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NTD-NRC-95-4536
DCP/NRC0387
Docket No.: STN-52-003

August 22, 1995

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: MR. T. R. QUAY

SUBJECT: AP600 MULTIPLE STEAM GENERATOR TUBE RUPTURE ANALYSIS IN SUPPORT OF RAIS 440.27 AND 440.170 (Revision 2)

Reference: NTD-NRC-95-4434, N. J. Liparulo to R. W. Borchardt, "AP600 Multiple Steam Generator Tube Rupture Analysis in Support of RAIs 440.27 and 440.170, Revision 1", April 6, 1995

Dear Mr. Quay:

The attachment to this letter provides a revision to analyses of multiple steam generator tube rupture events for the AP600 design. This revision incorporates changes and sensitivities discussed with NRC staff during a meeting on April 25, 1995. This analysis is intended to address NRC questions on containment bypass and steam generator tube rupture related to the SECY-93-087 requirement to assess design features to mitigate containment bypass due to steam generator tube rupture and RAIs 440.027 and 440.170, which requested analyses of 2 through 5 tube SGTRs.

The attachment is identified as draft and will be finalized following the completion of discussions with NRC staff related to the SECY-93-087 requirements. Please contact Brian A. McIntyre on (412) 374-4334 if you have any questions concerning this transmittal.

N. J. Liparulo, Manager
Nuclear Safety Regulatory And Licensing Activities

/nja

Attachment

cc: W. Huffman, NRC
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R. Landry, NRC
B. A. McIntyre, Westinghouse (w/o enclosures/attachments)

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AP600 Multiple Steam Generator Tube Rupture Analysis

1.0 Introduction

This report provides an evaluation of multiple steam generator tube ruptures (multiple-SGTRs) in the AP600 design. The analysis of multiple-SGTRs is prepared in response to the Nuclear Regulatory Commission's requests for additional information numbers 440.27 (reference 1) and 440.170 (reference 2) which recommend that beyond-design-basis best-estimate evaluations of one through five tube multiple-SGTRs be performed for the AP600 design. This evaluation is performed to demonstrate that the primary system automatic depressurization system (ADS) is not actuated and the secondary safety valves do not open to create a potential containment bypass pathway. These analyses are performed assuming no operator action. An additional analysis demonstrates that the core will remain covered and cooled throughout the multiple-SGTR accident scenario in the event that ADS is actuated manually. Sensitivity analyses which include the failure of the secondary system power-operated relief valves show that the operation of the PORV to depressurize the secondary system prevents the opening of the secondary safety valves.

2.0 Methodology

The Nuclear Regulatory Commission Staff has accepted the Westinghouse position on the multiple-SGTR issue. This position is documented in reference 3, which states, "The multiple steam generator tube rupture scenario should not be a design basis event. This event should be explicitly treated only in the risk assessment domain where best-estimate analyses are used to assess plant response to scenarios beyond the design basis events." Toward this end, an analysis of the one- through five-tube multiple-SGTRs is performed using the MAAP 4.0 accident analysis code (reference 4) to model the best-estimate thermal hydraulic response of the AP600 design. The break flow through the tube into the steam generator secondary system is calculated using the Henry-Fauske two-phase flow model, and the reactor coolant system response is modeled using 14 reactor vessel and loop nodes, and a one node 1600 ft^3 pressurizer. The steam generator secondary system is modeled as a single node. In the base cases best-estimate PRHR heat removal is modeled.

Important setpoints for the actuation of safety systems in this analysis are:

- core makeup tank injection begins due to pressurizer pressure, below 1850 psig (12.4 MPa),

- passive RHR heat exchanger is actuated on the same signal as the core makeup tank injection,

- automatic depressurization is actuated at core makeup tank level less than 13.1 feet (3.99 meters) from the CMT bottom.

- secondary system PORVs are fail closed valves which open at 1046 psia (7.21 MPa) and are reset (closed) when the pressure falls 25 psi below the opening setpoint,

- secondary system three safety valves open at 1100, 1130, and 1155 psia (7.58, 7.79 and 7.96 MPa) respectively.

All cases are assumed to begin from one hundred percent power. Startup feedwater provides two hundred gallons per minute flowrate to the steam generator secondary system with the level controlled to 535 inches (13.6 meters) in the steam generator downcomer. The base cases assume that 2 CMTs, 2 accumulators, 1 PRHR heat exchanger and ADS are available for operation. No other injection sources are credited. No operator actions are credited.

Sensitivity cases examine the performance of PRHR, elevation of the tube rupture, operator actuation of the ADS and failure of the secondary system PORVs to open.

3.0 Base Analyses Results

This section presents the description of the MAAP 4.0 results from the analyses of one- through five-tube multiple-steam generator tube rupture cases. A summary of the base case accident sequence timing is presented in Table 1.

3.1 Case SG1 - One Tube SGTR

The AP600 one-tube SGTR case, SG1, is a double-ended guillotine break of one cold-side steam generator tubes at the tubesheet elevation. The MAAP4 results for case SG1 are presented in Figures 1 through 9. At time zero, the tube rupture occurs, relieving primary system water into the broken steam generator (Figure 1). The RCS pressure (Figure 2) decreases and at 132 seconds the reactor scrams due to high steam generator narrow range level. The steam generator secondary system and the main feedwater system are isolated and startup feedwater is initiated. Steam generator pressure (Figure 3) increases to the setpoint of the secondary PORVs valves which begin relieving secondary steam to the environment at 221 seconds. Steam generator water level (Figure 4) increases due to startup feedwater injection and decreased heat transfer after reactor scram. The broken steam generator water level increases more than the unbroken steam generator due to the addition of primary system water, as well as feedwater.

The core makeup tank direct vessel injection line is opened to the RCS at 192 seconds (Figure 5) on a low pressurizer level signal. The CMT water injects in recirculation mode due to the density difference between the cold CMT water and the hot RCS water (Figure 6). As RCS water is drawn into the CMT, the CMT water temperature increases. The recirculation injection mode allows the CMT to inject without decreasing the water level in the tank (Figure 7).

The passive RHR heat exchanger is actuated by the CMT injection signal (Figure 8). The heat removal by the PRHR decreases and maintains the primary system and faulted steam generator pressure below the secondary system relief valve setpoints, stopping the loss of coolant from the system at 532 seconds. The flow between the primary and secondary systems fluctuates around zero (Figure 1), and the full primary system water level is maintained throughout the transient (Figure 9). The secondary safety valves do not open since the pressure in the faulted steam generator remains below the safety valve actuation pressure throughout the entire accident scenario (Figure 3). The water level in the core makeup tank (Figure 7) does not decrease due to the recirculation injection mode. Therefore, automatic depressurization of the RCS does not occur.

3.2 Case SG2 - Two Tube Multiple-SGTR

The AP600 two-tube SGTR case, SG2, is a double-ended guillotine break of two cold-side steam generator tubes at the tubesheet elevation. The MAAP4 results for case SG2 are presented in Figures 10 through 18. At time zero, the tube rupture occurs, relieving primary system water into the broken steam generator (Figure 10). The RCS pressure (Figure 11) decreases and at 92 seconds the reactor scrams due to high steam generator narrow range level. The steam generator secondary system and the main feedwater system are isolated and startup feedwater is initiated.

Steam generator pressure (Figure 12) increases to the setpoint of the secondary PORVs valves which begin relieving secondary steam to the environment at 152 seconds. Steam generator water level (Figure 13) increases due to startup feedwater injection and decreased heat transfer after reactor scram. The broken steam generator water level increases more than the unbroken steam generator due to the addition of primary system water, as well as feedwater.

The core makeup tank direct vessel injection line is opened to the RCS at 111 seconds (Figure 14) on a low pressurizer level signal. The CMT water injects in recirculation mode due to the density difference between the cold CMT water and the hot RCS water (Figure 15). As RCS water is drawn into the CMT, the CMT water temperature increases. The recirculation injection mode allows the CMT to inject without decreasing the water level in the tank (Figure 16).

The passive RHR heat exchanger is actuated by the CMT injection signal (Figure 17). The heat removal by the PRHR decreases and maintains the primary system and faulted steam generator pressure below the secondary system relief valve setpoints, stopping the loss of coolant from the system at 285 seconds. The flow between the primary and secondary systems fluctuates around zero (Figure 10), and the full primary system water level is maintained throughout the transient (Figure 18). The secondary safety valves do not open since the pressure in the faulted steam generator remains below the safety valve actuation pressure throughout the entire accident scenario (Figure 12). The water level in the core makeup tank (Figure 16) does not decrease due to the recirculation injection mode. Therefore, automatic depressurization of the RCS does not occur.

3.3 Case SG3 - Three Tube Multiple-SGTR

The AP600 three-tube SGTR case, SG3, is a double-ended guillotine break of three cold-side steam generator tubes at the tubesheet elevation. The MAAP4 results for case SG3 are presented in Figures 19 through 27. At time zero, the tube rupture occurs, relieving primary system water into the broken steam generator (Figure 19). The RCS pressure (Figure 20) decreases and at 74 seconds the reactor scrams due to high steam generator narrow range level. The steam generator secondary system and the main feedwater system are isolated and startup feedwater is initiated. Steam generator pressure (Figure 21) increases to the setpoint of the secondary PORVs which begin relieving secondary steam to the environment at 143 seconds. Steam generator water level (Figure 22) increases due to startup feedwater injection and decreased heat transfer after reactor scram. The broken steam generator water level increases more than the unbroken steam generator due to the addition of primary system water, as well as feedwater.

