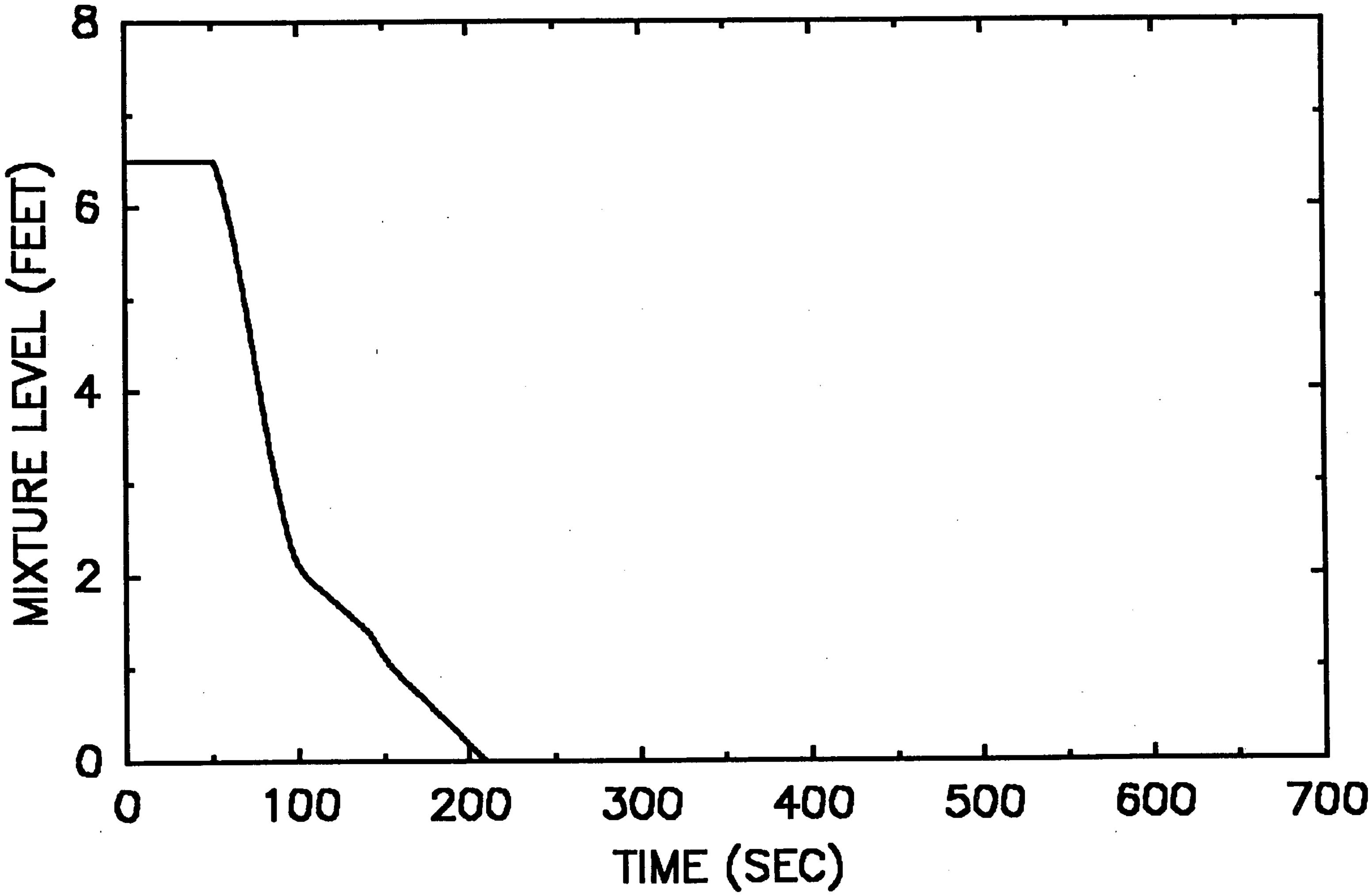
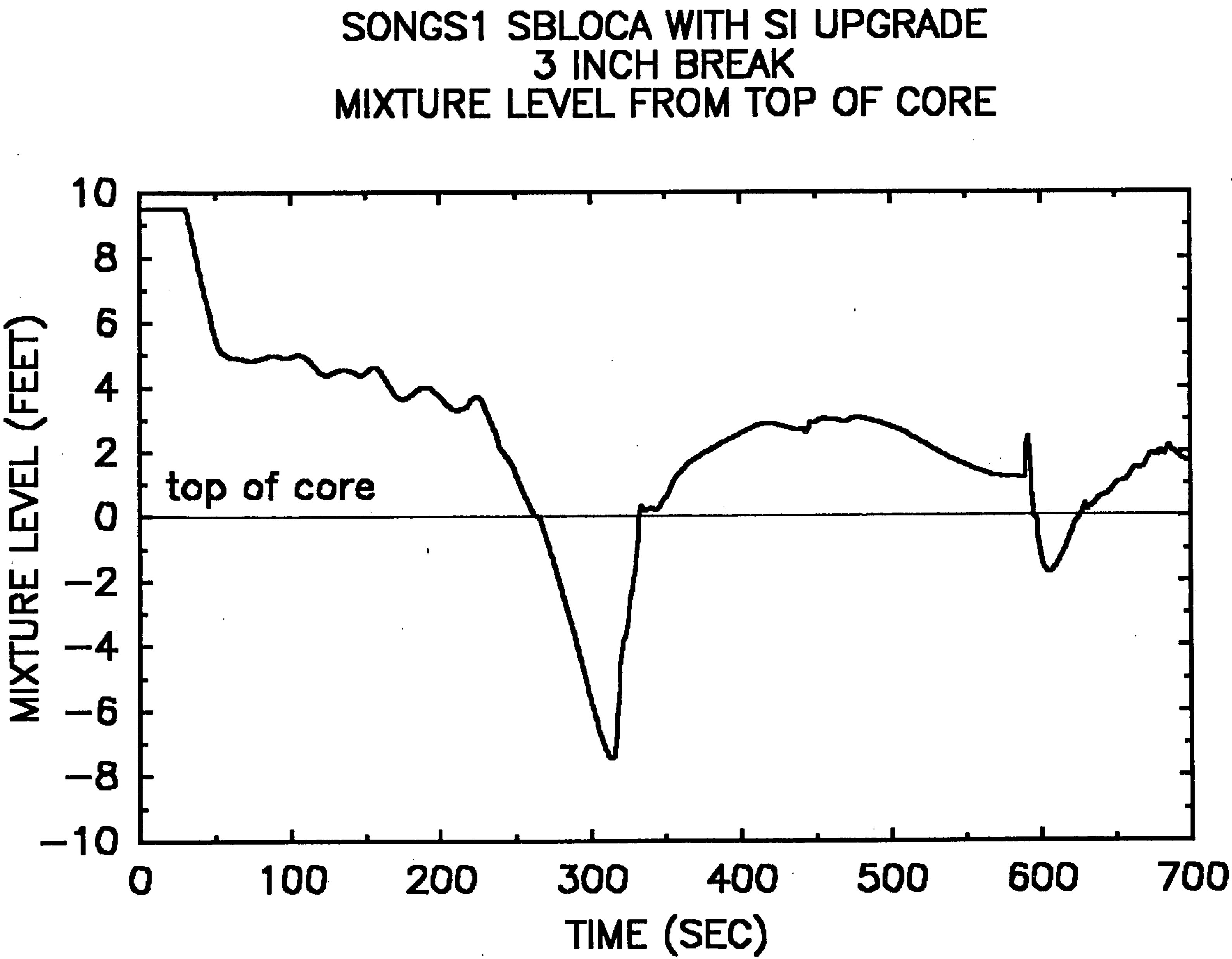


Figure 9



SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
MIXTURE LEVEL FROM TOP OF CORE
MIXTURE LEVEL (FEET)
TIME (SEC)
top of core
10
8
6
4
2
0
−2
−4
−6
−8
−10
0
100
200
300
400
500
600
700