The core makeup tank direct vessel injection line is opened to the RCS at 84 seconds (Figure 23) on a low pressurizer level signal. The CMT water injects in recirculation mode due to the density difference between the cold CMT water and the hot RCS water (Figure 24). As RCS water is drawn into the CMT, the CMT water temperature increases. The recirculation injection mode allows the CMT to inject without decreasing the water level in the tank (Figure 25).

The passive RHR heat exchanger is actuated by the CMT injection signal (Figure 26). The heat removal by the PRHR decreases and maintains the primary system and faulted steam generator pressure below the secondary system relief valve setpoints, stopping the loss of coolant from the system at 239 seconds. The flow between the primary and secondary systems fluctuates around zero (Figure 19), and the full primary system water level is maintained throughout the transient (Figure 27). The secondary safety valves do not open since the pressure in the faulted steam generator remains below the safety valve actuation pressure throughout the entire accident scenario (Figure 21). The water level in the core makeup tank (Figure 25) does not decrease due to the recirculation injection mode. Therefore, automatic depressurization of the RCS does not occur.

3.4 Case SG4 - Four Tube Multiple-SGTR

The AP600 four-tube SGTR case, SG4, is a double-ended guillotine break of four cold-side steam generator tubes at the tubesheet elevation. The MAAP4 results for case SG4 are presented in Figures 28 through 36. At time zero, the tube rupture occurs, relieving primary system water into the broken steam generator (Figure 28). The RCS pressure (Figure 29) decreases and at 58 seconds the reactor scrams due to high steam generator narrow range level. The steam generator secondary system and the main feedwater system are isolated and startup feedwater is initiated. Steam generator pressure (Figure 30) increases to the setpoint of the secondary PORVs valves which begin relieving secondary steam to the environment at 119 seconds. Steam generator water level (Figure 31) increases due to startup feedwater injection and decreased heat transfer after reactor scram. The broken steam generator water level increases more than the unbroken steam generator due to the addition of primary system water, as well as feedwater.

The core makeup tank direct vessel injection line is opened to the RCS at 67 seconds (Figure 32) on a low pressurizer level signal. The CMT water injects in recirculation mode due to the density difference between the cold CMT water and the hot RCS water (Figure 33). As RCS water is drawn into the CMT, the CMT water temperature increases. The recirculation injection mode allows the CMT to inject without decreasing the water level in the tank (Figure 34).

The passive RHR heat exchanger is actuated by the CMT injection signal (Figure 35). The heat removal by the PRHR decreases and maintains the primary system and faulted steam generator pressure below the secondary system relief valve setpoints, stopping the loss of coolant from the system at 185 seconds. The flow between the primary and secondary systems fluctuates around zero (Figure 28), and the full primary system water level is maintained throughout the transient (Figure 36). The secondary safety valves do not open since the pressure in the faulted steam generator remains below the safety valve actuation pressure throughout the entire accident scenario (Figure 30). The water level in the core makeup tank (Figure 34) does not decrease due to the recirculation injection mode. Therefore, automatic depressurization of the RCS does not occur.

3.5 Case SG5 - Five-Tube Multiple-SGTR

The AP600 five-tube SGTR case, SG5, is a double-ended guillotine break of five cold-side steam generator tubes at the tubesheet elevation. The MAAP4 results for case SG5 are presented in Figures 37 through 45. At time zero, the tube rupture occurs, relieving primary system water into the broken steam generator (Figure 37). The RCS pressure (Figure 38) decreases and at 49 seconds the reactor scrams due to high steam generator narrow range level. The steam generator secondary system and the main feedwater system are isolated and startup feedwater is initiated. Steam generator pressure (Figure 39) increases to the setpoint of the secondary PORVs valves which begin relieving secondary steam to the environment at 107 seconds. Steam generator water level (Figure 40) increases due to startup feedwater injection and decreased heat transfer after reactor scram. The broken steam generator water level increases more than the unbroken steam generator due to the addition of primary system water, as well as feedwater.

The core makeup tank direct vessel injection line is opened to the RCS at 55 seconds (Figure 41) on a low pressurizer level signal. The CMT water injects in recirculation mode due to the density difference between the cold CMT water and the hot RCS water (Figure 42). As

RCS water is drawn into the CMT, the CMT water temperature increases. The recirculation injection mode allows the CMT to inject without decreasing the water level in the tank (Figure 43).

The passive RHR heat exchanger is actuated by the CMT injection signal (Figure 44). The heat removal by the PRHR decreases and maintains the primary system and faulted steam generator pressure below the secondary system relief valve setpoints, stopping the loss of coolant from the system at 132 seconds. The flow between the primary and secondary systems fluctuates around zero (Figure 37), and the full primary system water level is maintained throughout the transient (Figure 45). The secondary safety valves do not open since the pressure in the faulted steam generator remains below the safety valve actuation pressure throughout the entire accident scenario (Figure 39). The water level in the core makeup tank (Figure 43) does not decrease due to the recirculation injection mode. Therefore, automatic depressurization of the RCS does not occur.

4.0 Sensitivity Cases

The cases presented in this section examine variations in the plant conditions and in the modeling to demonstrate that the base results of the analysis are robust. The cases examine the sensitivity of the results to break elevation, and variations in the effectiveness of the PRHR heat removal. All the sensitivity cases will be based on the SG5 base case. A summary of the sensitivity case accident sequence timing is presented in Table 2.

4.1 Case SG5B - Break Elevation Sensitivity

Case SG5B is initiated by a five-tube multiple SGTR at the top of the steam generator tube bundle. Each of the breaks in the base cases were assumed to occur at the top of the tubesheet. The results of the MAAP4 analysis are presented in Figures 46 through 54. As in the base case, the CMTs remain full of water throughout the transient (Figure 52) and the PRHR heat removal (Figure 53) stops the loss of coolant though the break. Therefore, no ADS actuation is predicted. The pressure in the faulted steam generator remains below the safety valve actuation pressure throughout the entire accident scenario (Figure 48). The results do not show a sensitivity to break elevation.

4.2 Case SG5max - Maximum PRHR Heat Exchanger Performance

Case SG5max is initiated by a five-tube multiple SGTR at the top of the tubesheet. The maximum expected PRHR performance is modeled. The base cases model best-estimate PRHR performance. The MAAP4 results of the analysis are presented in Figures 55 through 63. As in the base cases, the CMTs remain full of water throughout the transient (Figure 61) and the PRHR heat removal (Figure 62) stops the loss of coolant through the break. Therefore, no ADS actuation is predicted. The pressure in the faulted steam generator remains below the safety valve actuation pressure throughout the entire accident scenario (Figure 57). The results do not show a sensitivity to the increase in PRHR heat removal.

4.3 Case SG5min - Minimum PRHR Heat Exchanger Performance

Case SG5min is initiated by a five-tube multiple SGTR at the top of the steam generator tubesheet. The heat removal capability of the PRHR heat exchanger is assumed to be the minimum expected performance The base cases model best-estimate PRHR performance. The MAAP4 results of the analysis are presented in Figures 64 through 72. As in the base case, the CMT remains full of water throughout the transient (Figure 70) and the heat removal of the PRHR (Figure 71) stops the loss of coolant through the break. Therefore, no ADS actuation is predicted. The pressure in the faulted steam generator remains below the safety valve actuation pressure throughout the entire accident scenario (Figure 66). The results do not show a sensitivity to a significant decrease in PRHR heat removal.

5.0 Case SG5A - Manual ADS Actuation

This section presents a variation of the multiple-SGTR case in which the operator manually actuates the automatic depressurization system. This case is presented to show that the actuation of the ADS system will not cause the core to uncover in the multiple-SGTR accident scenario.

Case SG5A is initiated by a five-tube multiple SGTR at the top of the steam generator tubesheet. The operator is assumed to manually depressurize the RCS at 1800 seconds. This time was chosen as a point in which the SG5 base case had become relatively stabilized. Both flow paths of each of the first three ADS stages are assumed to open sequentially. Two of four stage four ADS valves are assumed to open. The results of the analysis are presented in Figures 73 through 81.

The transient progresses like the base case until 1800 seconds when the operator manually actuates the ADS system. The first stage flow paths are open at 1865 seconds causing the pressure in the primary system and faulted steam generator to fall (Figure 74). As the RCS pressure falls, water from the faulted steam generator secondary flows into the RCS (Figure 73). During this backflow from the steam generator, the accumulators and the CMTs (Figures 77 and 78) are injecting into the downcomer, providing boration to the RCS. The second and third stage flow paths open at 1980 and 2100 seconds, respectively. The accumulator water is depleted at 2580 seconds. The CMT injection continues throughout the draining of the faulted steam generator into the RCS.

The fourth stage flow path opens when the CMT water level (Figure 79) reaches a low-low setpoint at 5771 seconds. IRWST injection begins at approximately 5500 seconds. The RCS water level never falls below the top of the core.

6.0 Failure of the Secondary PORVs to Open

Each of the base one through five tube multiple-SGTR cases is analyzed assuming the failure of both of the secondary PORVs to open. The results of these cases are presented in Figures 82 through 126. A summary of the accident sequence timing for the PORV failure cases is presented in Table 3. In each of the cases, the failure of the PORVs allowed the secondary pressure to increase to the 1100 psig opening setpoint of the secondary safety valve. Following opening of the secondary safety valve the event progressed to a stable state in the same fashion as cases in which the steam generator PORVs were modeled to open.

7.0 Conclusions

One- through five-tube multiple steam generator tube rupture cases are analyzed with MAAP 4.0 without crediting any operator actions. The base cases presented in section 3 show that the heat removal by the passive RHR stops the loss of coolant from the primary and secondary systems, and the CMT level is maintained throughout the transients since there is no cold leg voiding to break the siphon in the balance line. The CMT injects in recirculation mode with no reduction in level. Therefore, no automatic ADS signal is generated by a low level in the CMT. In each case, the secondary system PORV opens and the pressure in the faulted steam generator remains below the secondary side safety valve opening setpoint. Therefore, the safety valve remains closed throughout the analyses demonstrating that the AP600 is not susceptible to containment bypass due to a stuck open safety valve consequential to a multiple-SGTR. The sensitivity analyses presented in section 4 show that the conclusions are also valid considering high and low variations in passive RHR heat removal capacity and location of the tube rupture.

In the event that ADS is actuated manually during the accident sequence, the analysis in section 5 shows that the core remains covered throughout the accident. The accumulators and the CMTs provide boration to the RCS during the backflow of water from the faulted steam generator as the RCS depressurizes. IRWST water injection, and later, passive containment cooling water recirculation will maintain water coverage of the core over the long term. No core damage is predicted.

8.0 References

1. Letter, Thomas J. Kenyon (NRC) to Nicholas J. Liparulo (Westinghouse), Dated September 23, 1992.

2. Letter, Thomas J. Kenyon (NRC) to Nicholas J. Liparulo (Westinghouse), Dated June 1, 1994.

3. Letter ET-NRC-92-3748, N.J. Liparulo to Dr. Ivan Selin dated September 17, 1992.

4. EPRI Research Project Number 3131-02, "MAAP4 - Modular Accident Analysis Program for LWR Power Plants Computer Code Manual," May 1994.

Table 1
Summary of AP600 Multiple Steam Generator Tube Rupture Base Case Analyses

	Number of Failed Tubes				
	1	2	3	4	5
Time of Reactor Trip	132 sec	92 sec	74 sec	58 sec	49 sec
Time of CMT Actuation	192 sec	111 sec	84 sec	67 sec	55 sec
Time of PRHR Actuation	202 sec	115 sec	85 sec	68 sec	57 sec
Time SG PORV Open	222 sec	152 sec	143 sec	119 sec	107 sec
Time SG Relief Terminated	536 sec	286 sec	239 sec	185 sec	132 sec

Table 2
Summary of AP600 Multiple Steam Generator Tube Rupture Sensitivity Case Analyses
Five Tube Multiple-SGTR

	Case			
	Base	PRHR Max	PRHR Min	Break Elevation
Time of Reactor Trip	49 sec	49 sec	49 sec	49 sec
Time of CMT Actuation	55 sec	55 sec	55 sec	55 sec
Time of PRHR Actuation	57 sec	57 sec	57 sec	57 sec
Time SG PORV Open	107 sec	107 sec	107 sec	107 sec
Time SG Relief Terminated	132 sec	132 sec	131 sec	132 sec

Table 3
Summary of AP600 Multiple Steam Generator Tube Rupture PORV Failure Analyses

	Number of Failed Tubes				
	1	2	3	4	5
Time of Reactor Trip	132 sec	92 sec	74 sec	58 sec	49 sec
Time of CMT Actuation	192 sec	111 sec	84 sec	67 sec	55 sec
Time of PRHR Actuation	202 sec	115 sec	85 sec	68 sec	57 sec
Time SG Safety Valve Open	439 sec	246 sec	210 sec	163 sec	153 sec

Figure 1

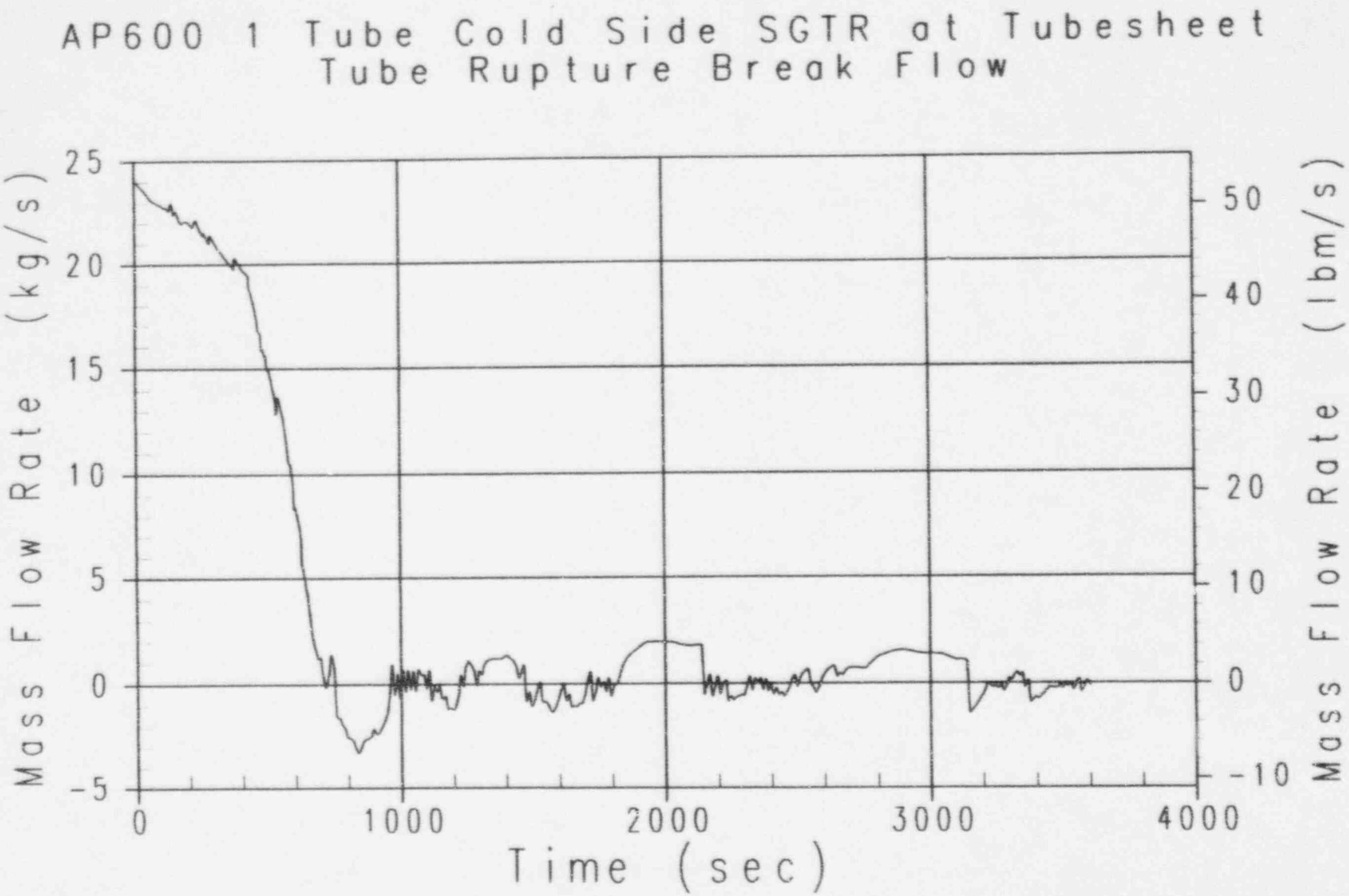

AP600 1 Tube Cold Side SGTR at Tubesheet
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
25
20
15
10
5
0
-5
50
40
30
20
10
0
-10
0
1000
2000
3000
4000