Figure 10

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
LOOP SEAL MIXTURE LEVEL

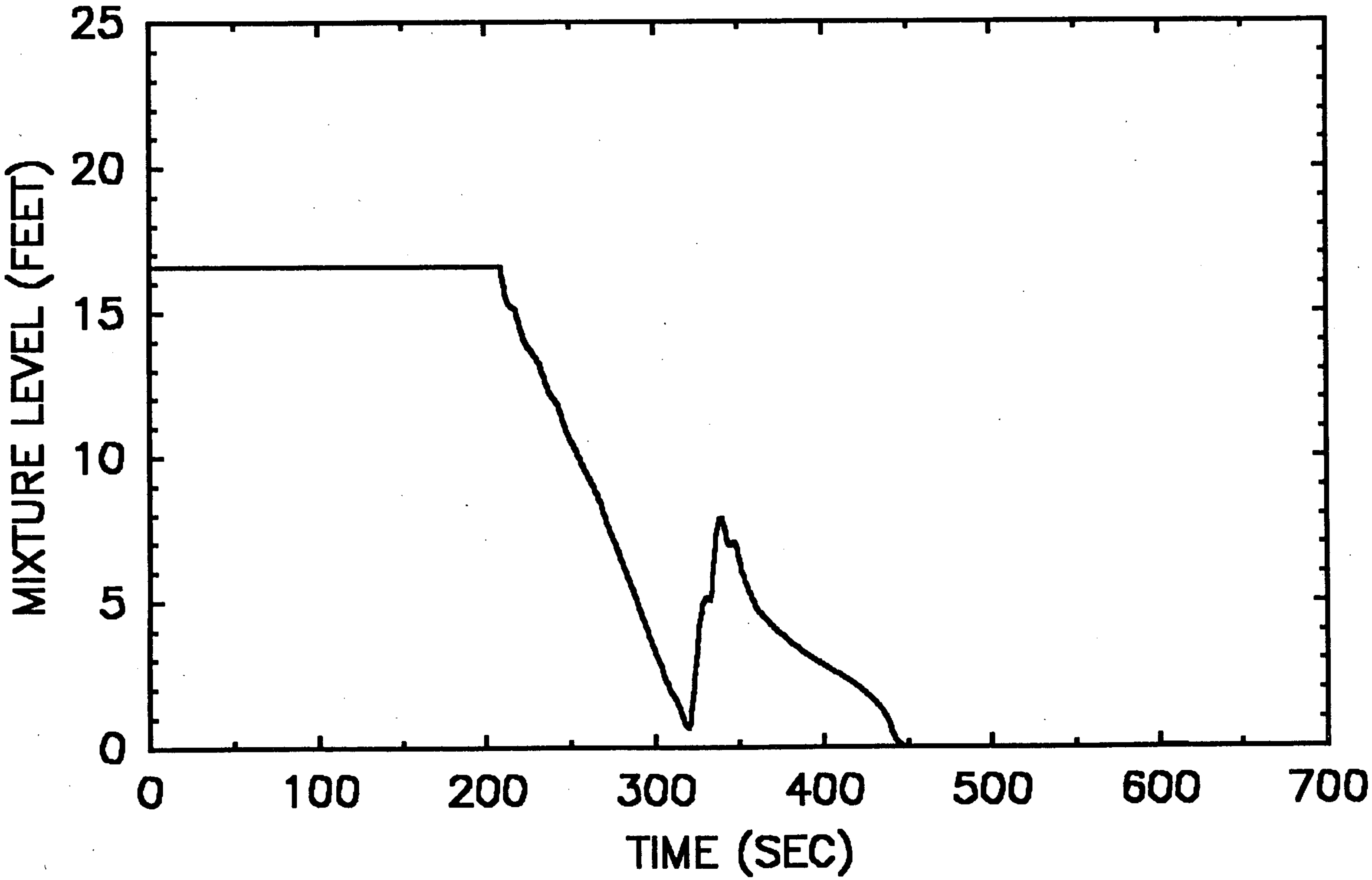


Figure 11

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
BREAK FLOW AND SI FLOW

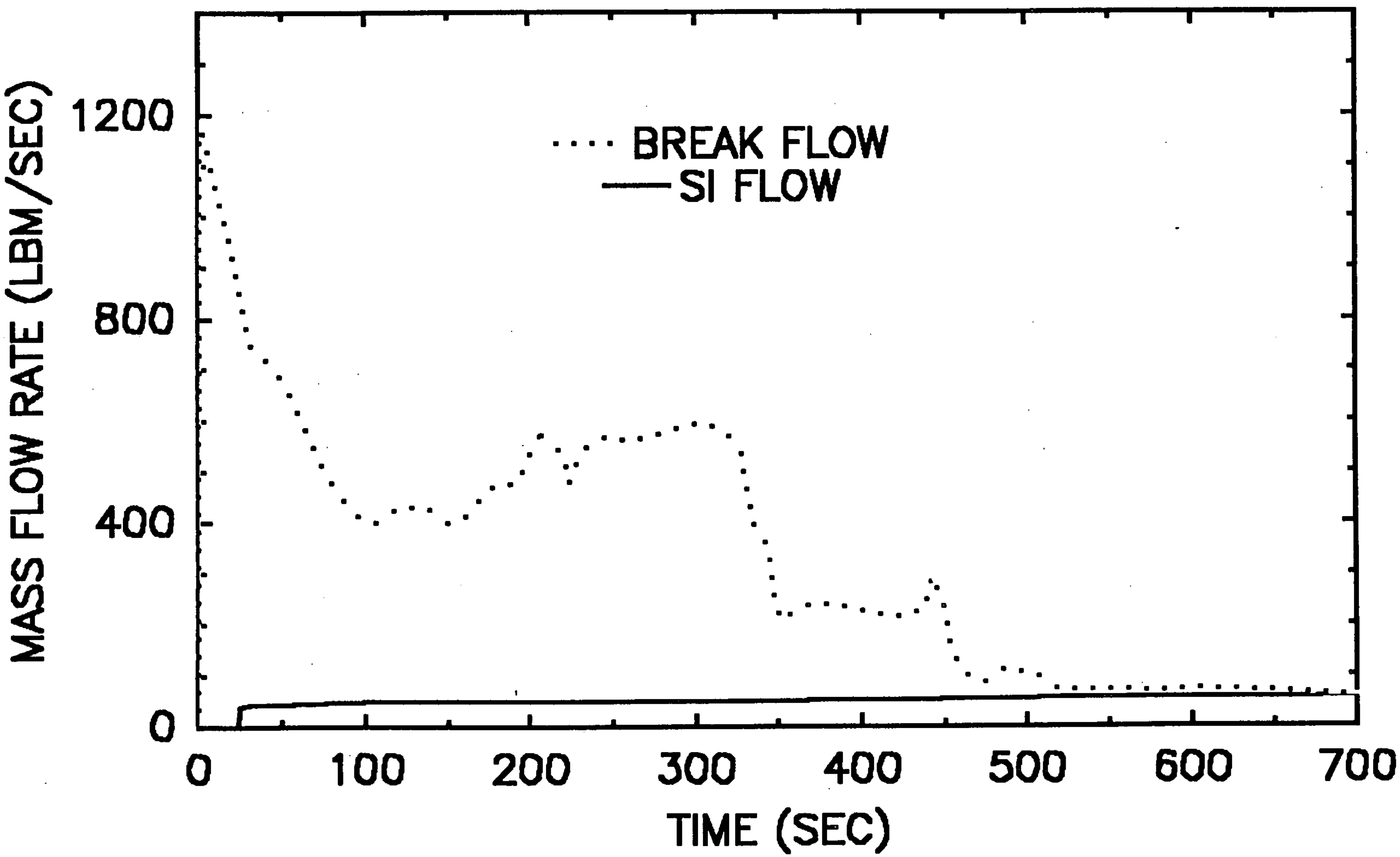


Figure 12

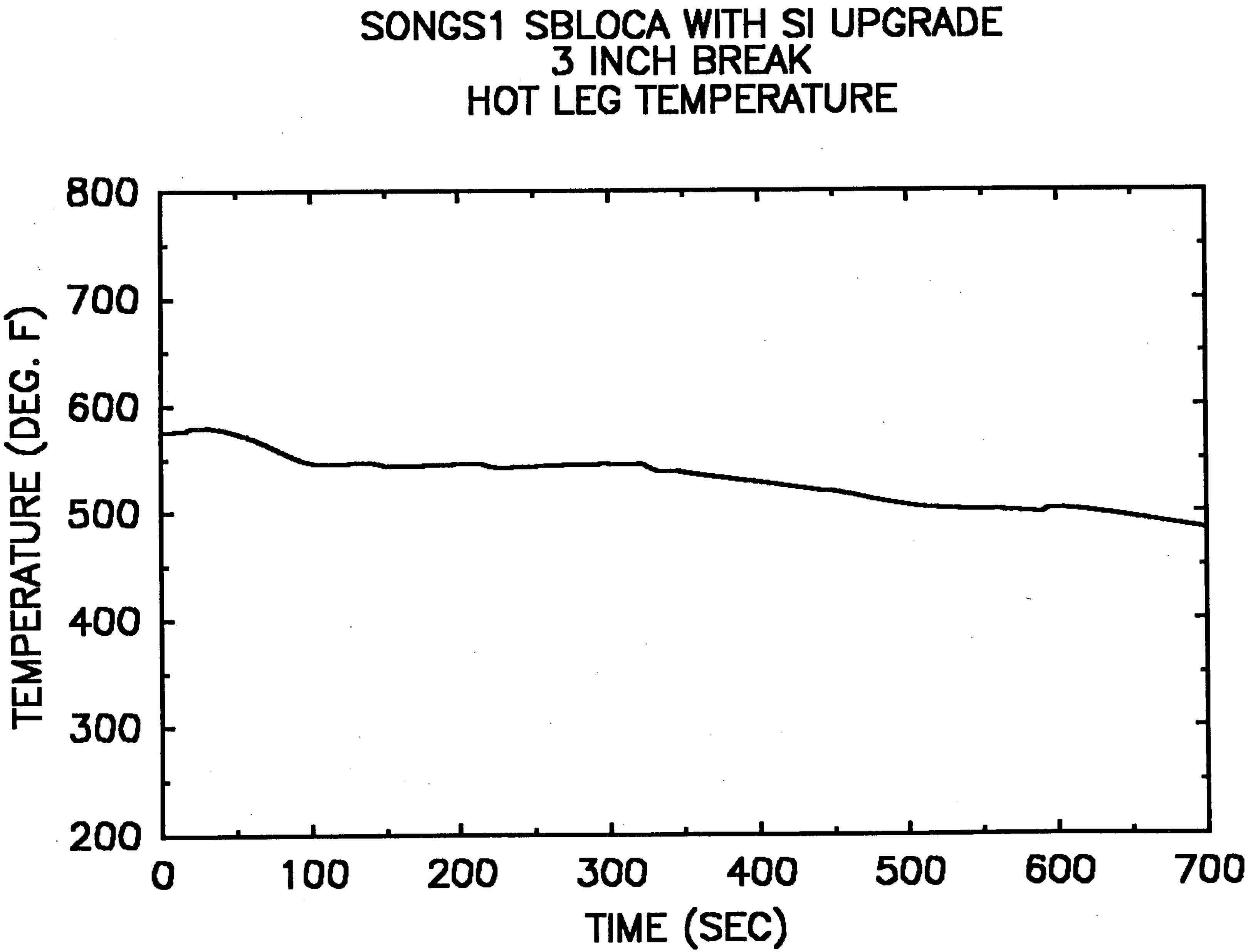
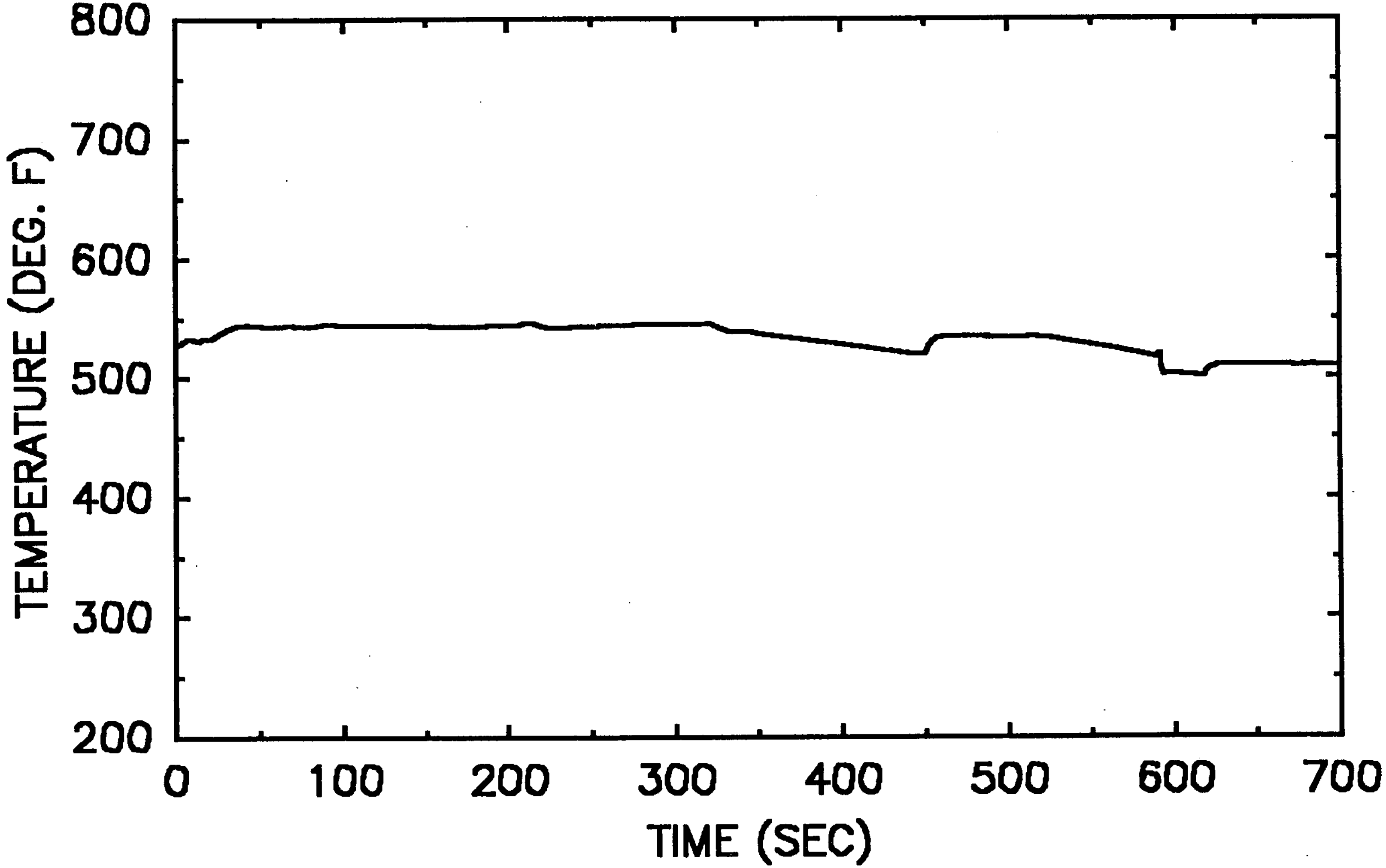

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
HOT LEG TEMPERATURE
TEMPERATURE (DEG. F)
800
700
600
500
400
300
200
0
100
200
300
400
500
600
700
TIME (SEC)

Figure 13

SONGS1 SBLOCA WITH SI UPGRADE
3 INCH BREAK
COLD LEG TEMPERATURE



FIGURES FOR 4 INCH BREAK

Figure 14

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
NORMALIZED REACTOR POWER

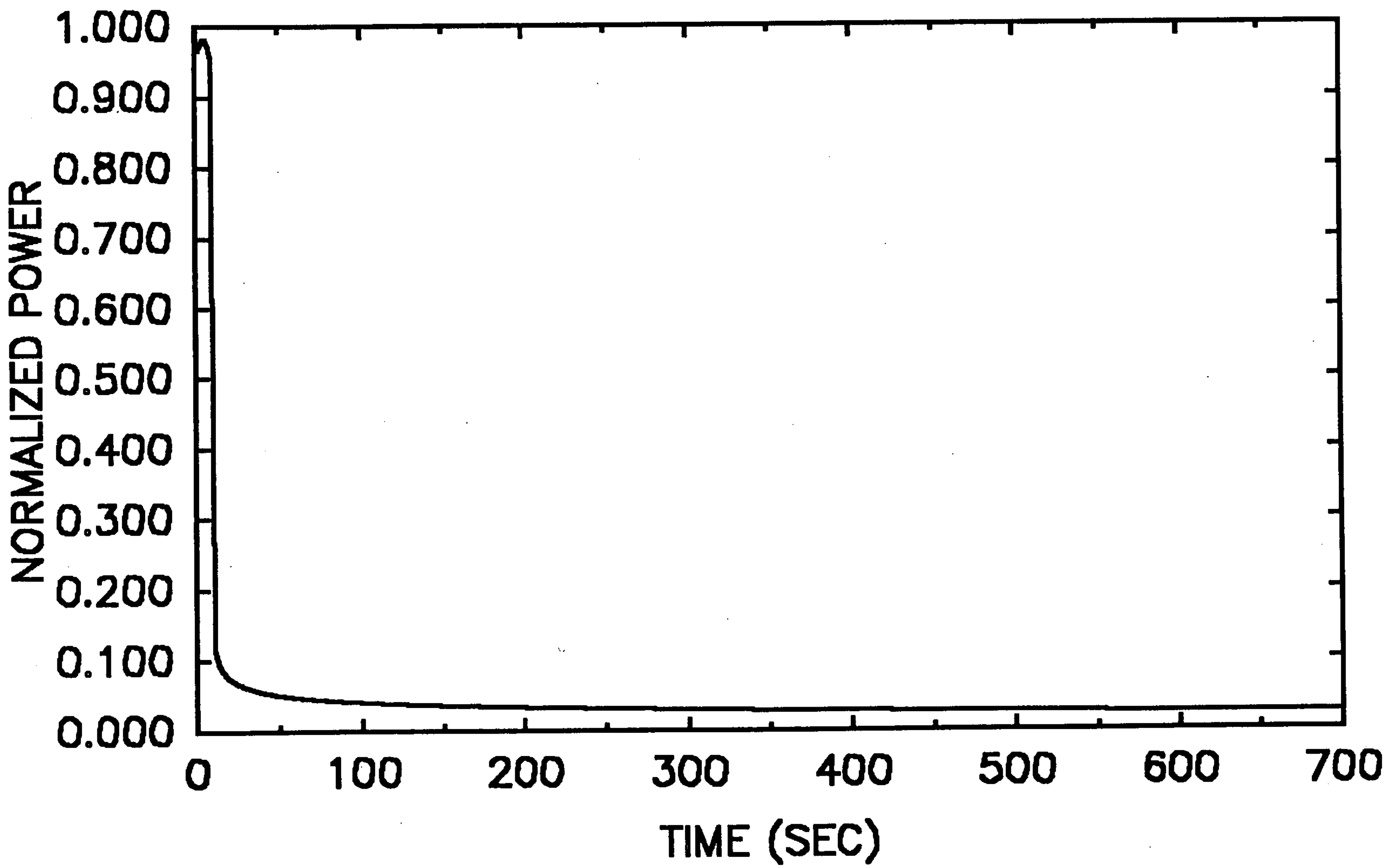


Figure 15

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
RCS PRESSURE

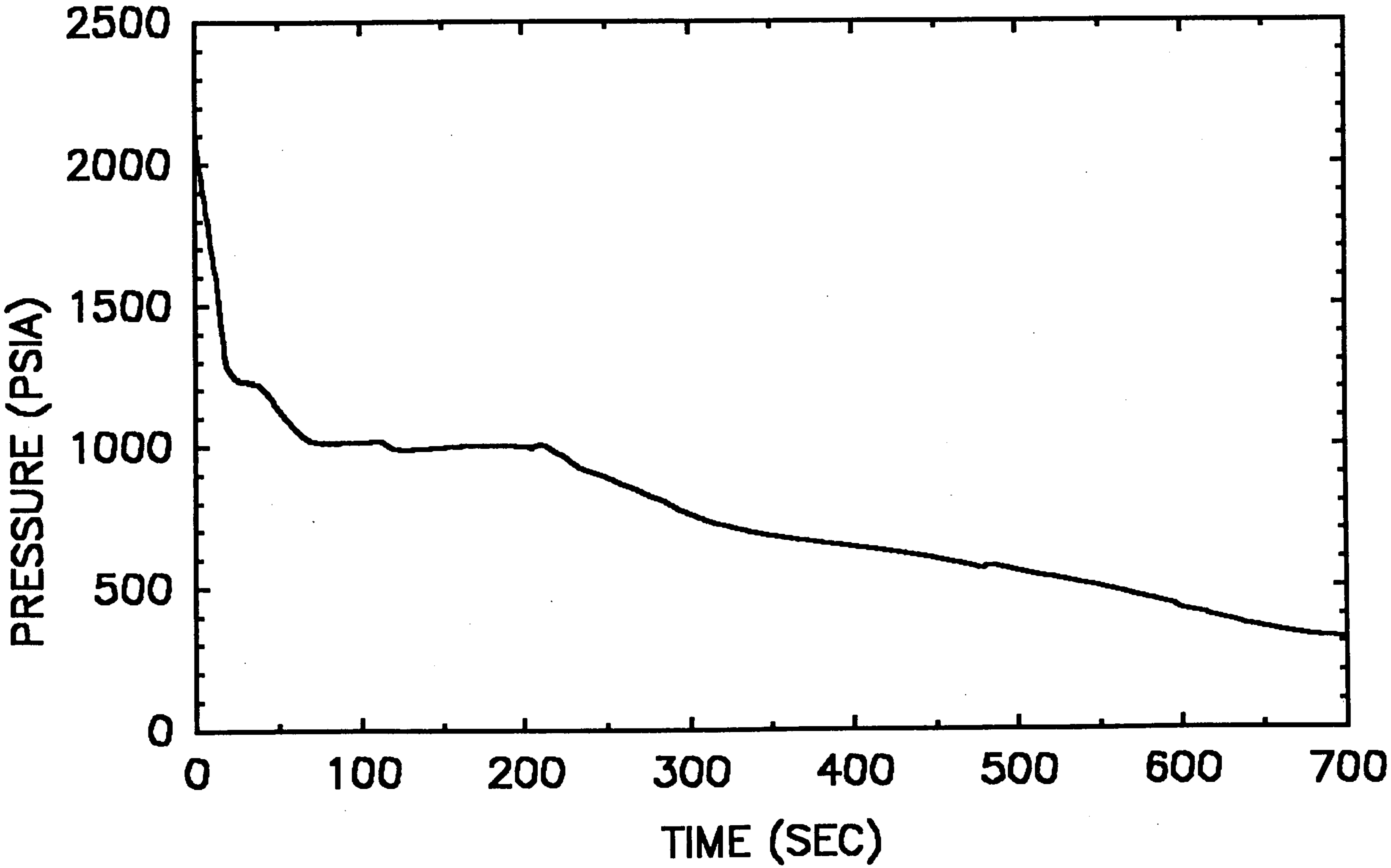


Figure 16

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
PRESSURIZER MIXTURE LEVEL

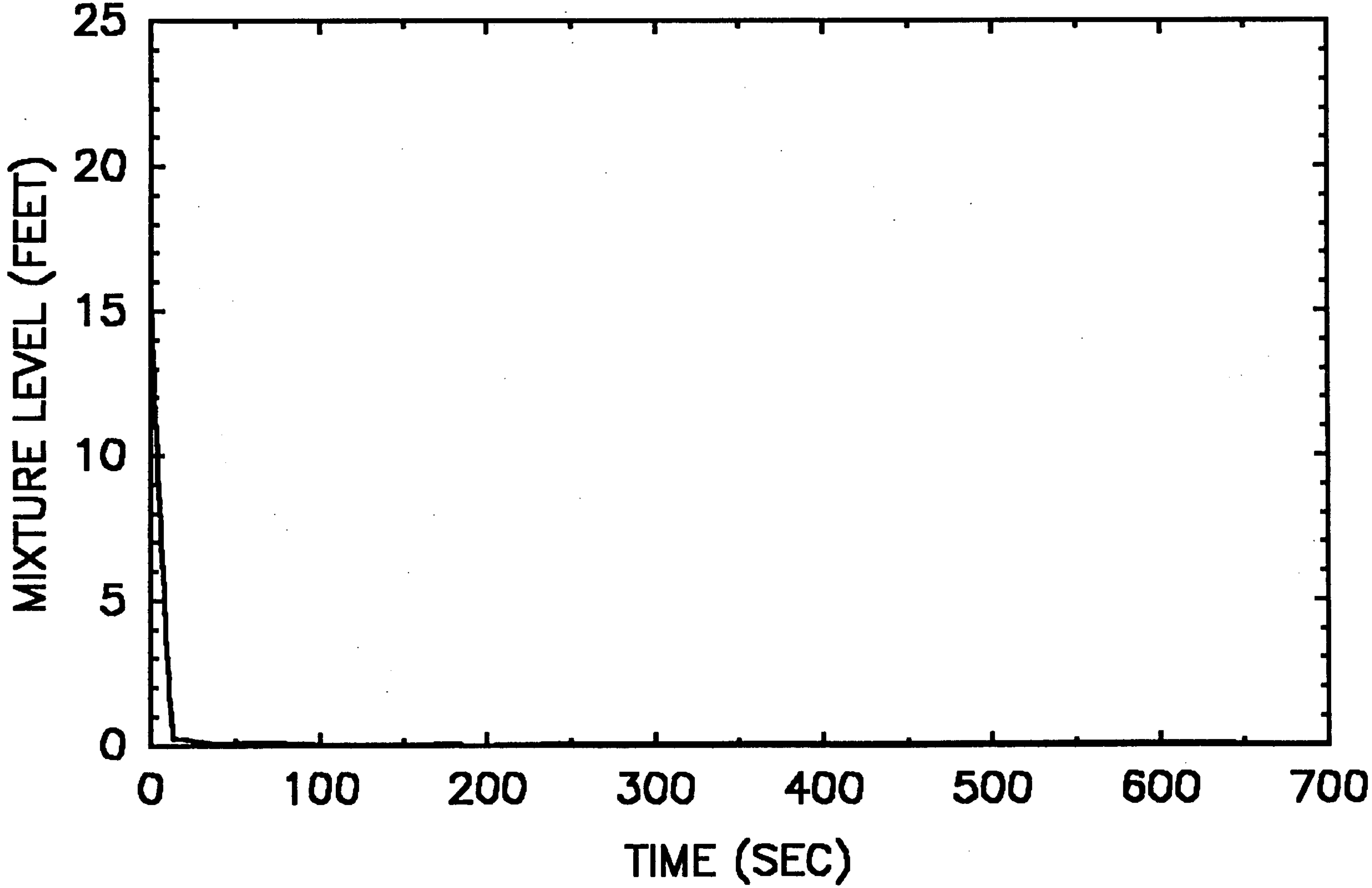


Figure 17

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
STEAM GENERATOR PRESSURE

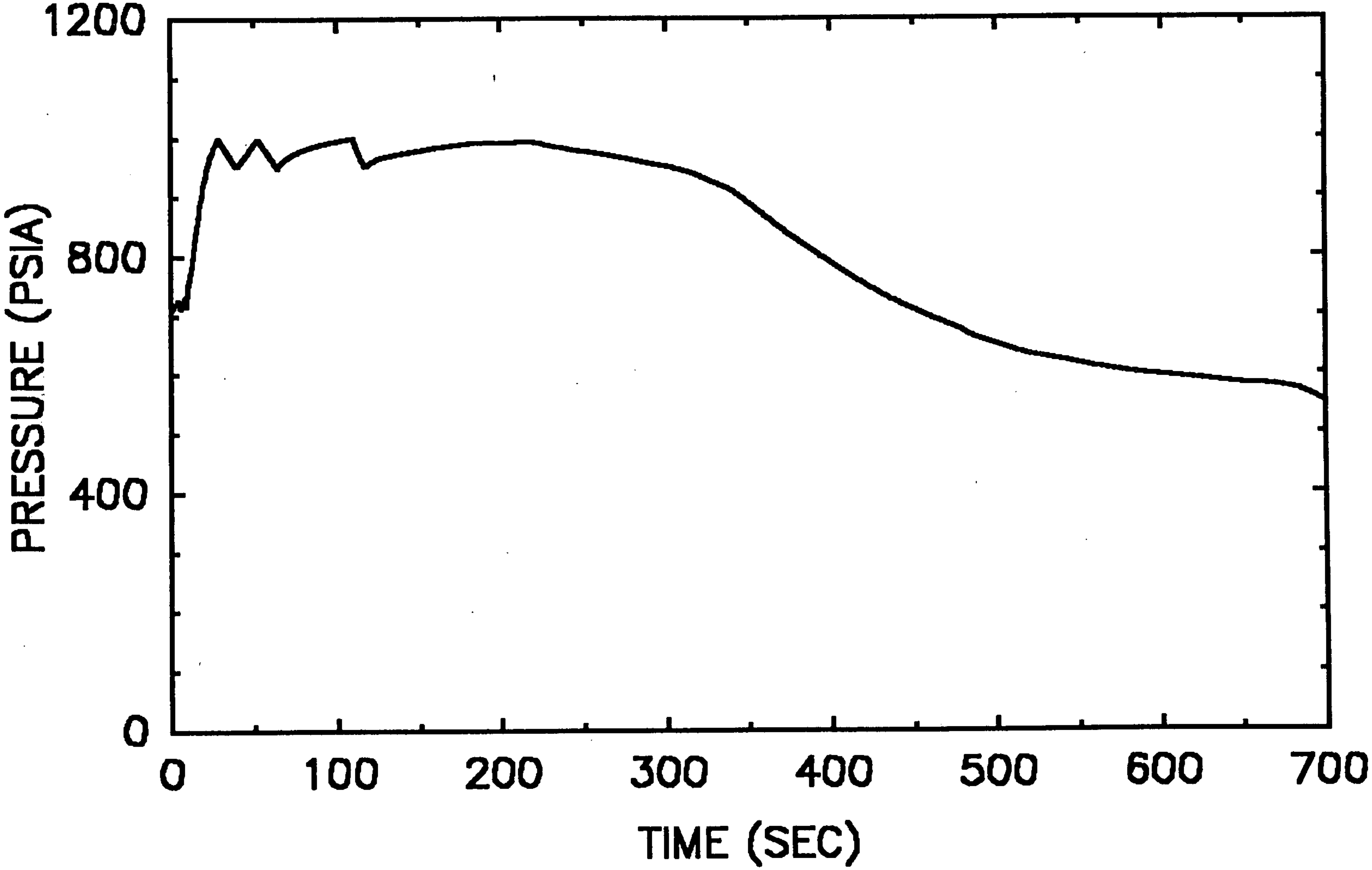
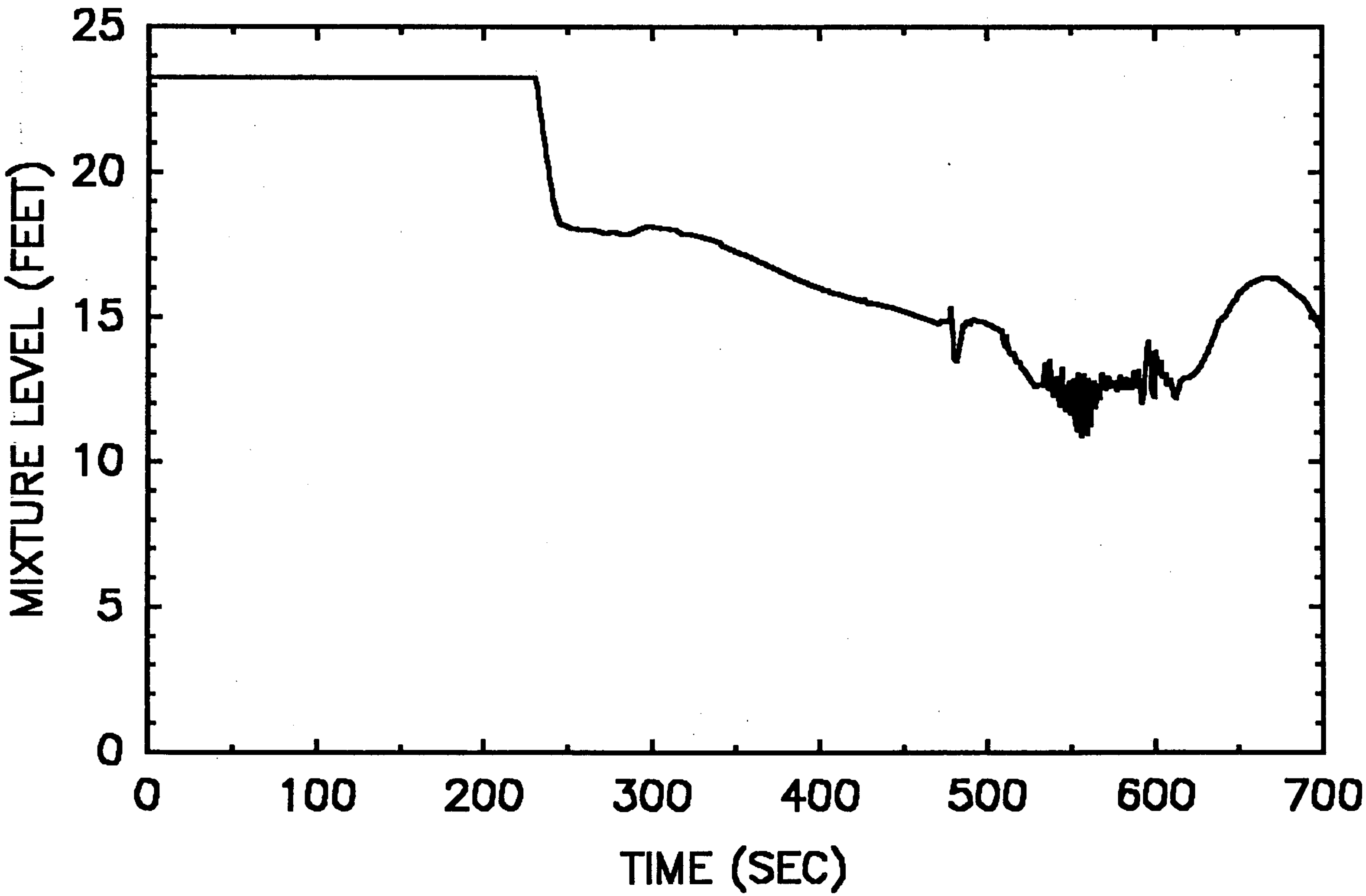


Figure 18

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
RX VESSEL DOWNCOMER MIXTURE LEVEL



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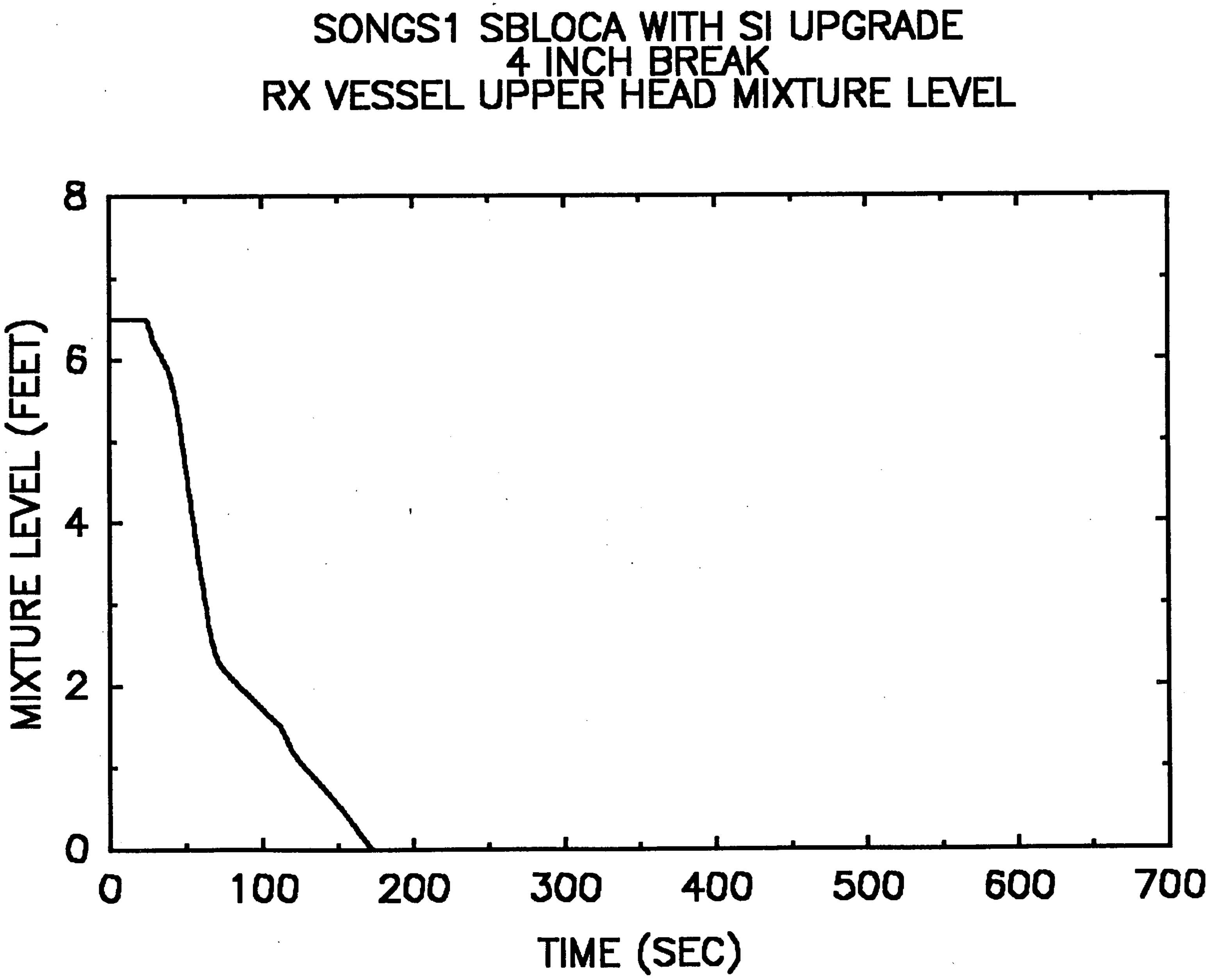


SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
RX VESSEL UPPER HEAD MIXTURE LEVEL
MIXTURE LEVEL (FEET)
0
2
4
6
8
0
100
200
300
400
500
600
700
TIME (SEC)

Figure 20

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
MIXTURE LEVEL FROM TOP OF CORE

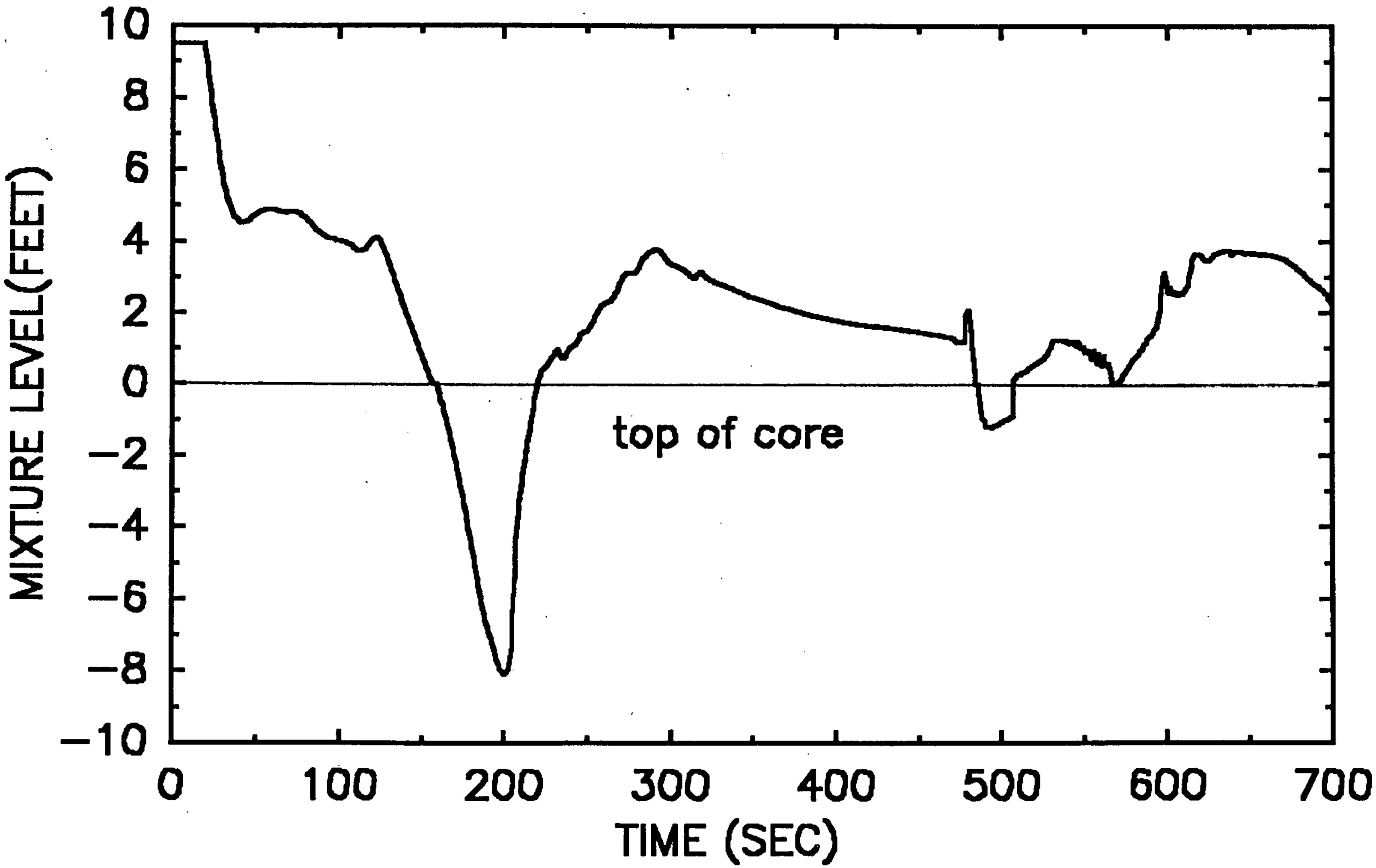


Figure 21

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
LOOP SEAL MIXTURE LEVEL

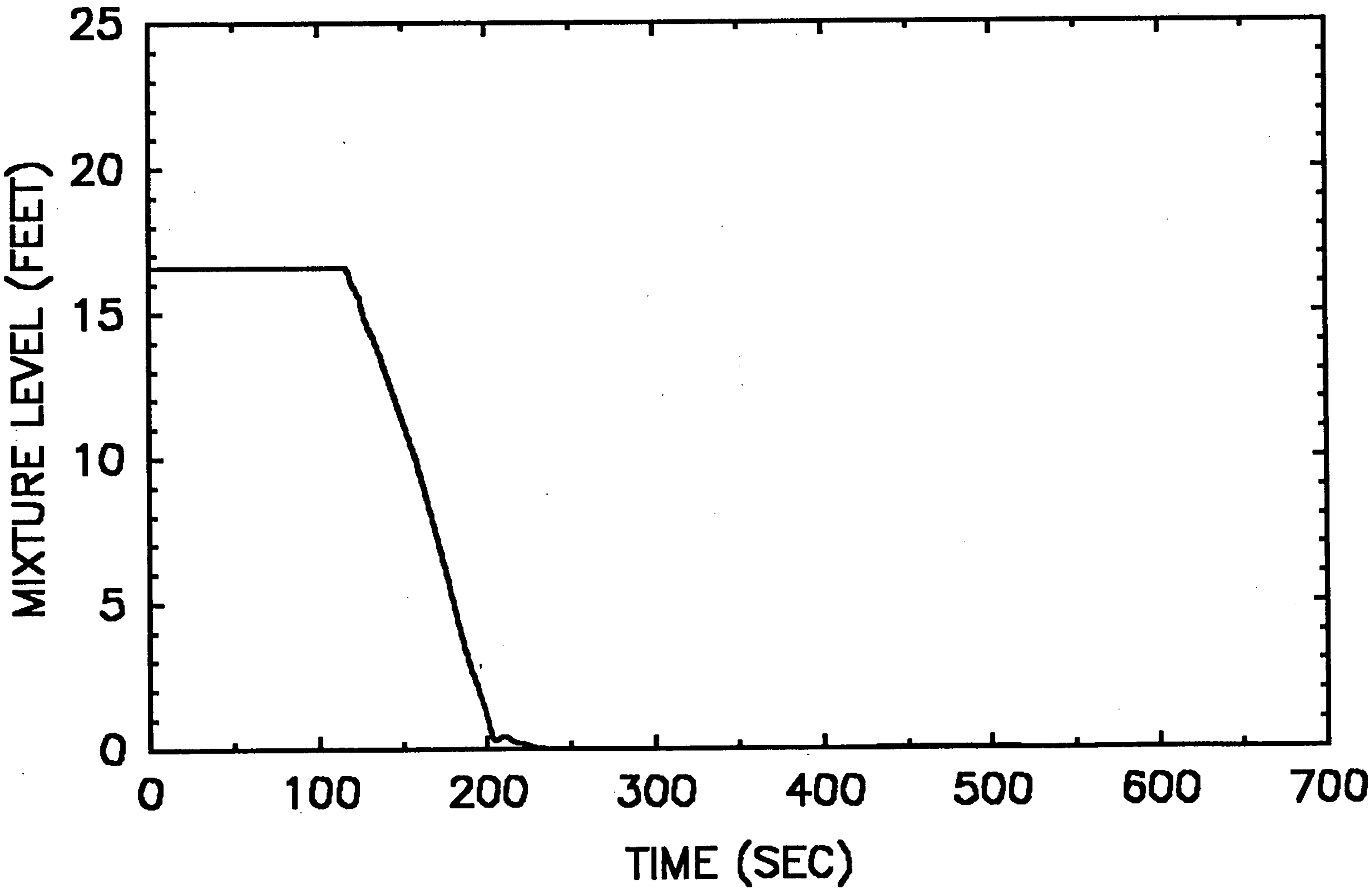
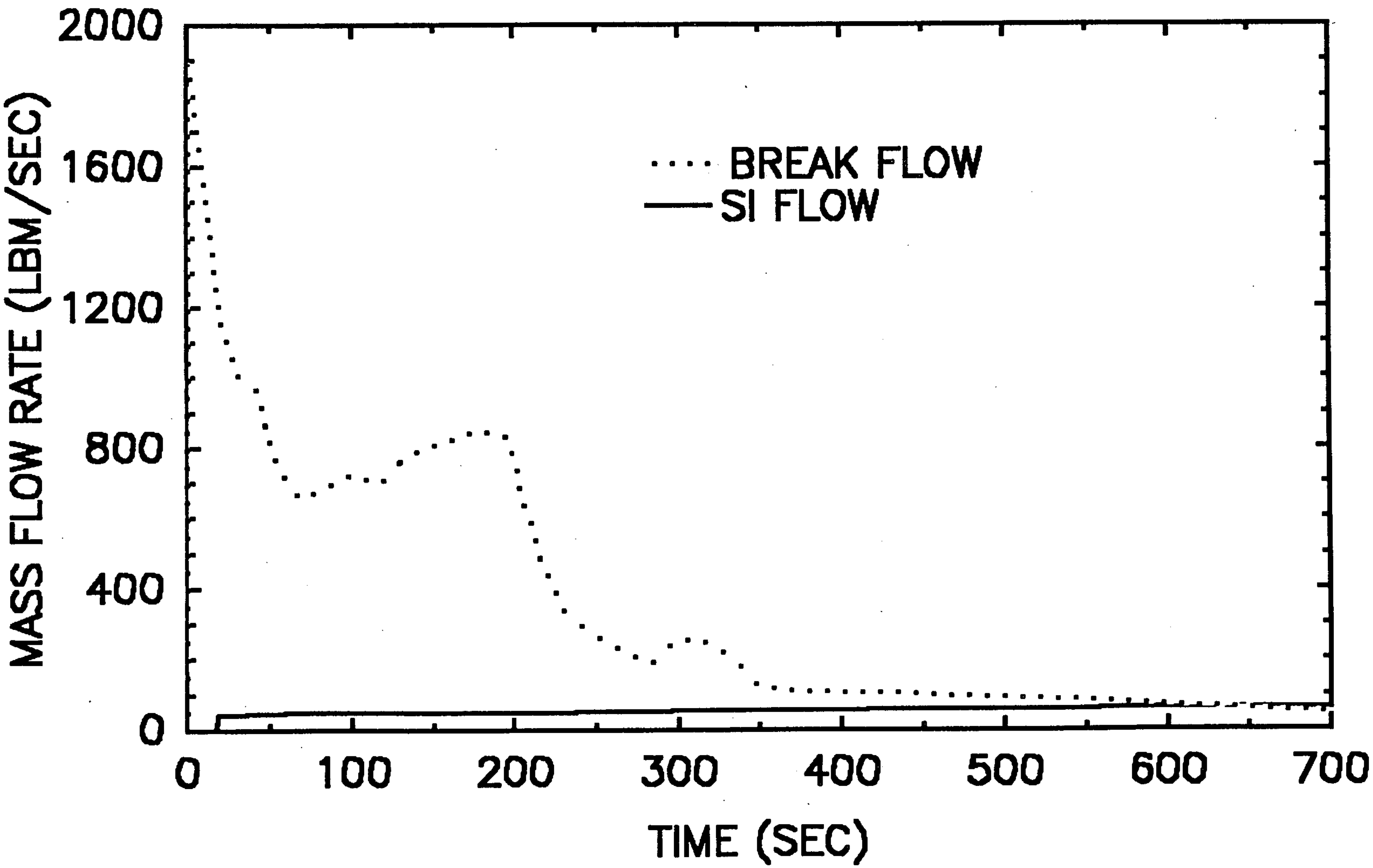