Figure 4

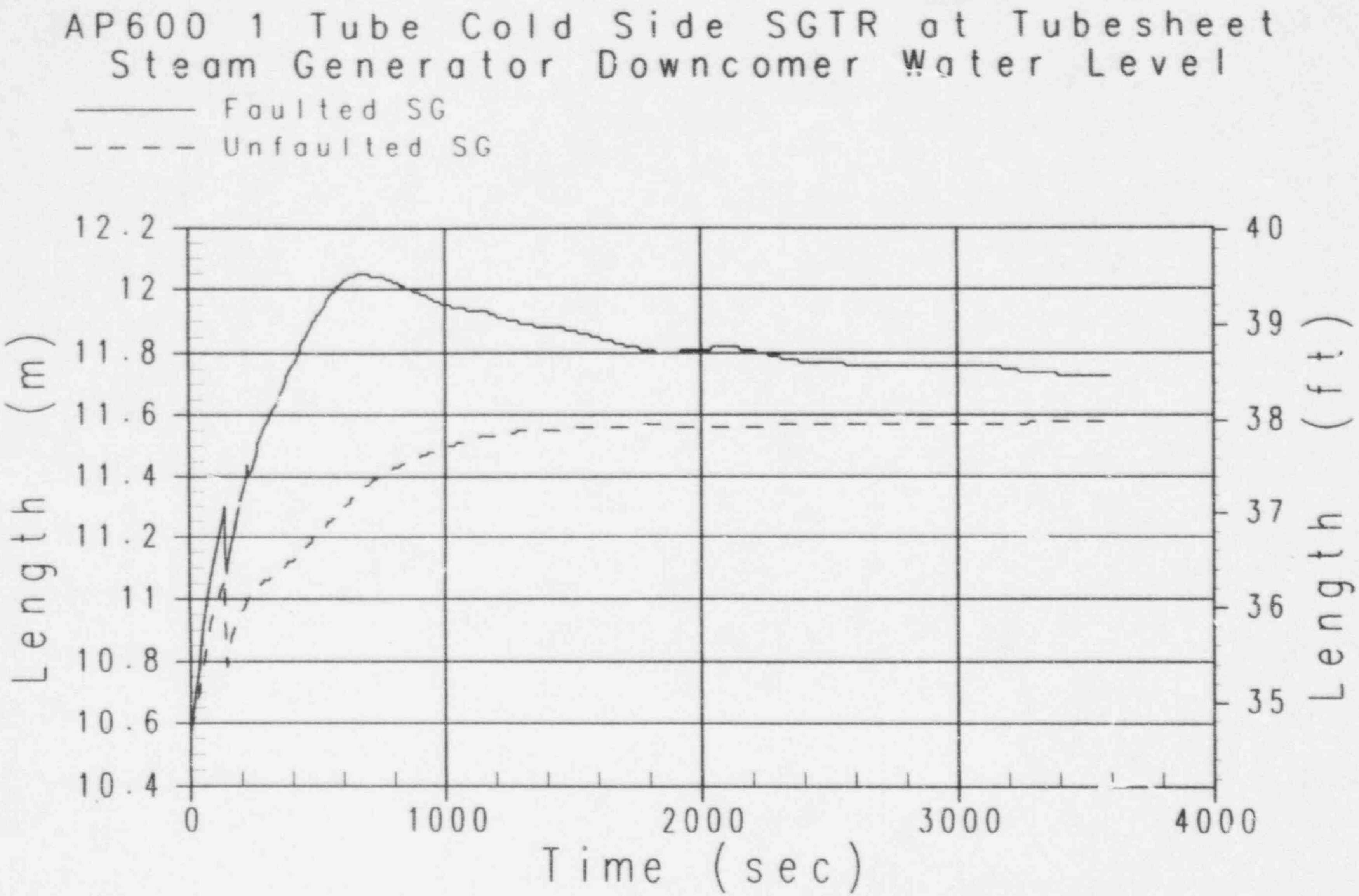

AP600 1 Tube Cold Side SGTR at Tubesheet
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
Length (m)
40
39
38
37
36
35
Length (ft)
0
1000
2000
3000
4000
Time (sec)

Figure 5

AP600 1 Tube Cold Side SGTR at Tubesheet
CMT Water Mass Flowrates

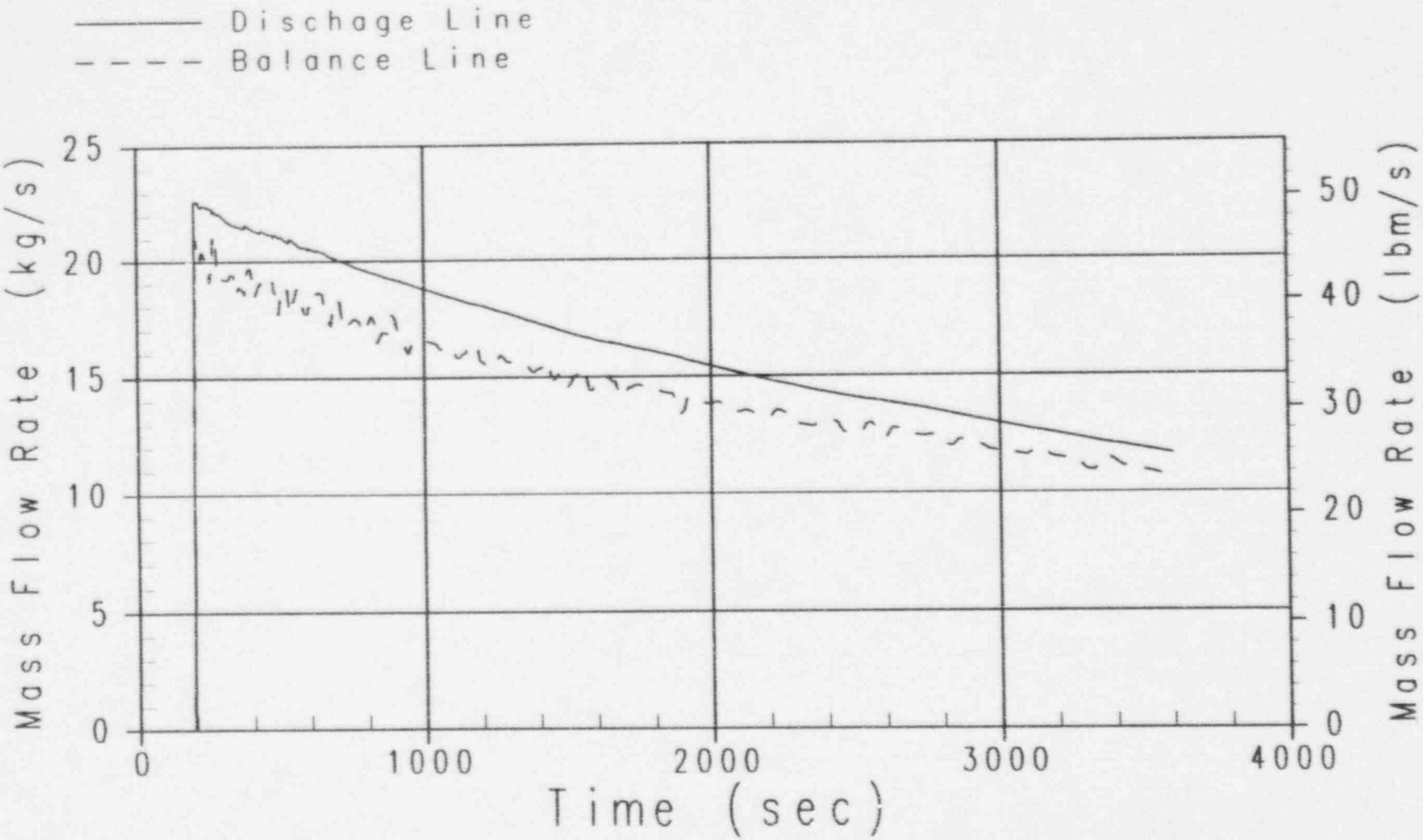
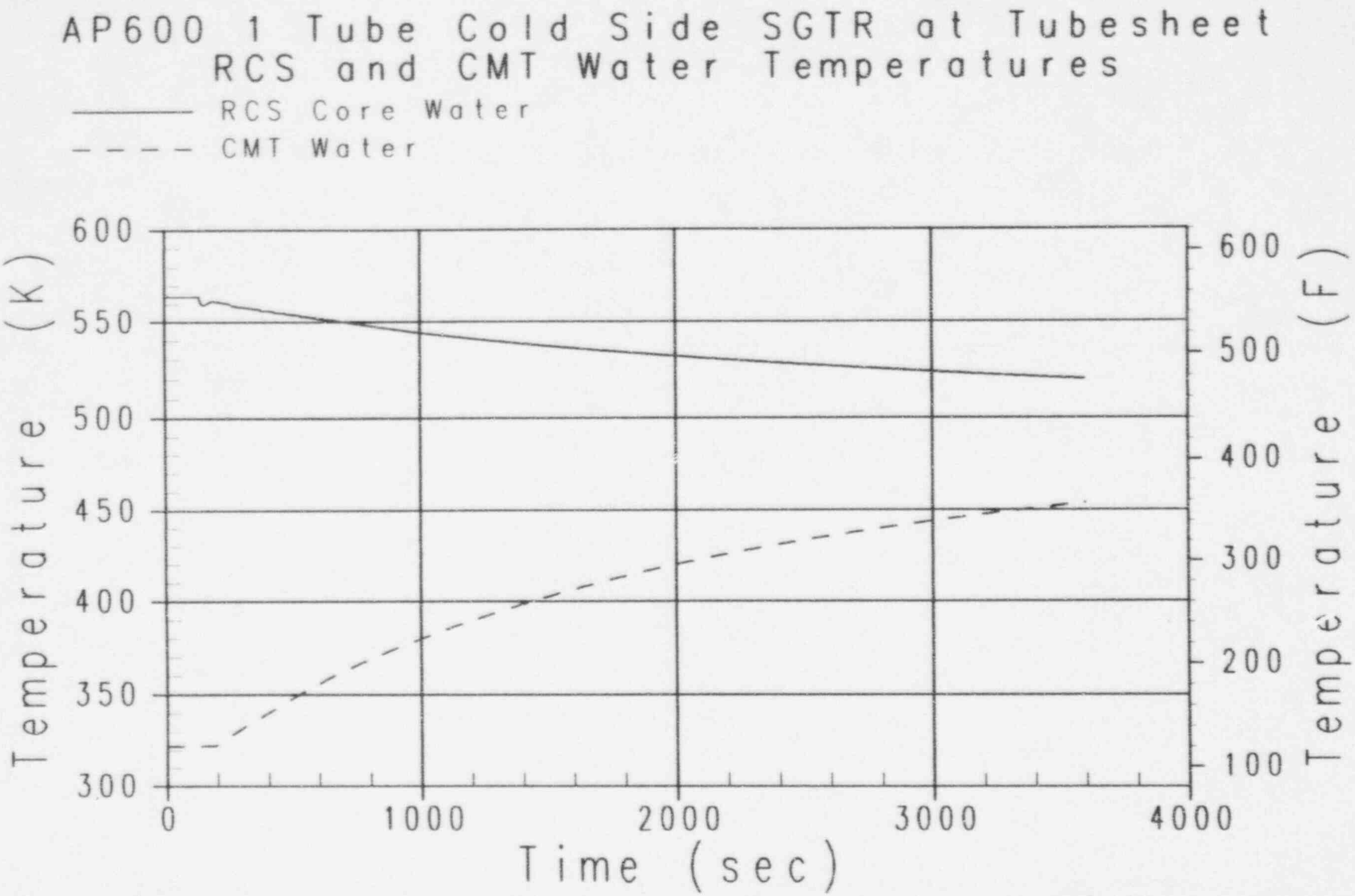