Figure 22

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
SI FLOW AND BREAK FLOW



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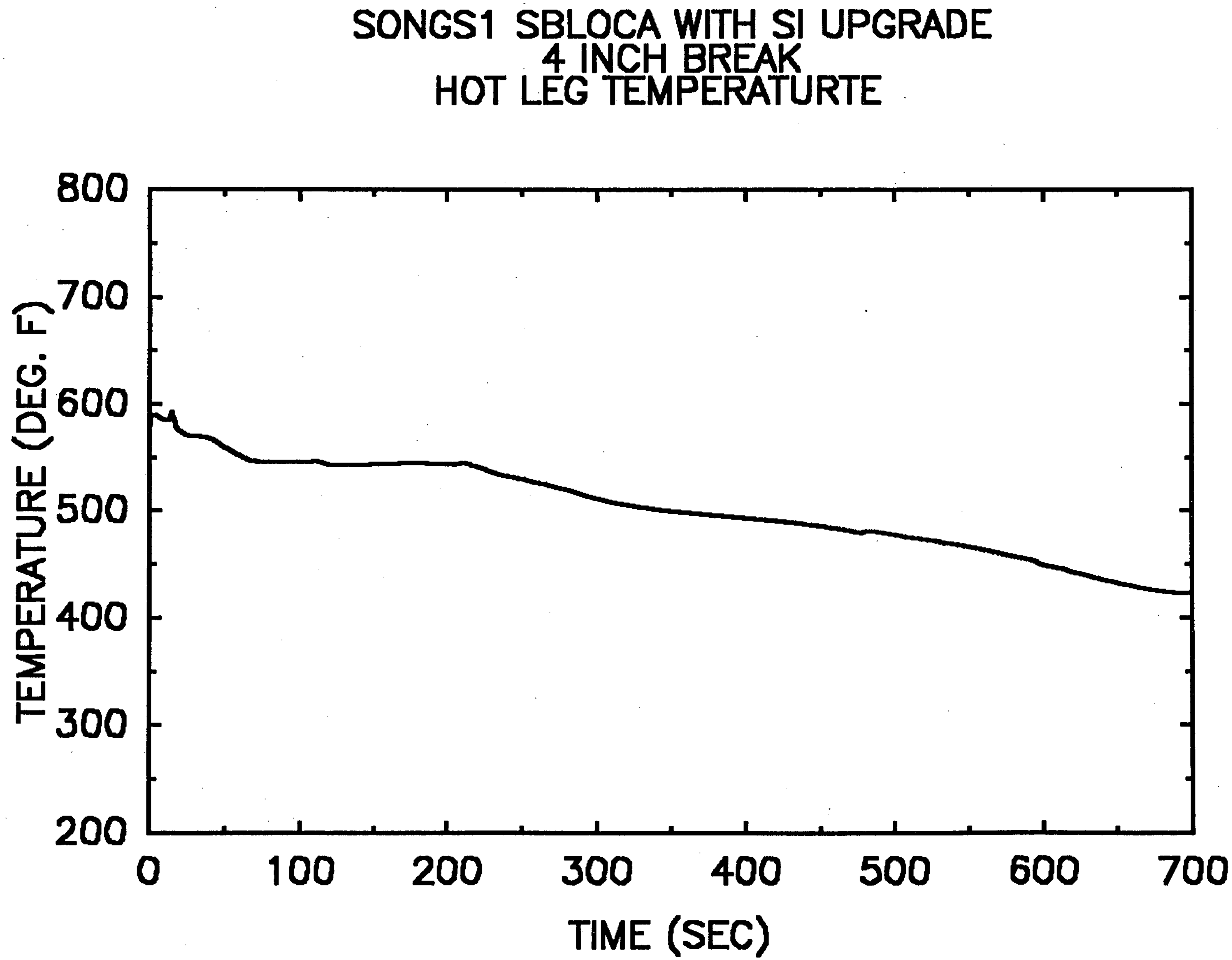
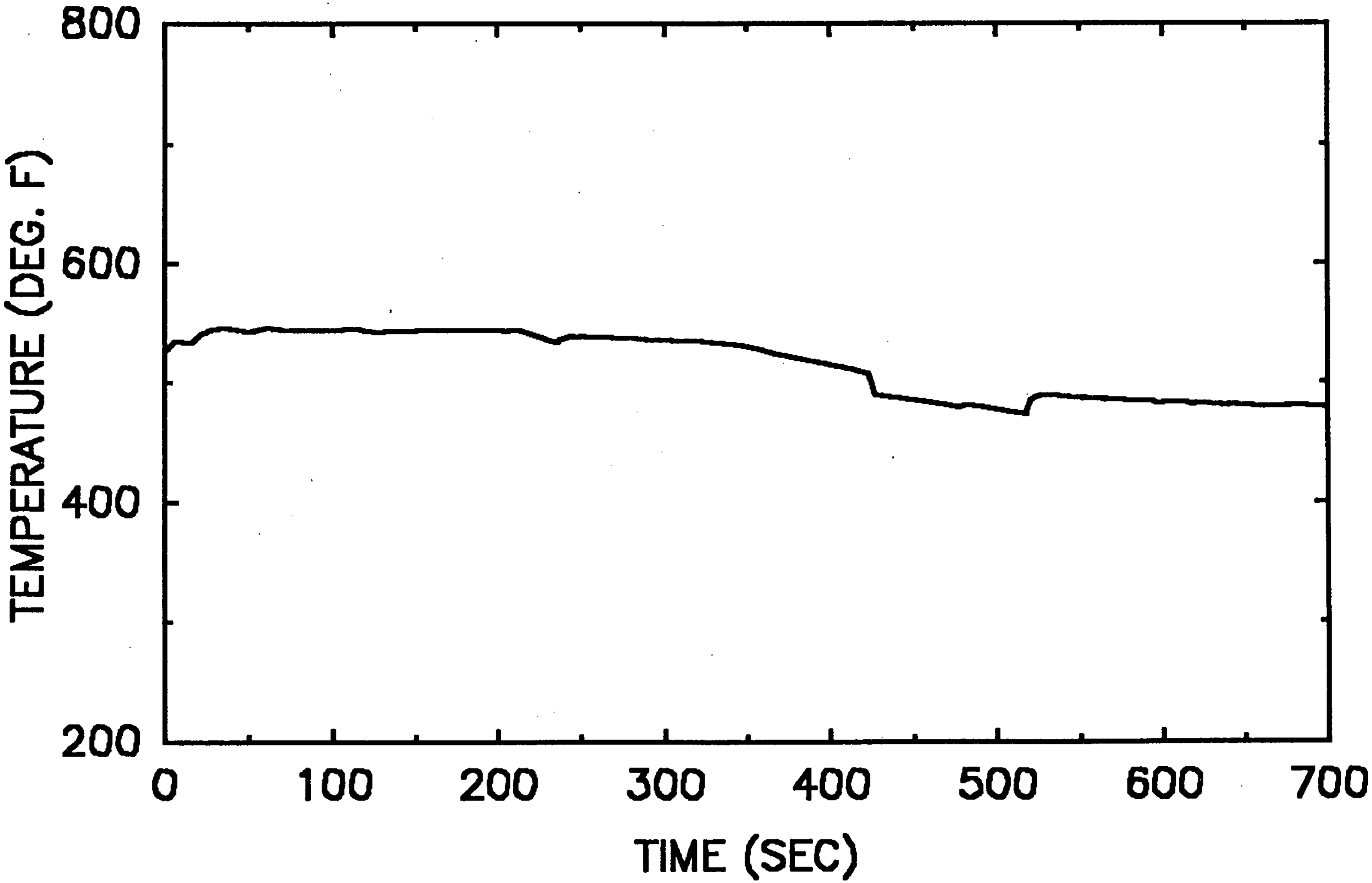

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
HOT LEG TEMPERATURTE
800
700
600
500
400
300
200
TEMPERATURE (DEG. F)
0
100
200
300
400
500
600
700
TIME (SEC)

Figure 24

SONGS1 SBLOCA WITH SI UPGRADE
4 INCH BREAK
COLD LEG TEMPERATURE



FIGURES FOR 6 INCH BREAK

Figure 25

SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
NORMALIZED REACTOR POWER

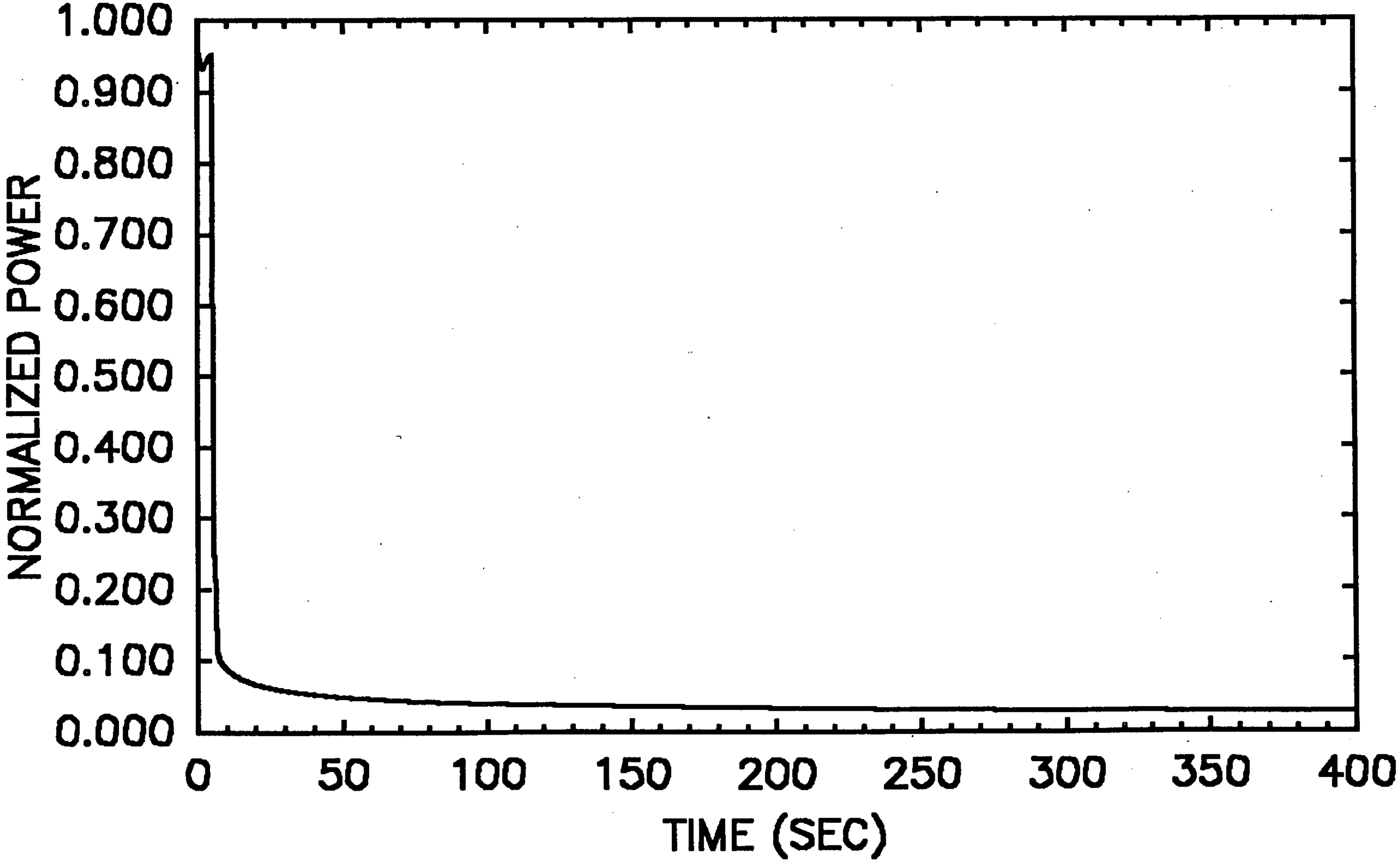


Figure 26

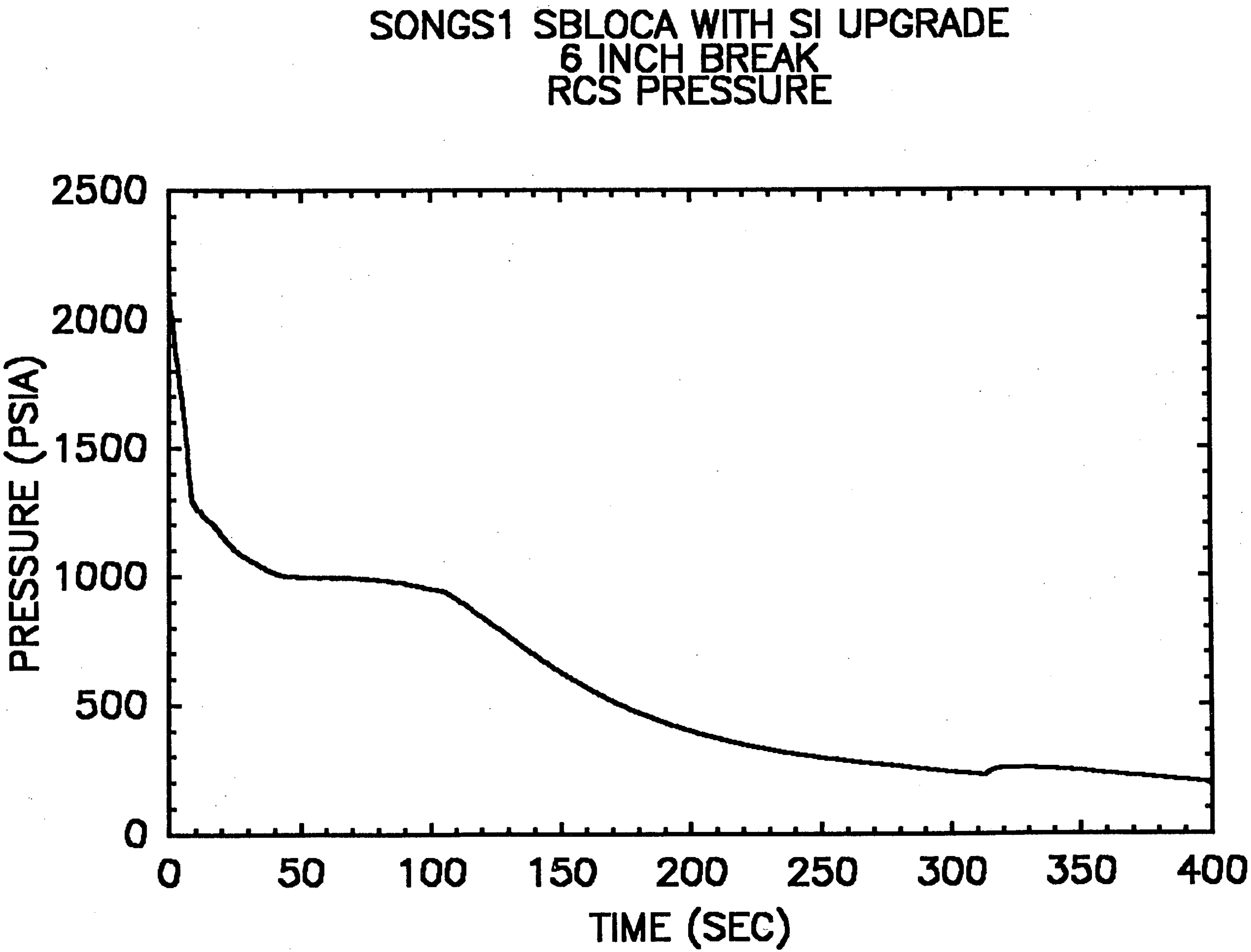

SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
RCS PRESSURE
PRESSURE (PSIA)
2500
2000
1500
1000
500
0
0
50
100
150
200
250
300
350
400
TIME (SEC)

Figure 27

SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
PRESSURIZER MIXTURE LEVEL

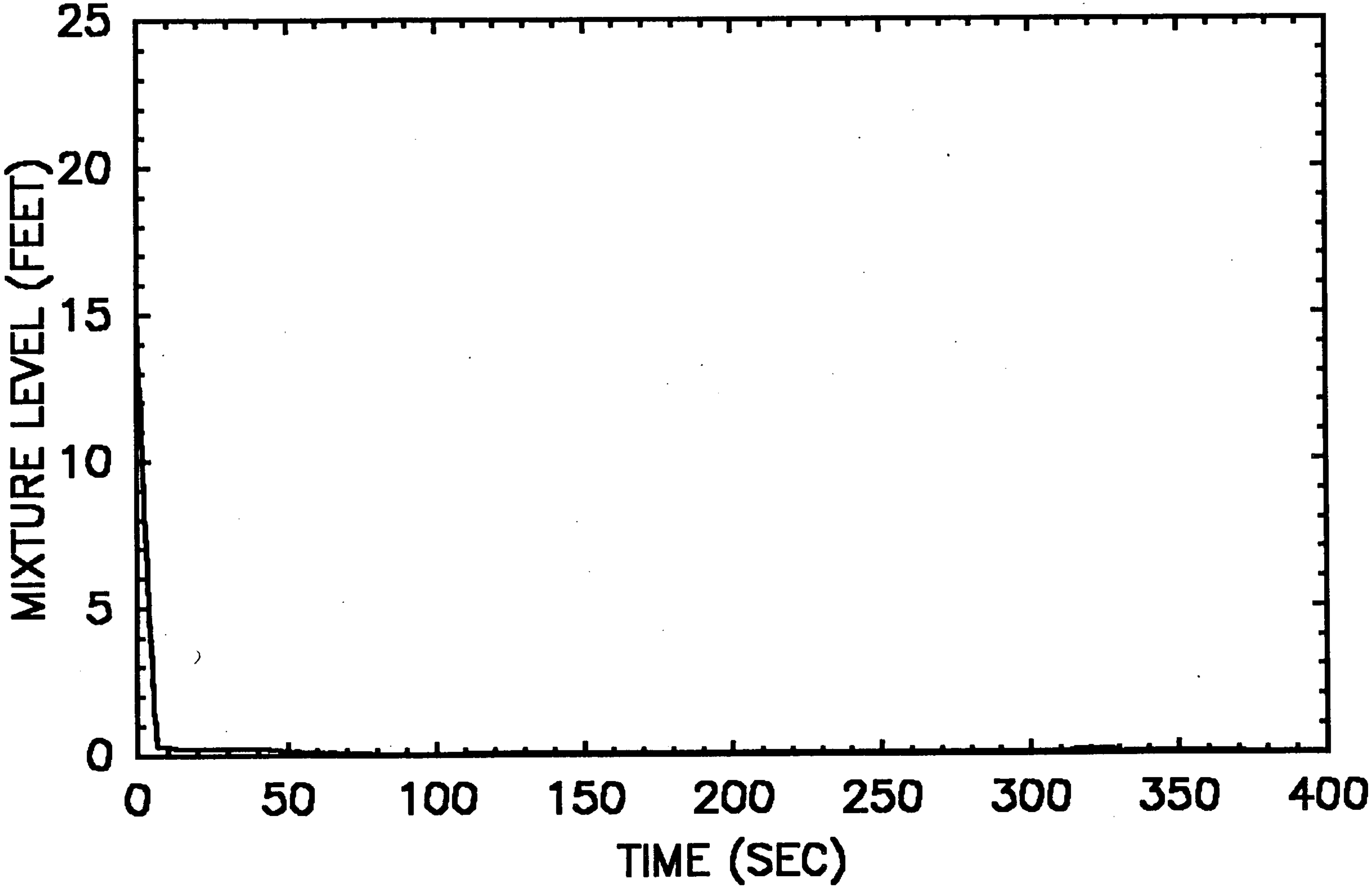


Figure 28

SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
STEAM GENERATOR PRESSURE

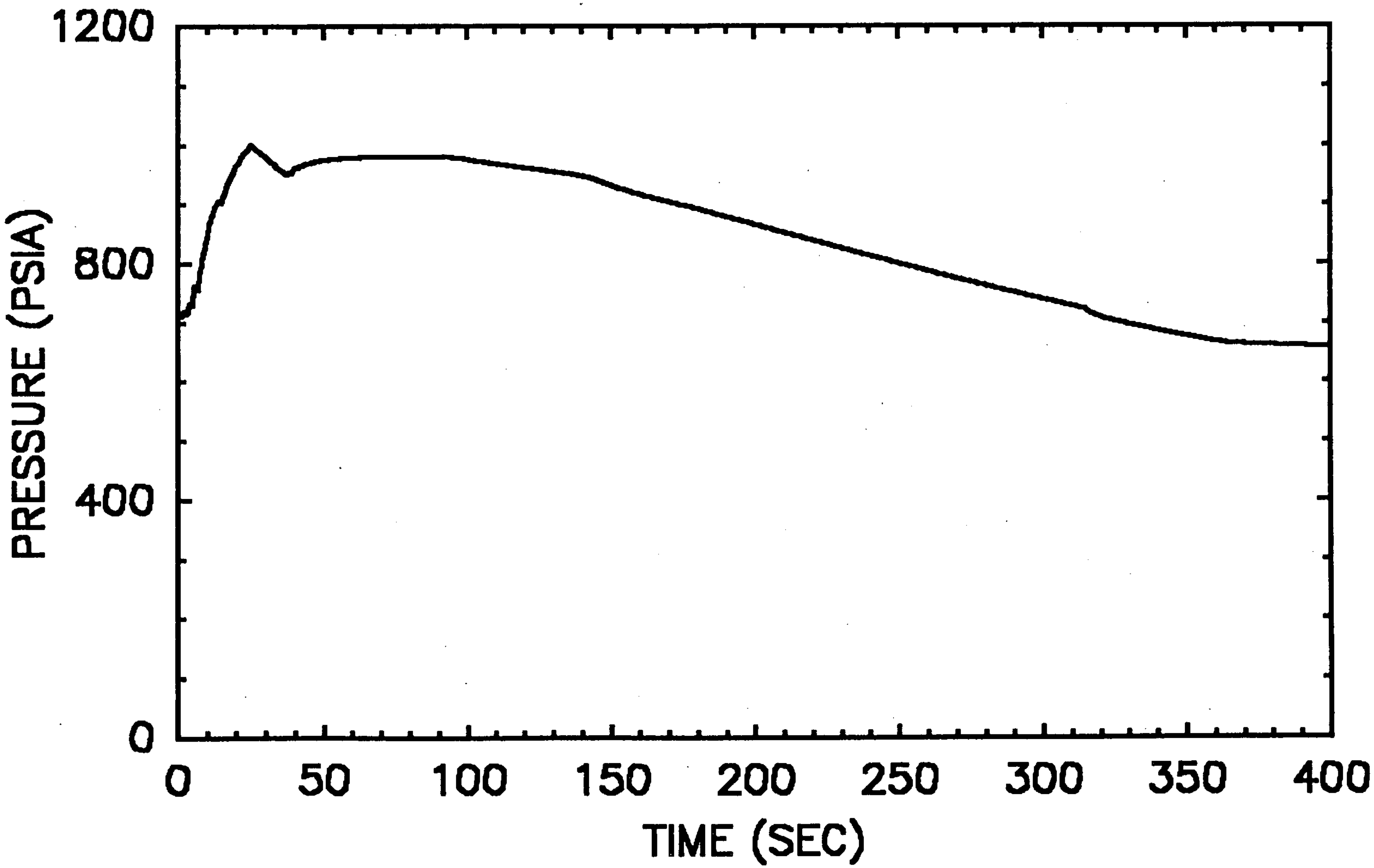


Figure 29
SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
RX VESSEL UPPER HEAD MIXTURE LEVEL

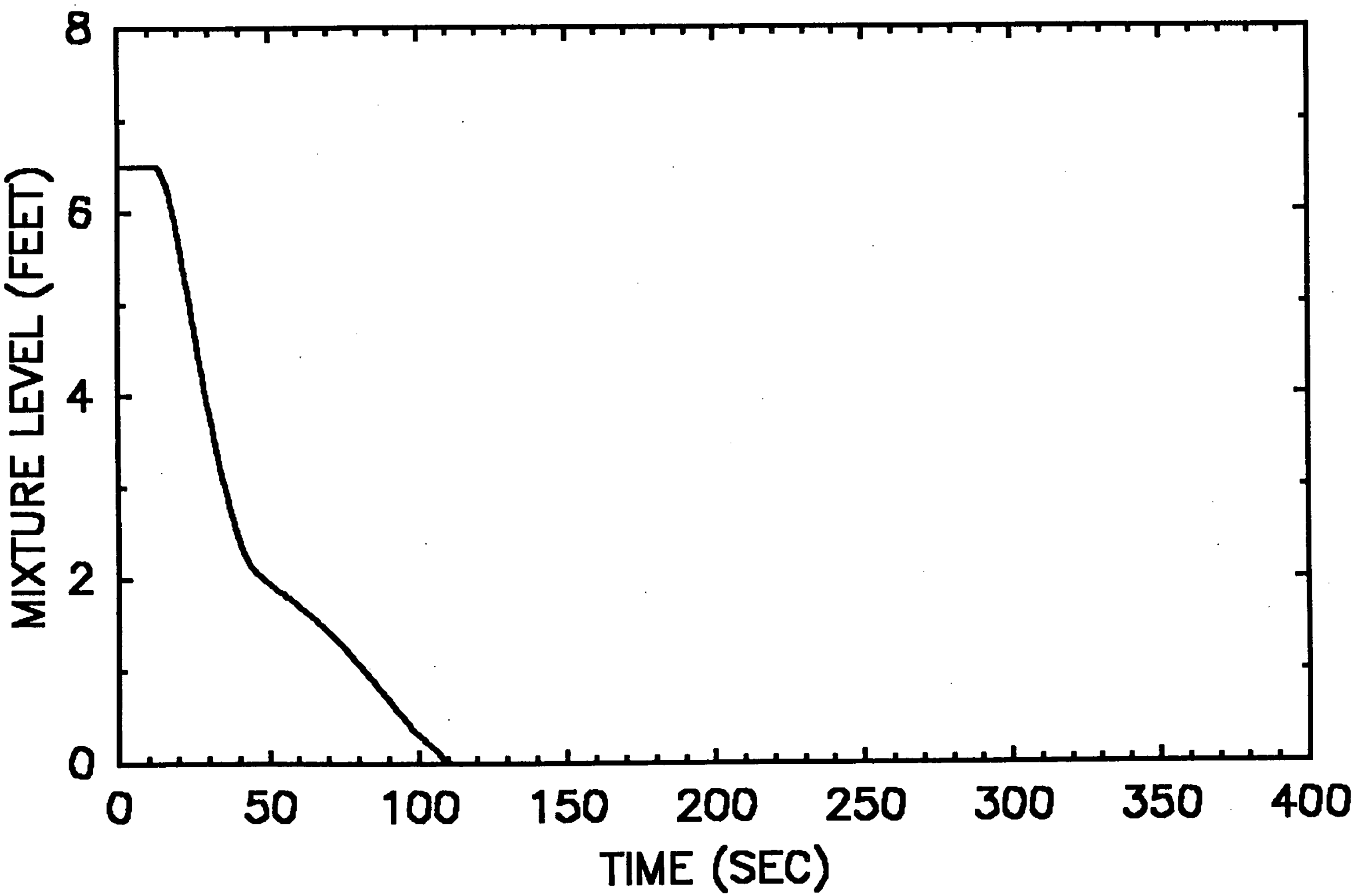


Figure 30

SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
REACTOR VESSEL DOWNCOMER MIXTURE LEVEL

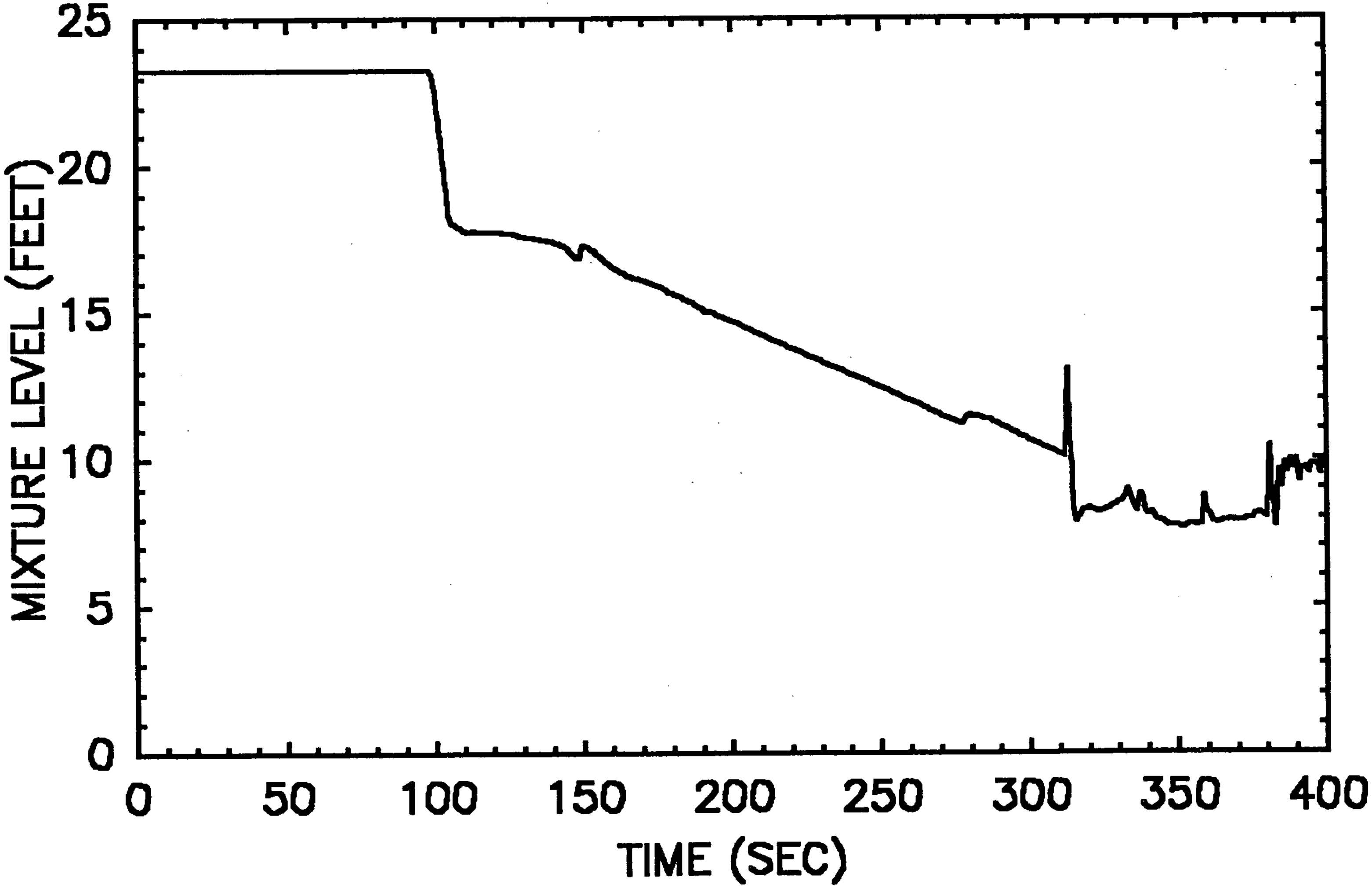


Figure 31

SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
MIXTURE LEVEL FROM TOP OF CORE