Figure 6



AP600 1 Tube Cold Side SGTR at Tubesheet
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
Temperature (K)
600
550
500
450
400
350
300
Temperature (F)
600
500
400
300
200
100
0
1000
2000
3000
4000
Time (sec)

Figure 7

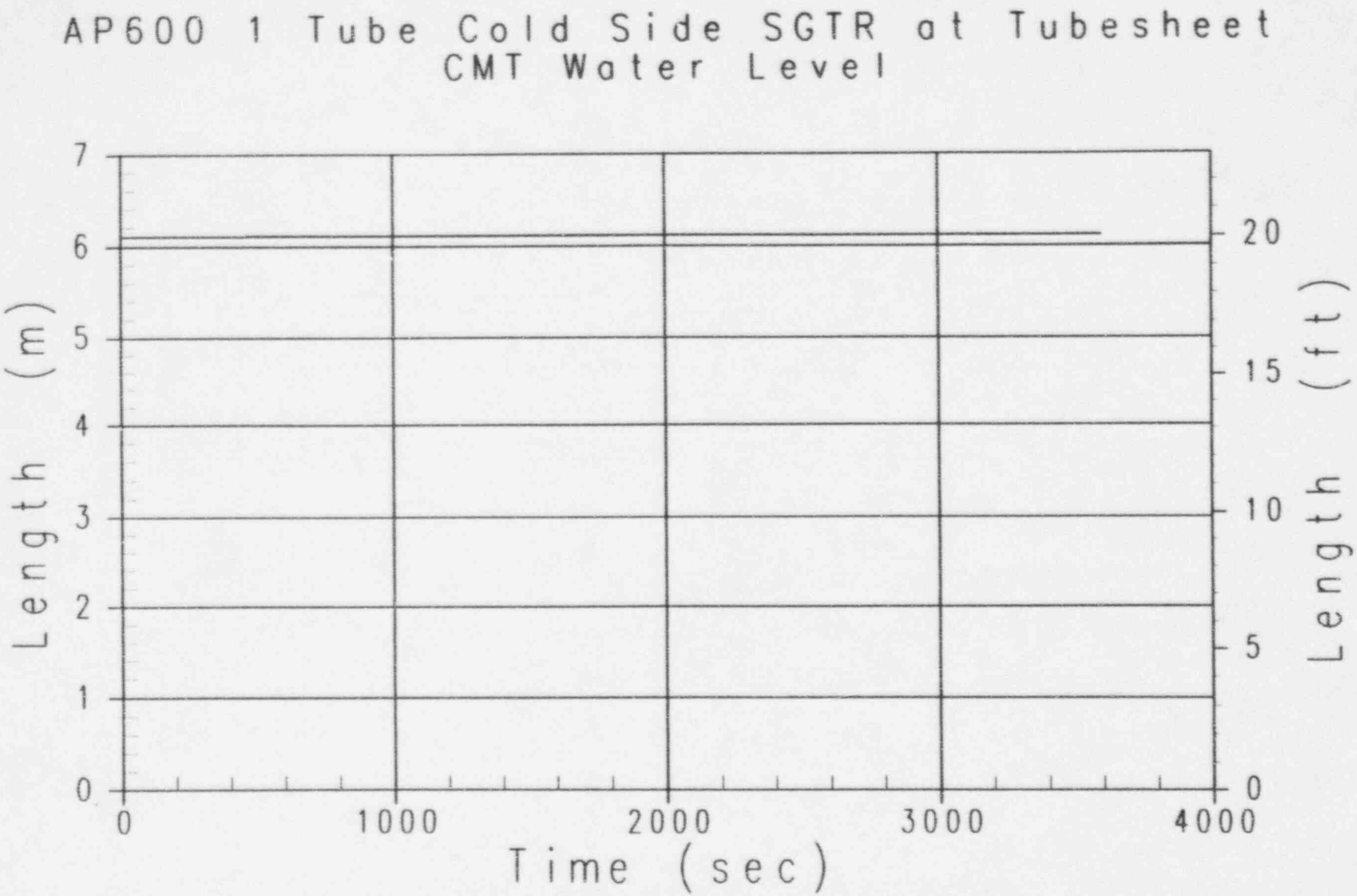

AP600 1 Tube Cold Side SGTR at Tubesheet
CMT Water Level
Length (m)
Length (ft)
Time (sec)
0
1
2
3
4
5
6
7
0
5
10
15
20
0
1000
2000
3000
4000

Figure 8

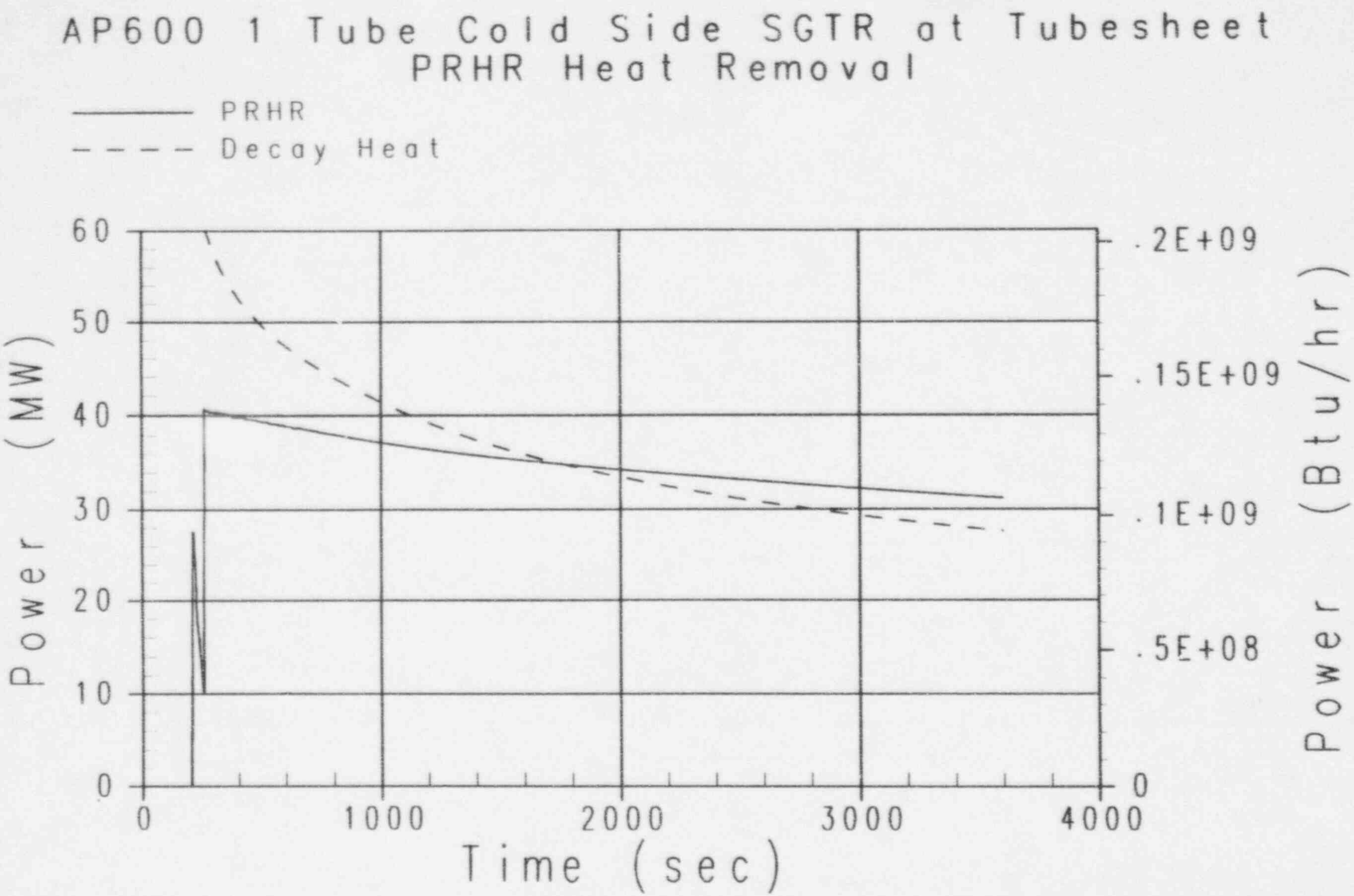
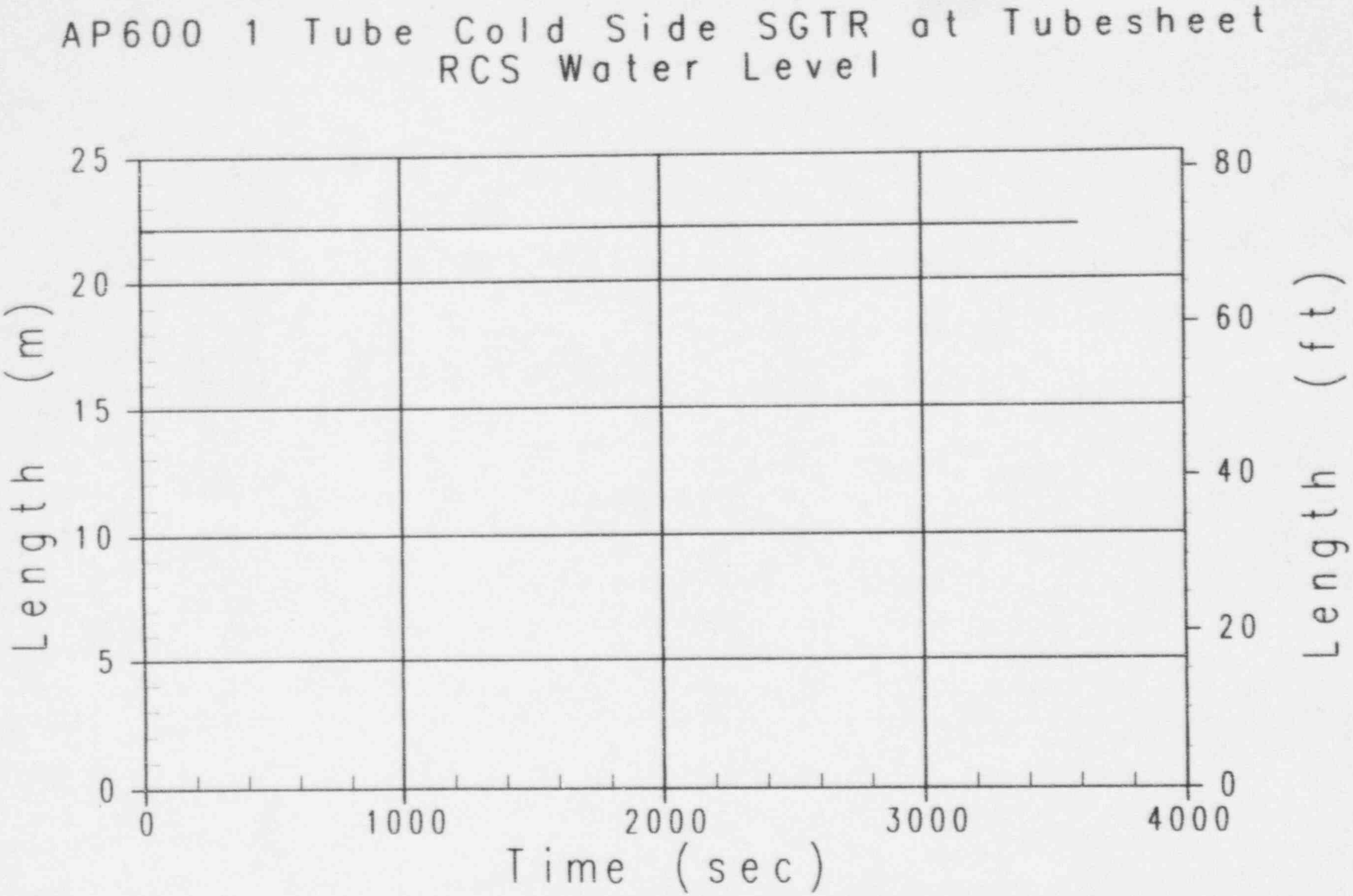