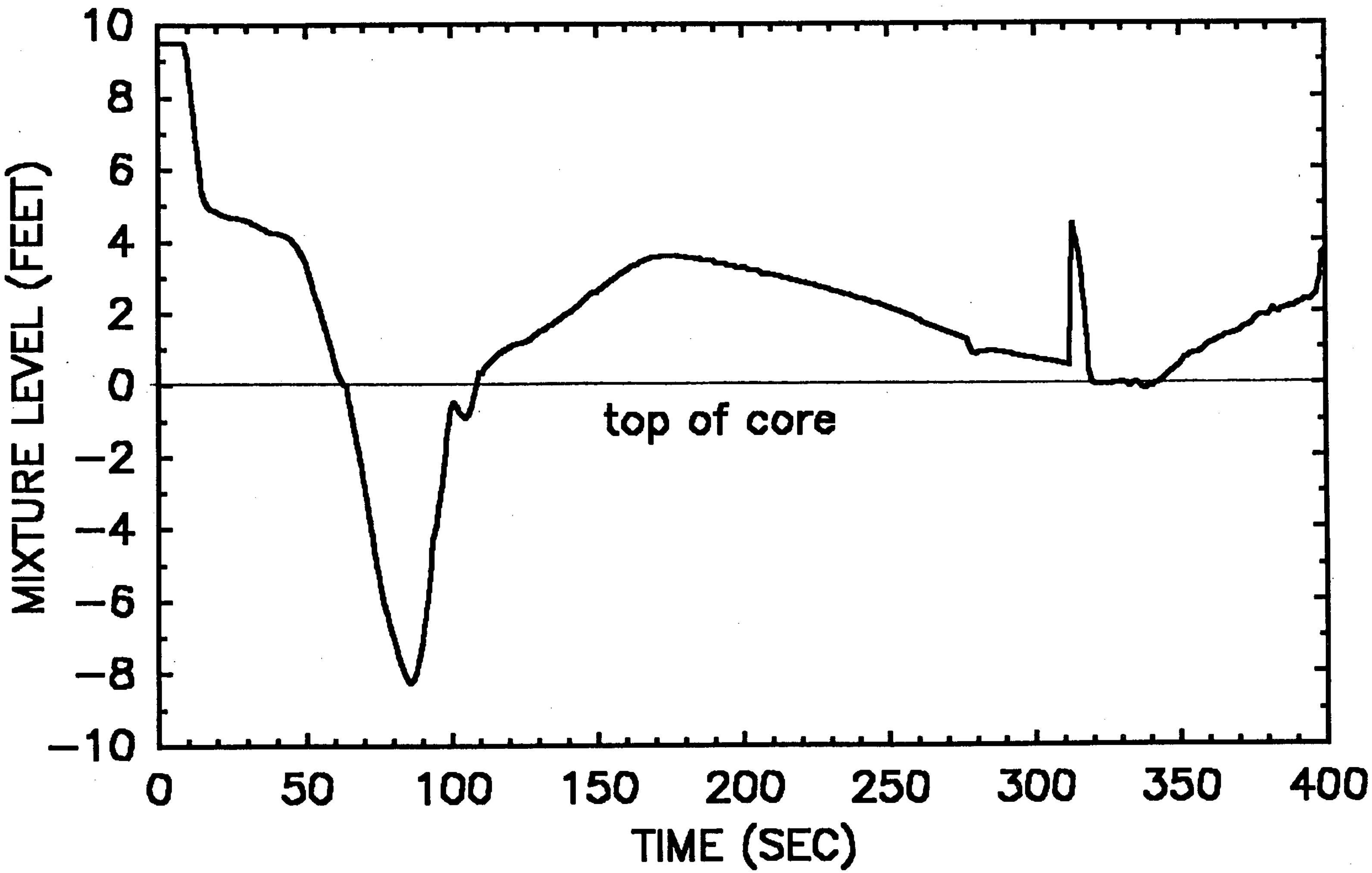
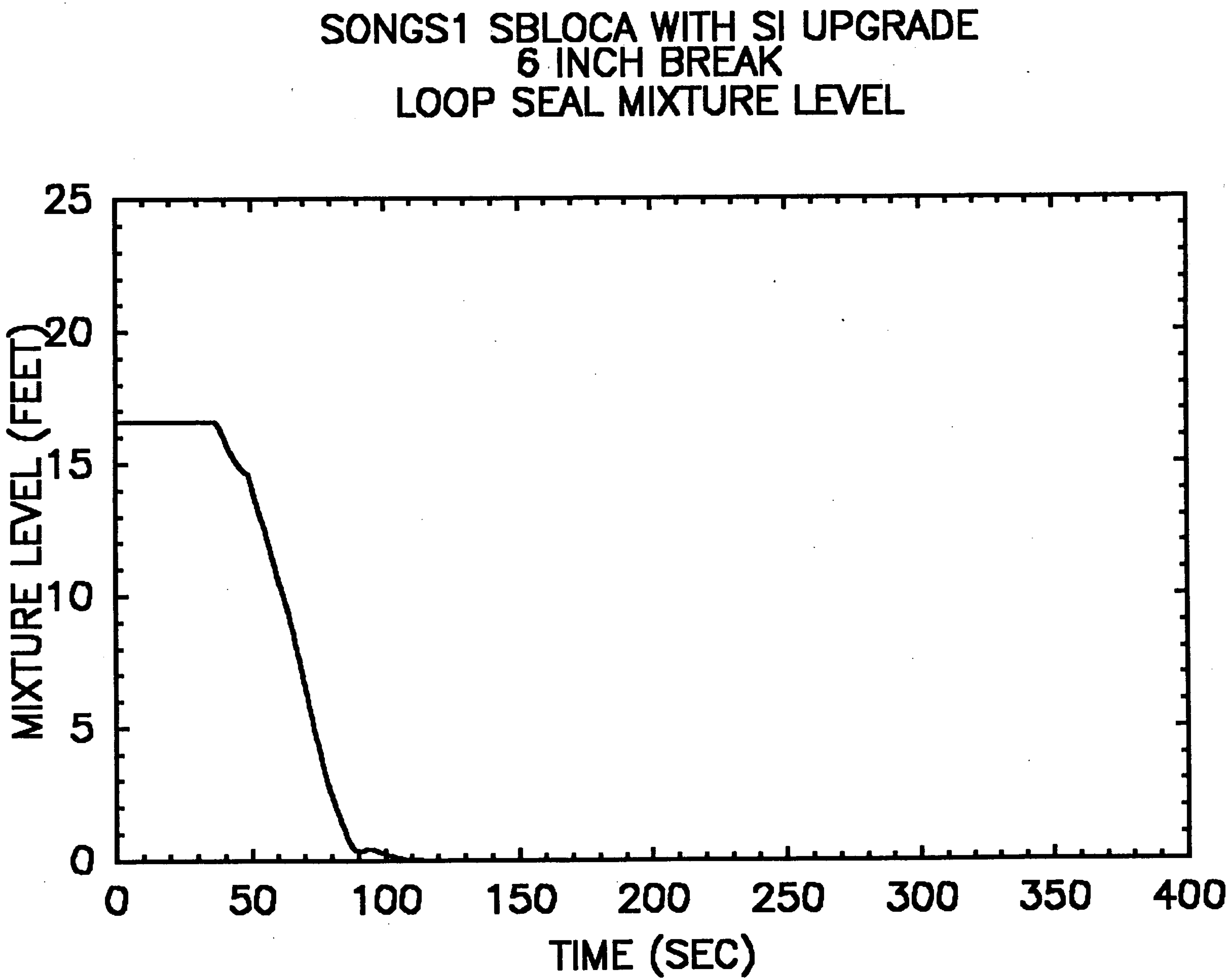


Figure 32



SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
LOOP SEAL MIXTURE LEVEL
MIXTURE LEVEL (FEET)
25
20
15
10
5
0
0
50
100
150
200
250
300
350
400
TIME (SEC)

Figure 33
SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
BREAK FLOW AND SI MASS FLOW RATE

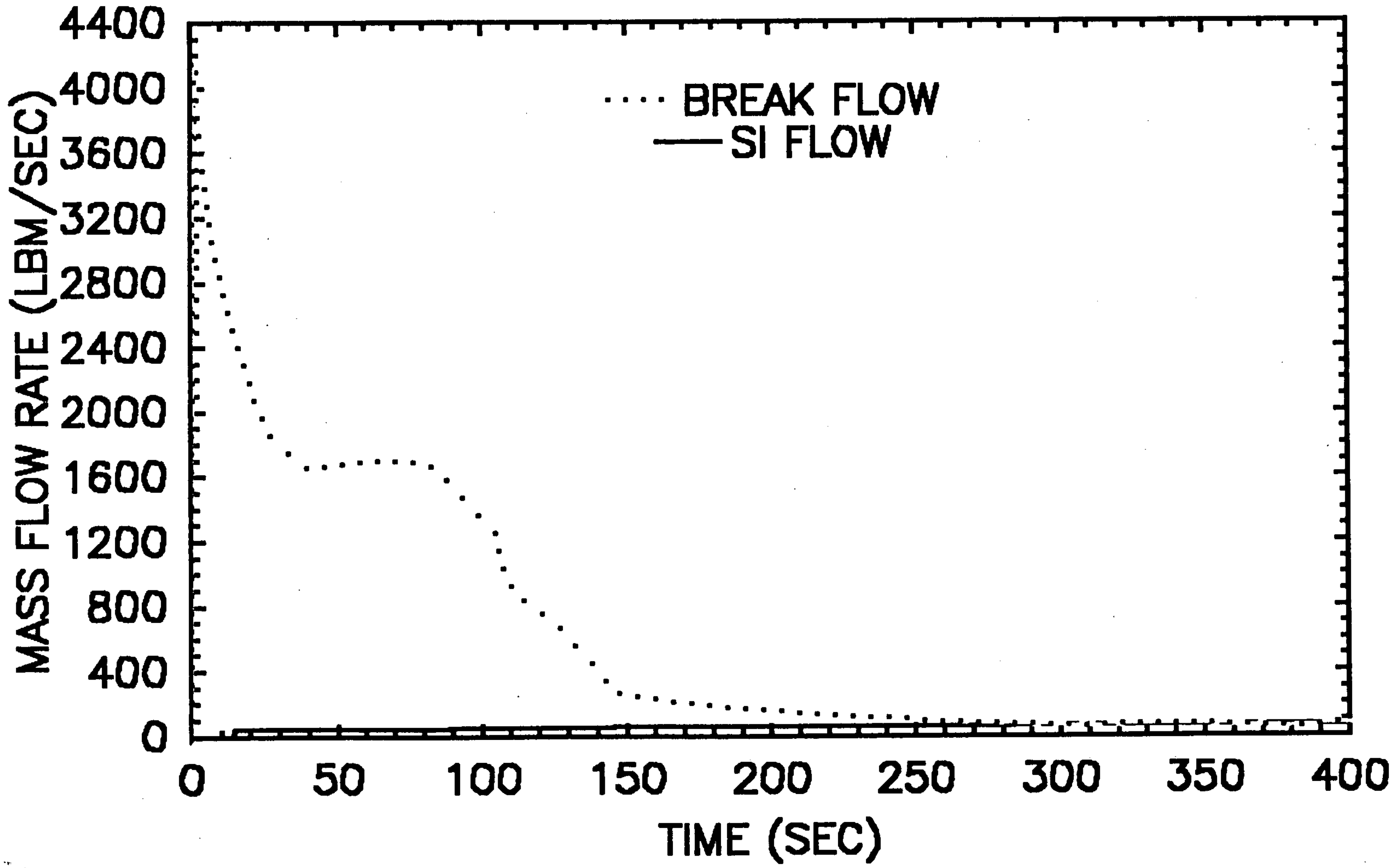


Figure 34

SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
HOT LEG TEMPERATURE

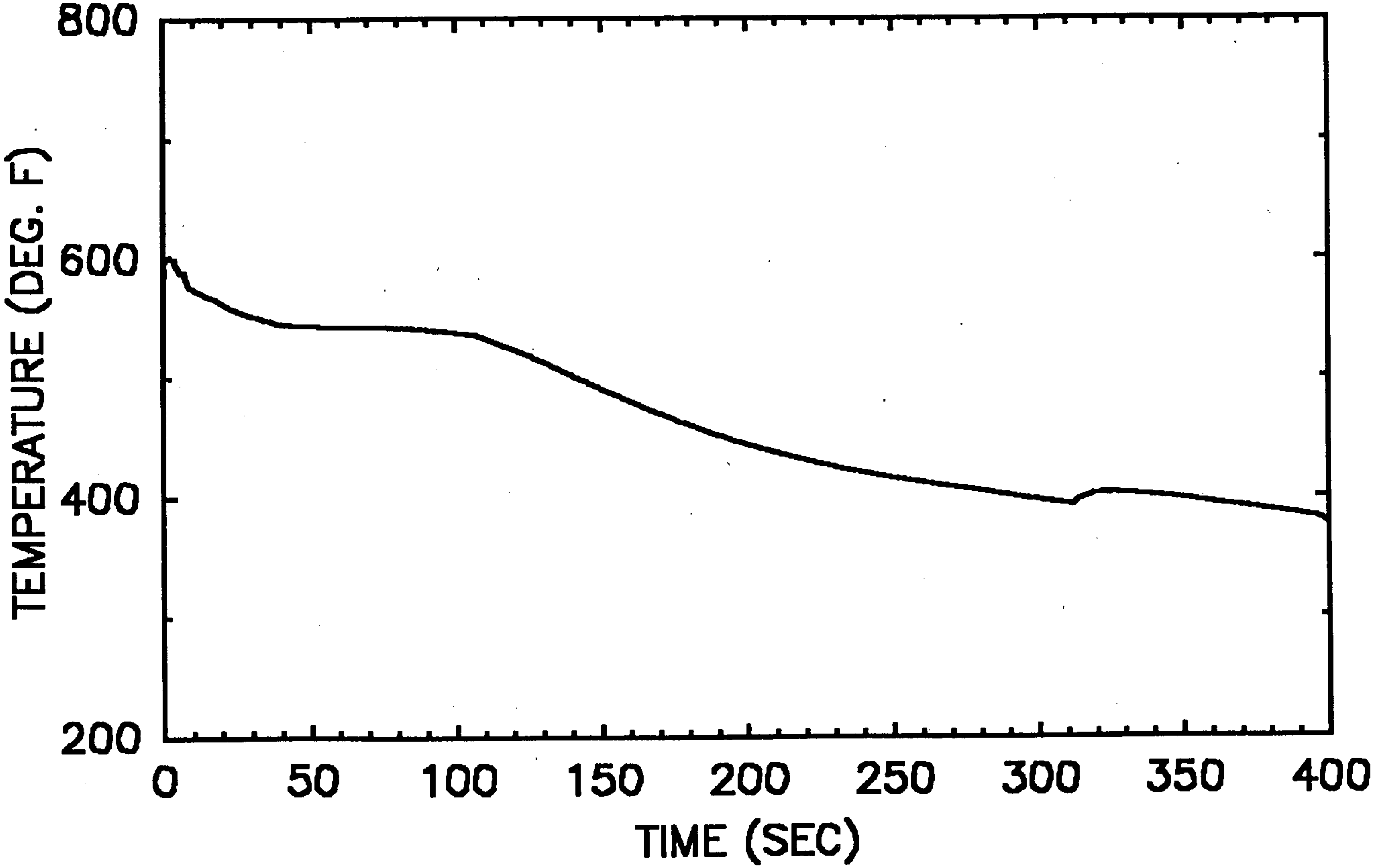
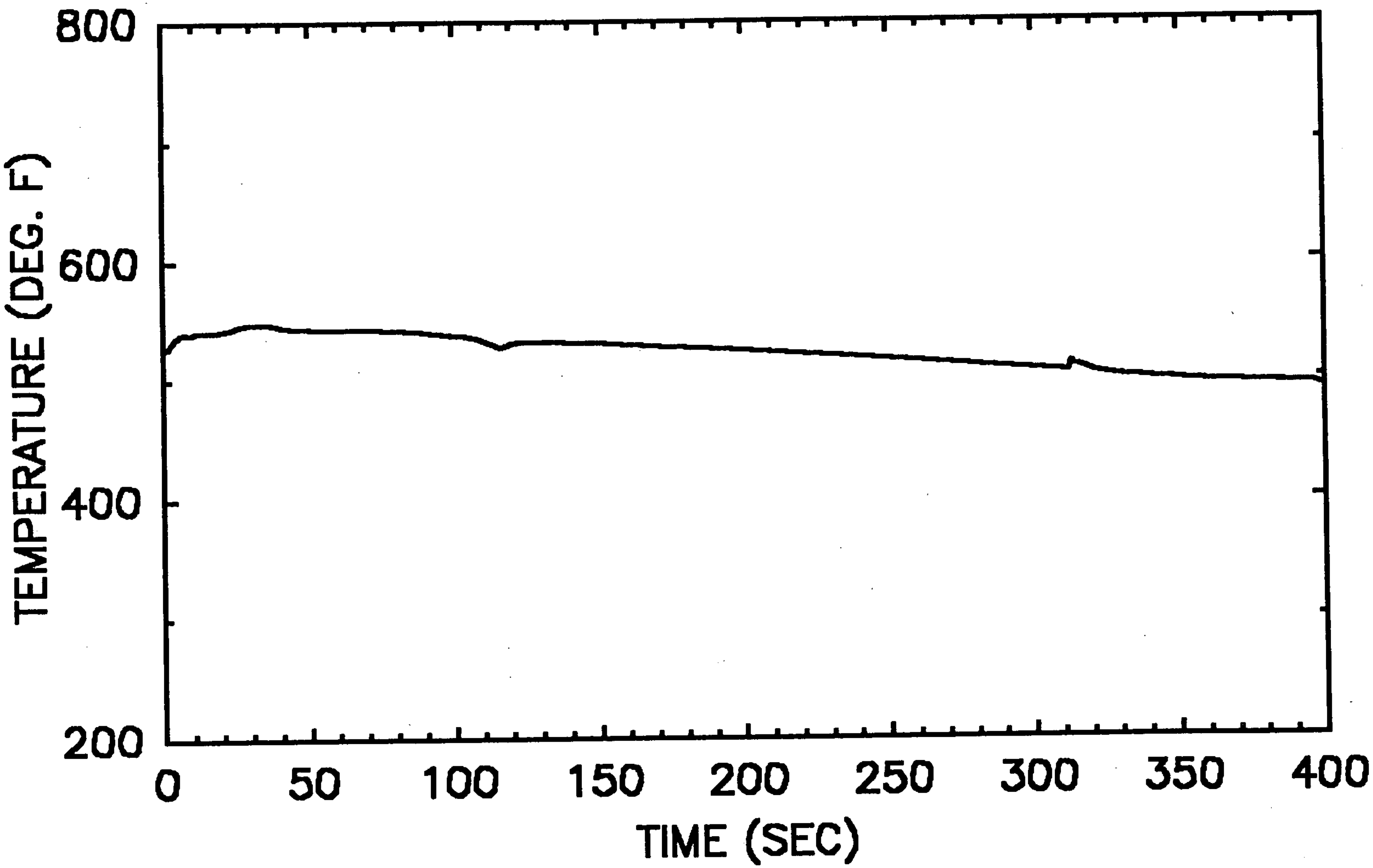