AP600 1 Tube Cold Side SGTR at Tubesheet
PRHR Heat Removal
PRHR
Decay Heat
Power (MW)
Power (Btu/hr)
Time (sec)
0
10
20
30
40
50
60
0
1000
2000
3000
4000
0
.5E+08
.1E+09
.15E+09
.2E+09

Figure 9



AP600 1 Tube Cold Side SGTR at Tubesheet
RCS Water Level
Length (m)
Length (ft)
Time (sec)
0
5
10
15
20
25
0
20
40
60
80
0
1000
2000
3000
4000

Figure 10

AP600 2 Tube Cold Side Multiple SGTR at Tubesheet
Tube Rupture Break Flow

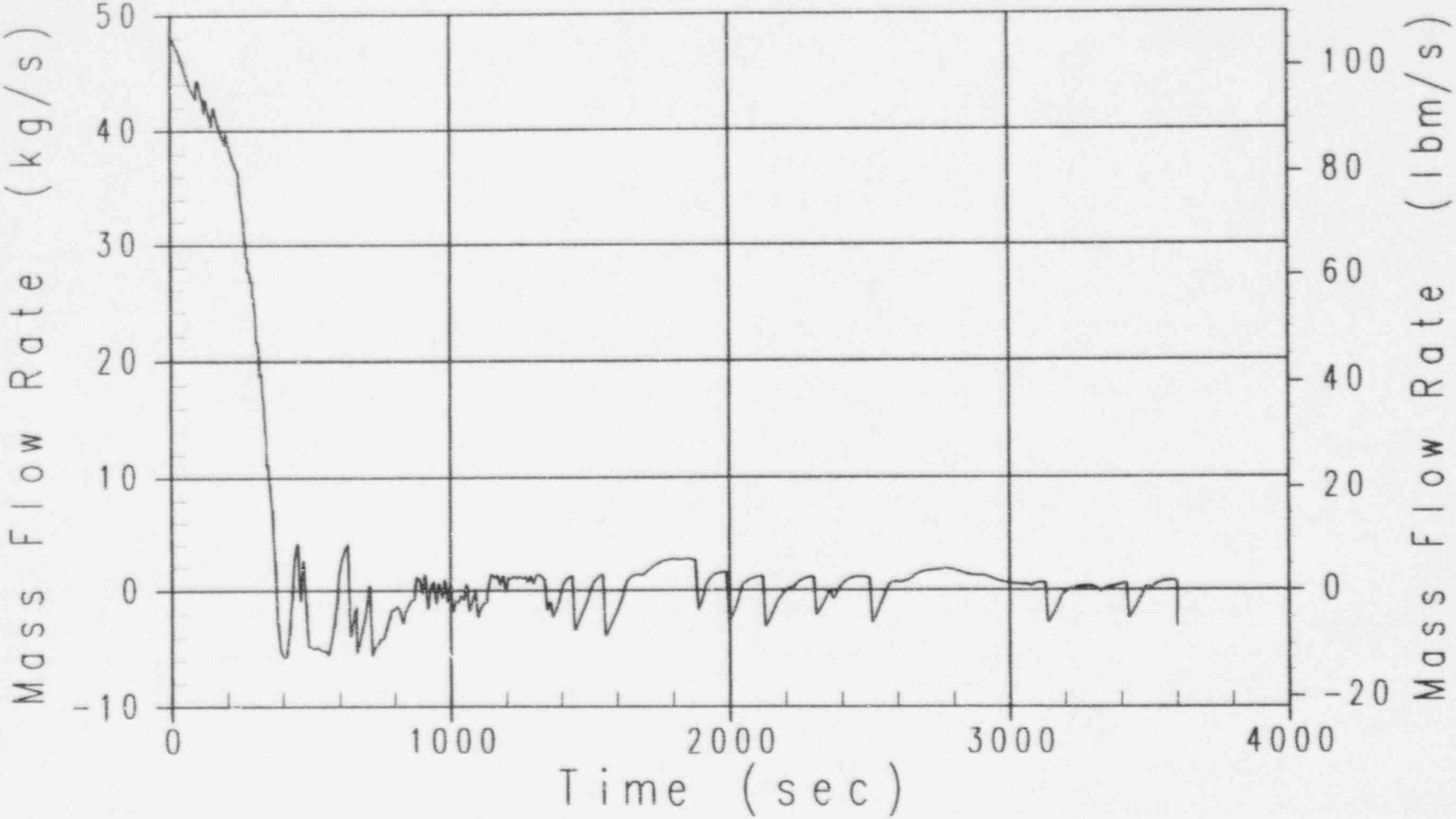


Figure 11

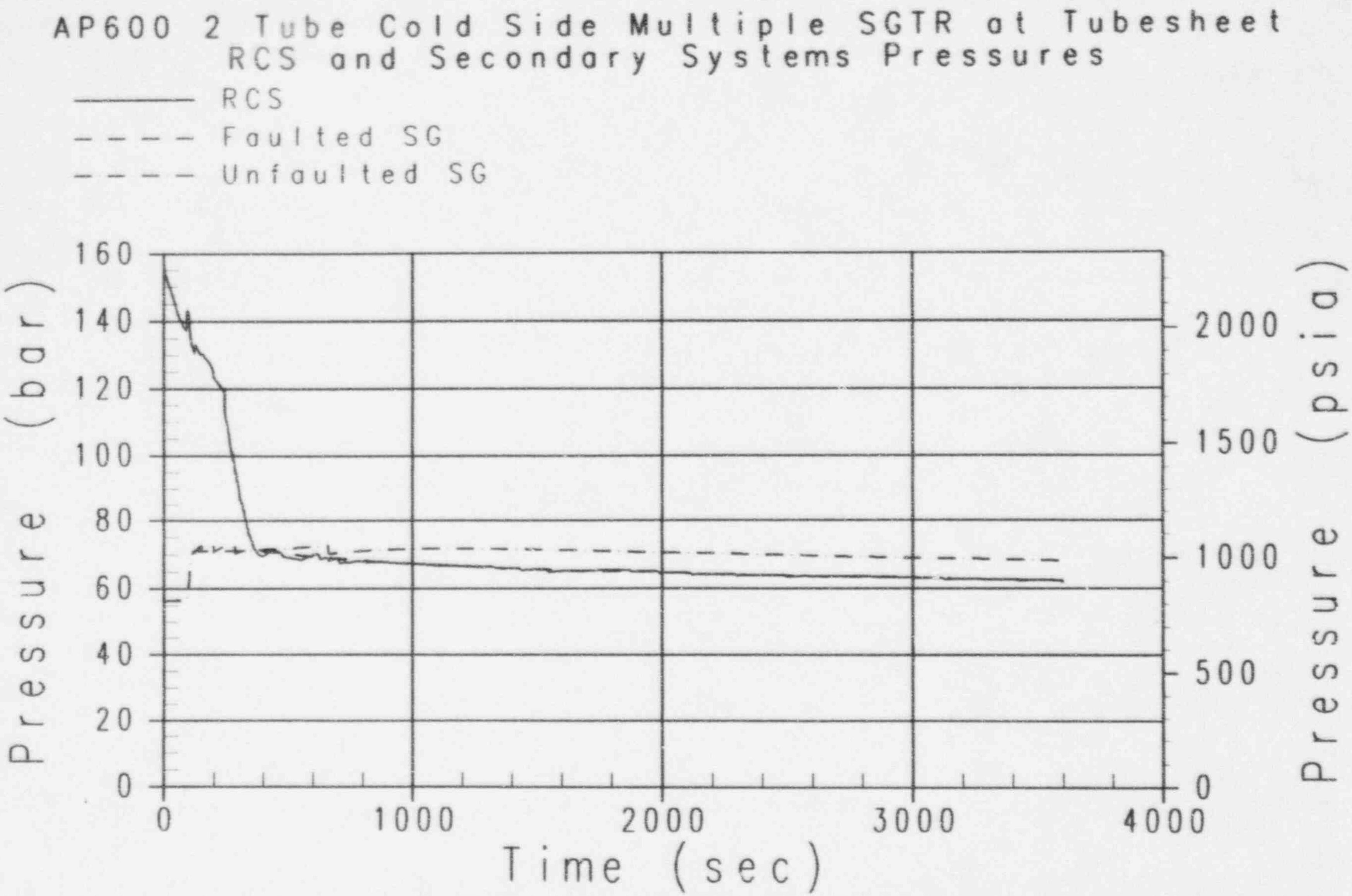
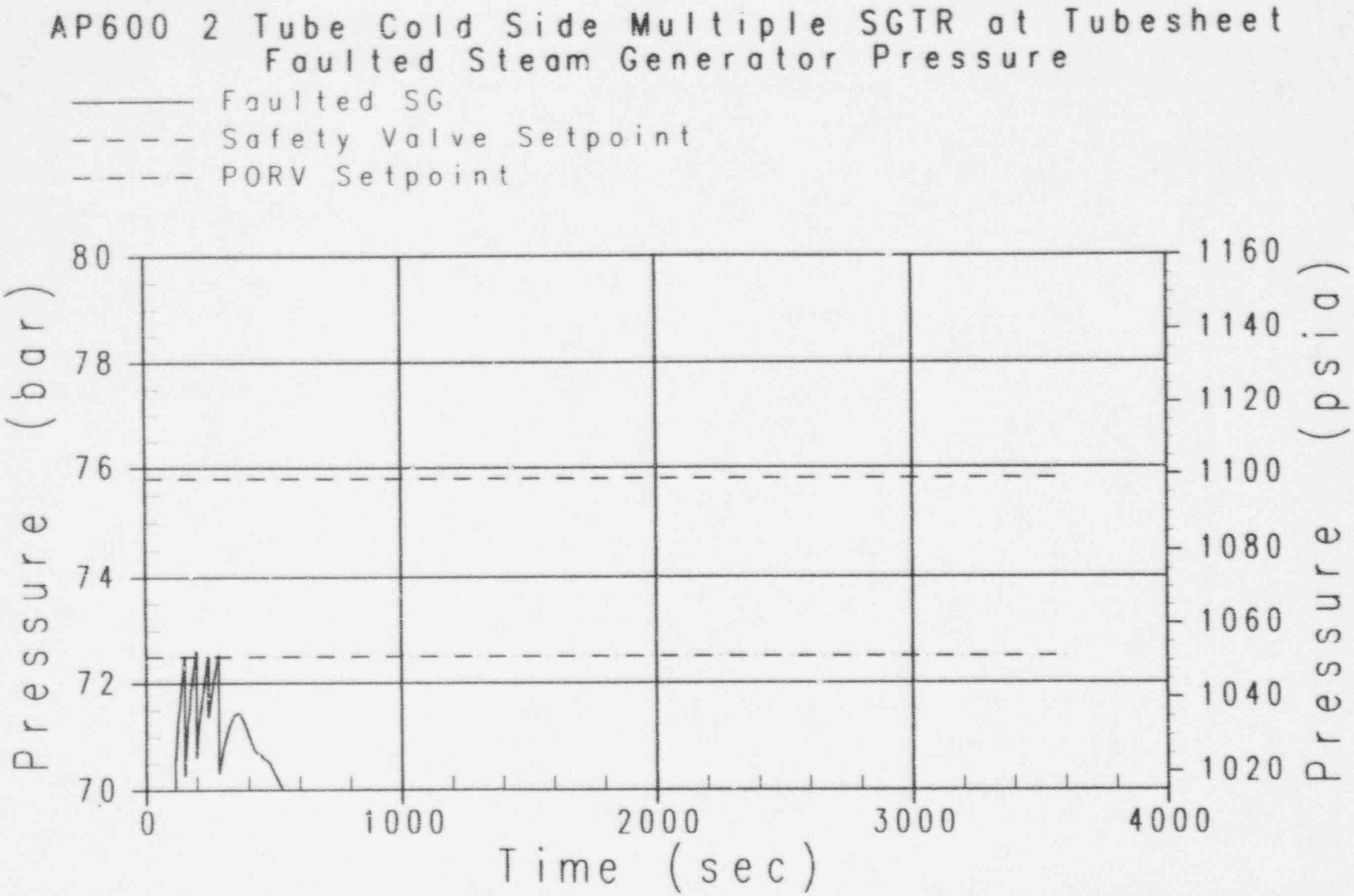

AP600 2 Tube Cold Side Multiple SGTR at Tubesheet
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
Pressure (psia)
Time (sec)
0
20
40
60
80
100
120
140
160
500
1000
1500
2000
1000
2000
3000
4000

Figure 12



AP600 2 Tube Cold Side Multiple SGTR at Tubesheet
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
PORV Setpoint
80
78
76
74
72
70
Pressure (bar)
1160
1140
1120
1100
1080
1060
1040
1020
Pressure (psia)
0
1000
2000
3000
4000
Time (sec)