Figure 35

SONGS1 SBLOCA WITH SI UPGRADE
6 INCH BREAK
COLD LEG TEMPERATURE



APPENDIX 1

ENHANCED CHARGING/SI BYPASS

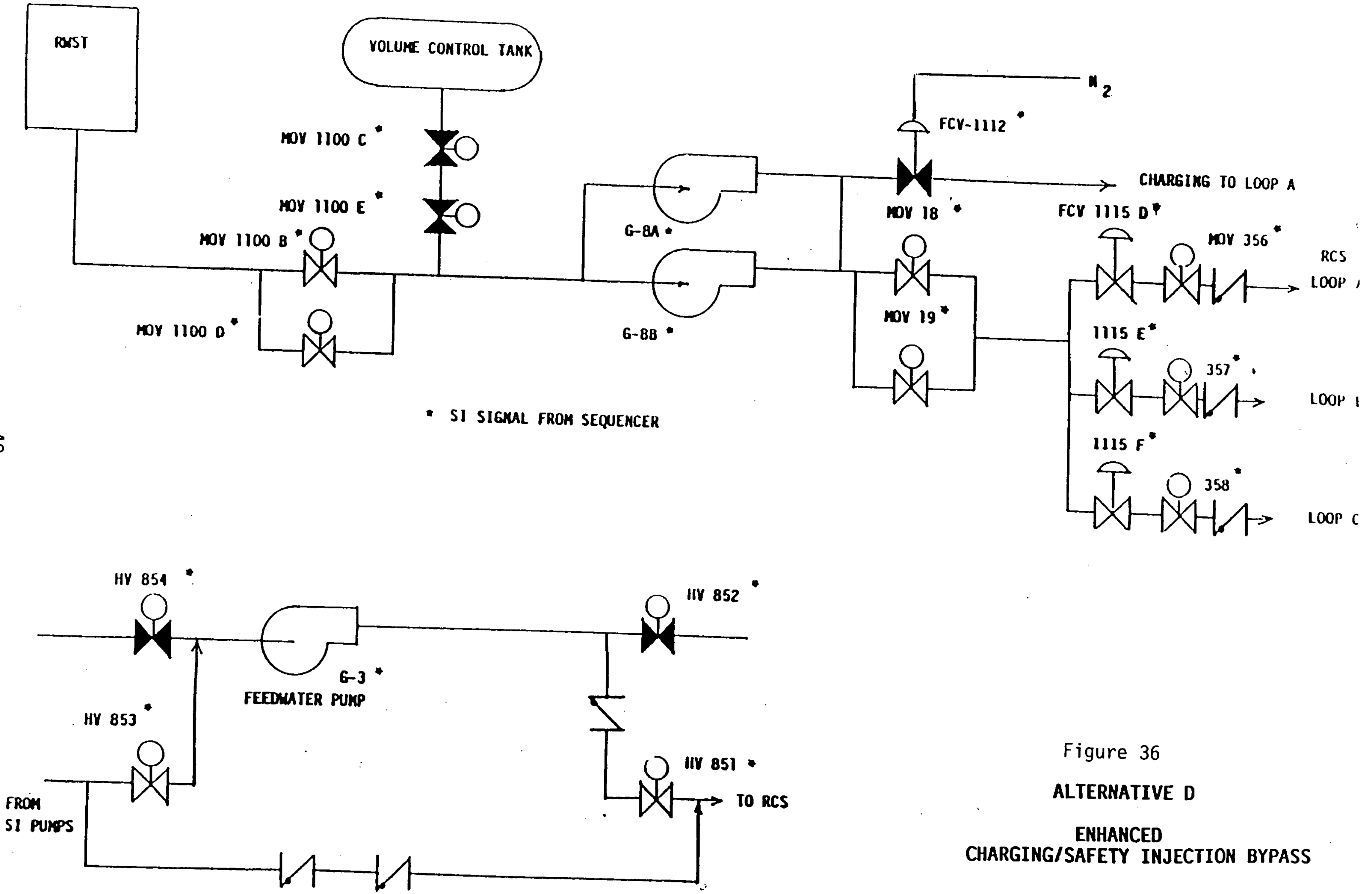
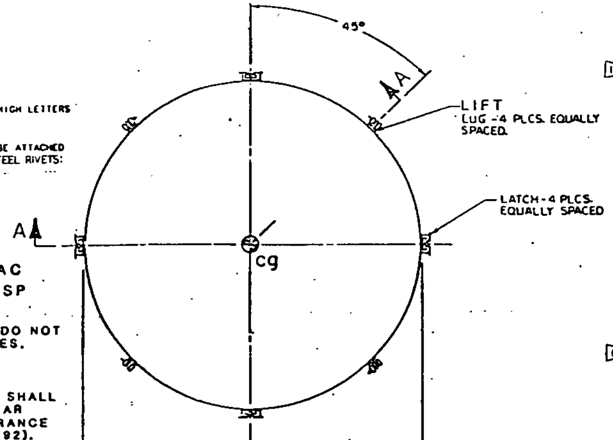


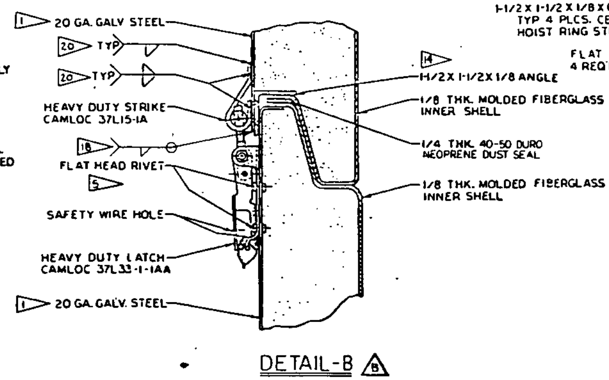
Figure 36

ALTERNATIVE D

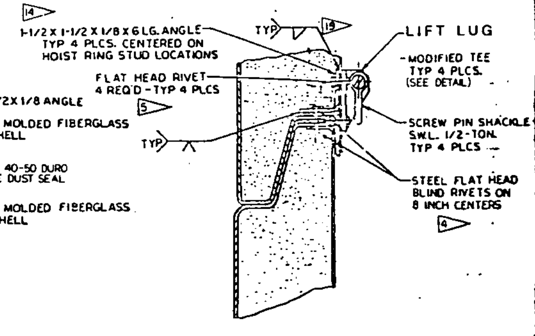
ENHANCED
CHARGING/SAFETY INJECTION BYPASS

LTR	DESCRIPTION	DATE	APPROVED
A	SEE DCN	10/87	[illegible]
B	SEE DCN	[illegible]	[illegible]

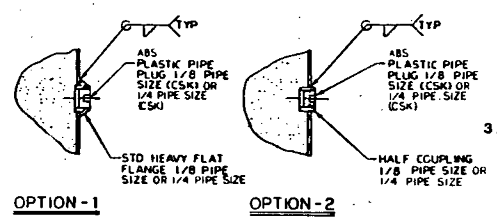




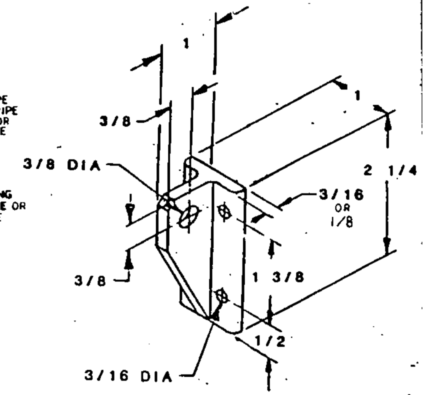
DETAIL-B (B)



DETAIL-C (B)



DETAIL-D (B)



LIFT LUG DETAIL (B)

12. STENCIL USA/9070/B(U). TYPE B IN 1/2 INCH HIGH LETTERS ON THE EXTERIOR SIDE OF THE OVERPACK.

11. (B) A STEEL NAMEPLATE WITH THE FOLLOWING DATA SHALL BE ATTACHED TO THE EXTERIOR SIDE OF THE OVERPACK WITH STEEL RIVETS:
   - A) ITEM: USA/9070/B(U) TYPE B
   - B) MODEL NO. N-55
   - C) GROSS WGT 750 LBS
   - D) SERIAL NUMBER

10. PROPRIETARY - SEE NUPAC DRAWING NO. X-60-200D-SP

9. THIS AREA SHALL BE MARKED: "DO NOT USE FOR TIEDOWN" (TYP 4 PLACES, ADJACENT TO EACH LIFT LUG).

8. FABRICATION OF THIS PACKAGE SHALL BE IN ACCORDANCE WITH NUCLEAR PACKAGING INC. QUALITY ASSURANCE PROGRAM. (NRC APPROVAL # 0192).

7. ALL ANGLES, LIFT LUGS, GALV SHEET, FLAT FLANGES & HALF COUPLINGS SHALL BE CARBON STEEL.

6. NOT REQUIRED ON PACKAGES MANUFACTURED AFTER 3/1/81.

5. (B) RIVET: USE STRUCTURAL SELF-PLUGGING RIVET, MONEL OR STAINLESS STEEL. MINIMUM AVERAGE TENSILE STRENGTH 1100 LBS. MINIMUM AVERAGE SHEAR STRENGTH 1450 LBS. PER MIL STD. 1312.

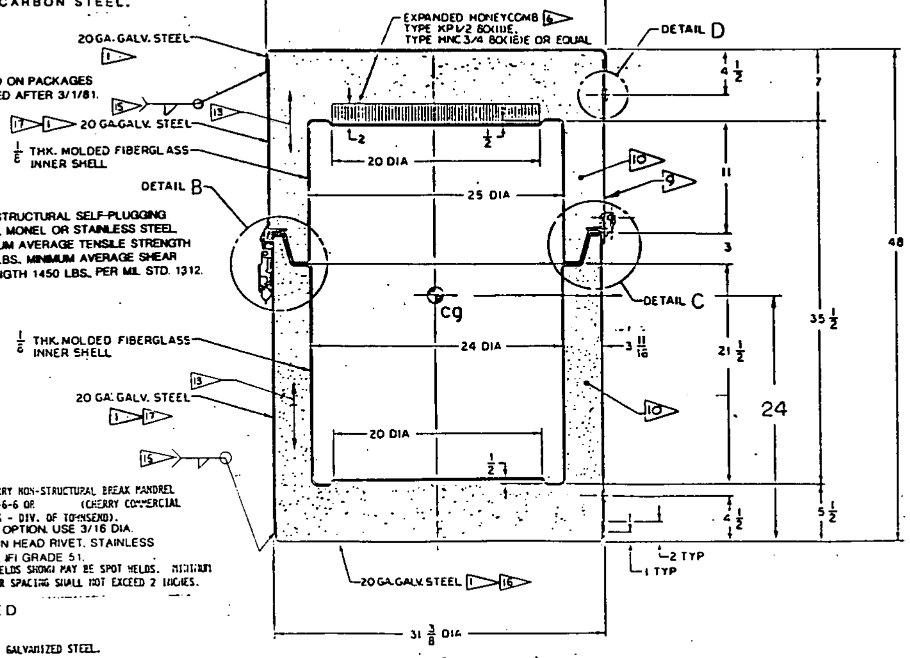
4. (B) RIVET: USE CHERRY NON-STRUCTURAL BREAK MANDREL NO. MSC-6-6 OR (CHERRY COMMERCIAL PRODUCTS - DIV. OF TOWNSEND). AS AN OPTION, USE 3/16 DIA. BUTTON HEAD RIVET, STAINLESS STEEL, IFI GRADE 51.

3. OPTIONAL: ALL WELDS SHOWN MAY BE SPOT WELDS. MINIMUM CENTER TO CENTER SPACING SHALL NOT EXCEED 2 INCHES.

2. REMOVED

1. OPTIONAL: 18 GA. GALVANIZED STEEL.

NOTES: UNLESS OTHERWISE SPECIFIED



SECTION A-A (B)

(B) 20. AS AN OPTION, THESE WELDS MAY BE OMITTED AND CAMLOC 37L15-1A MAY BE FASTENED USING THREE 5 LB. TINNER'S RIVETS, 3/16 DIA., FLAT HEAD OR COUNTERSUNK, WITH 3/8 MINIMUM EDGE MARGIN.

(B) 19. THESE WELDS ARE OPTIONAL.

(B) 18. AS AN OPTION, THIS WELD MAY BE OMITTED AND REPLACED WITH 5/32 DIA. BUTTON HEAD RIVETS, STEEL, IFI GRADE 30, ON 3 INCH SPACING AT 1/2 INCH EDGE DISTANCE.

(B) 17. LONGITUDINAL SEAM MAY BE SPOT WELDED THROUGH 5/32 HOLES ON 2 INCH CENTERS USING 3/4 LAP MINIMUM, 3/8 MINIMUM EDGE DISTANCE, OR 5/32 DIA. x 1/4 GRIP LENGTH, BUTTON HEAD RIVETS, STEEL, IFI GRADE 30, ON 2 INCH CENTERS, USING 3/4 LAP MINIMUM, 3/8 MINIMUM EDGE DISTANCE.

(B) 16. AS AN OPTION, THIS PIECE MAY BE SPUN WITH AN APPROXIMATELY 1/2 WIDE x 5/8 HIGH x 24 DIA. RING-SHAPED RIDGE WHICH PROTRUDES OUTWARD FROM THE PACKAGING

(B) 15. AS AN OPTION, END PIECE MAY BE RIVETED AS REQUIRED TO SIDE WALLS PRIOR TO FOAM FILL TO ALLOW THIS WELD TO BE INSTALLED AFTER FOAM FILL.

(B) 14. AS AN OPTION, THIS PART MAY BE FORMED FROM 14 GA. SHEET STEEL.

(B) 13. PROPRIETARY - SEE NUPAC DRAWING NO. X-60-200D-SP.

REL	[illegible]	8-2-8[illegible]
APPD		
APPD		
APPD	[illegible]	13-2-1[illegible]
APPD	[illegible]	[illegible]
APPD	[illegible]	[illegible]
APPD	[illegible]	1/3/[illegible]
APPD	A. Johnson	12-87
DRAWN	[illegible]	[illegible]
CHECK	[illegible]	[illegible]

NUCLEAR PACKAGING, INC.
TACOMA WASHINGTON

NUPAC
MODEL N-55
TYPE B OVERPACK

DWG SIZE D | REV (B) | DWG NO X-60-200D-SNF