Figure 13

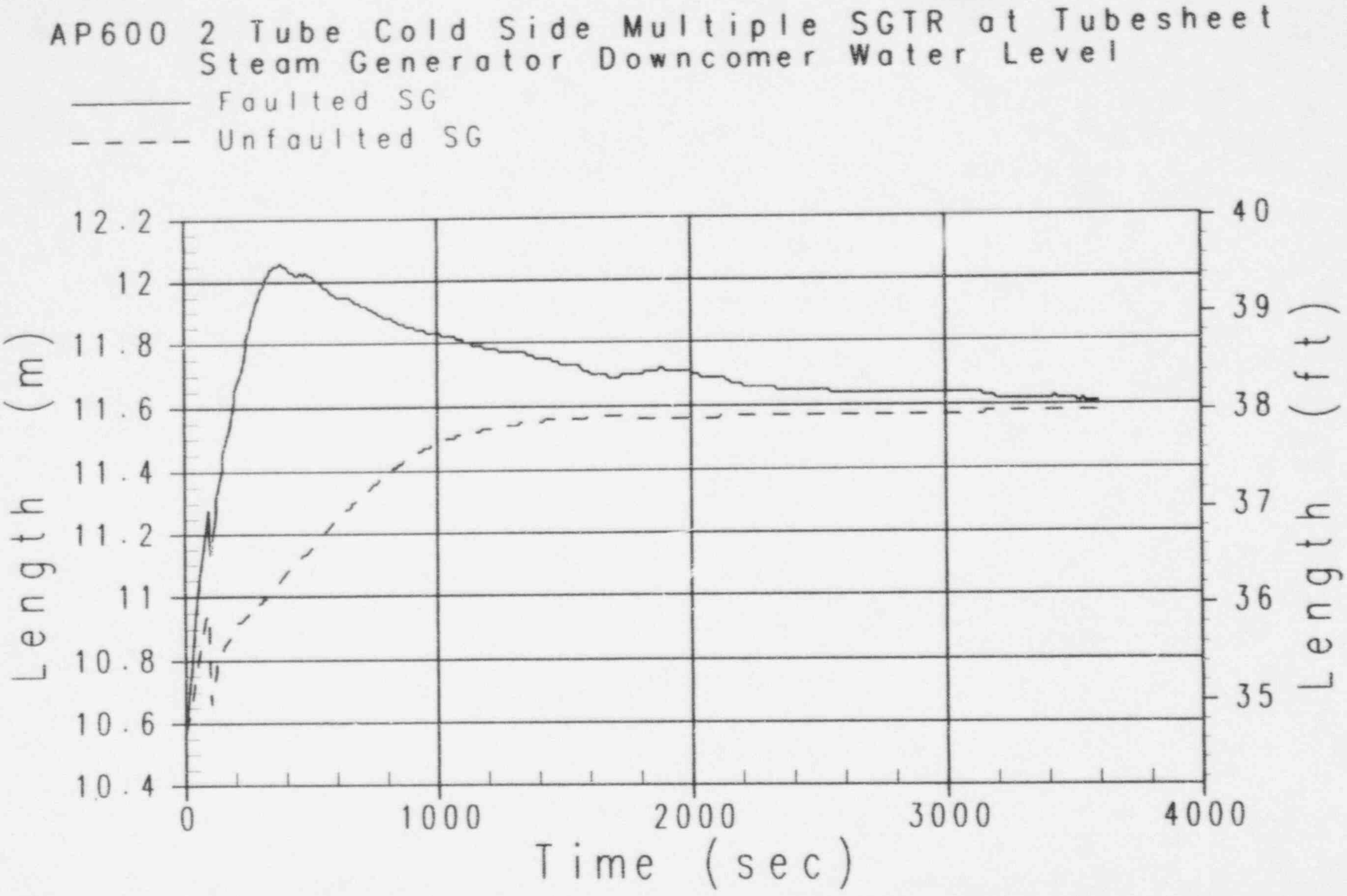
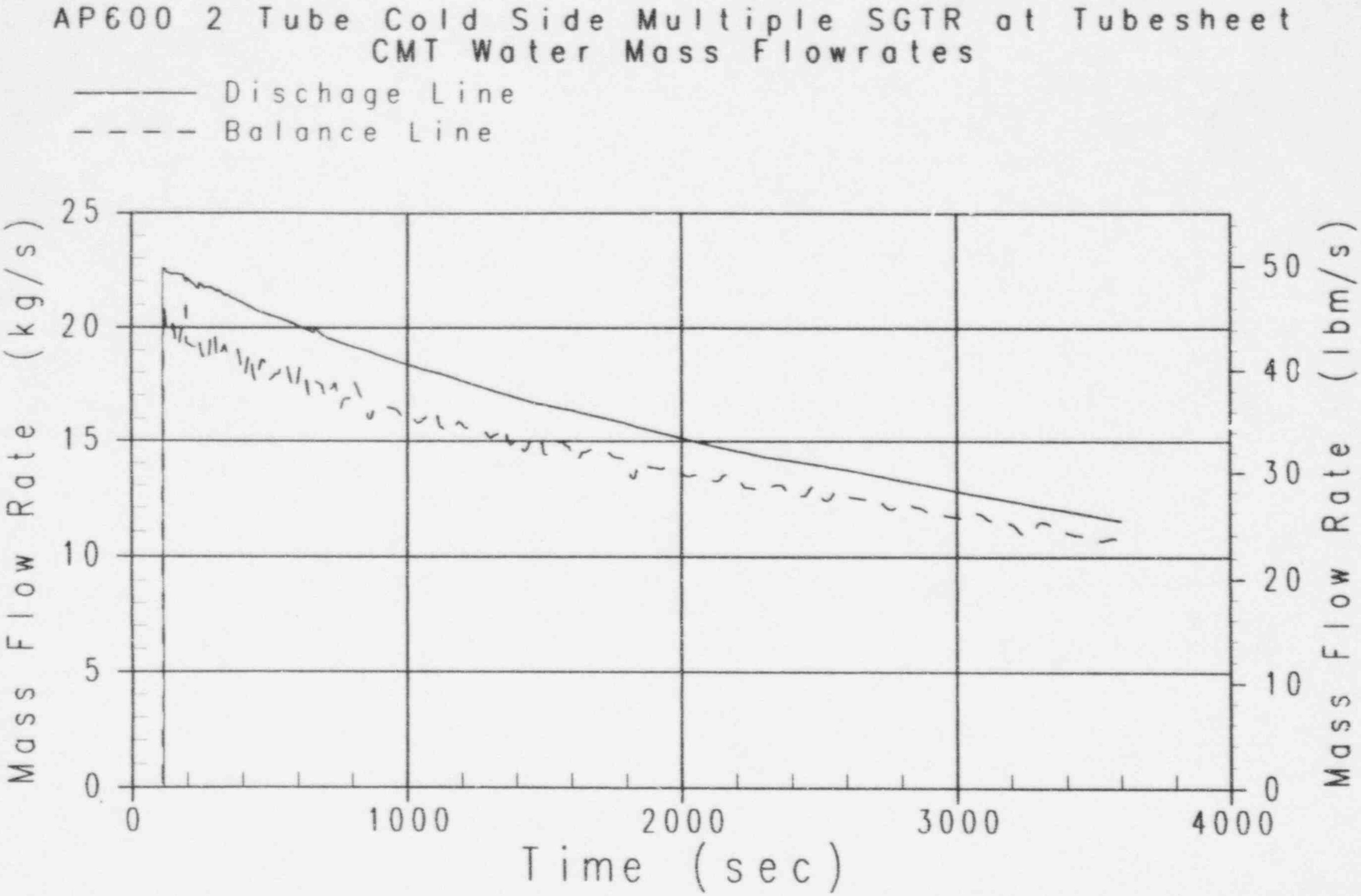

AP600 2 Tube Cold Side Multiple SGTR at Tubesheet
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
Length (m)
40
39
38
37
36
35
Length (ft)
0
1000
2000
3000
4000
Time (sec)

Figure 14



AP600 2 Tube Cold Side Multiple SGTR at Tubesheet
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
5
10
15
20
25
0
10
20
30
40
50
0
1000
2000
3000
4000

Figure 15

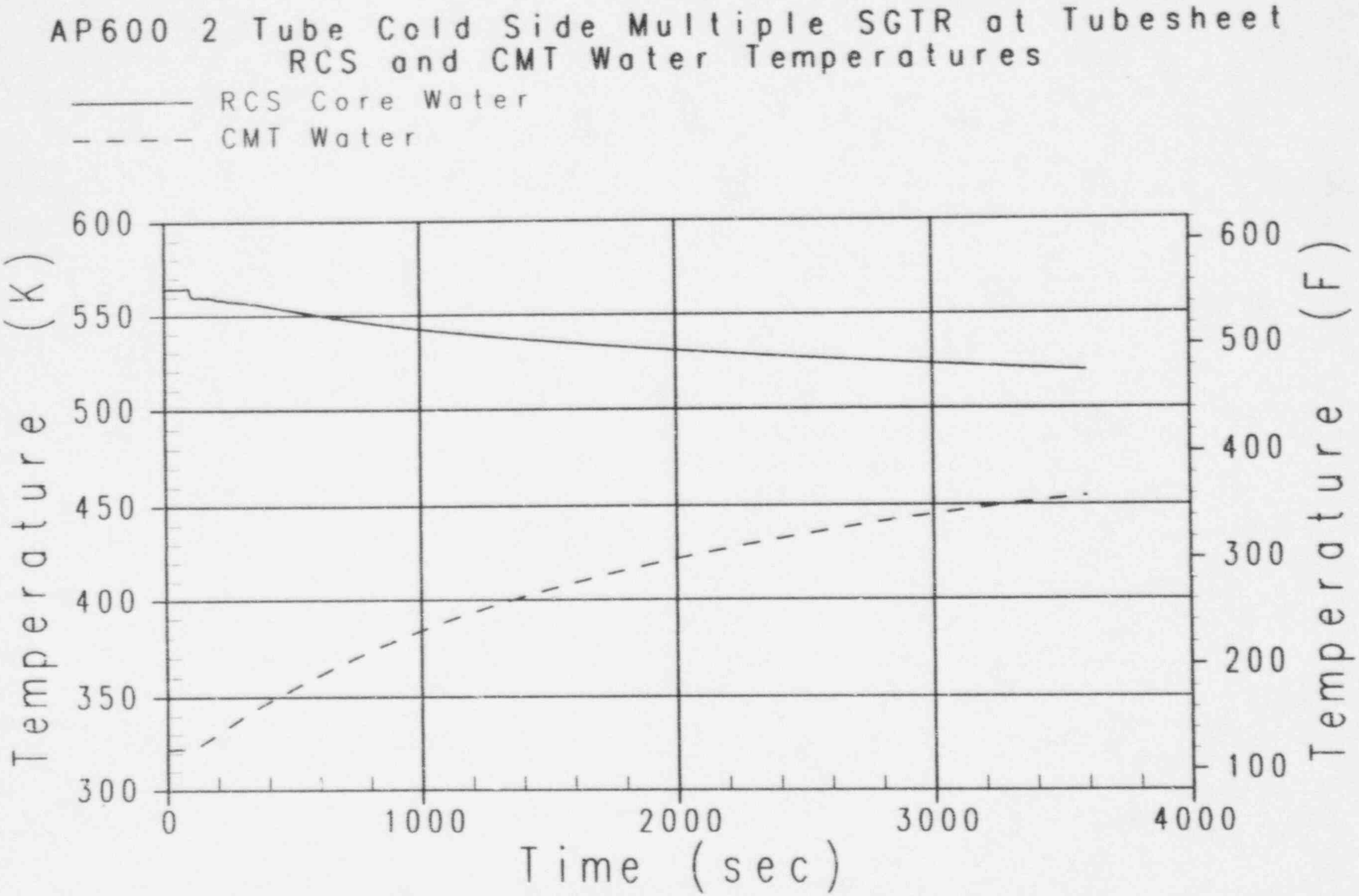
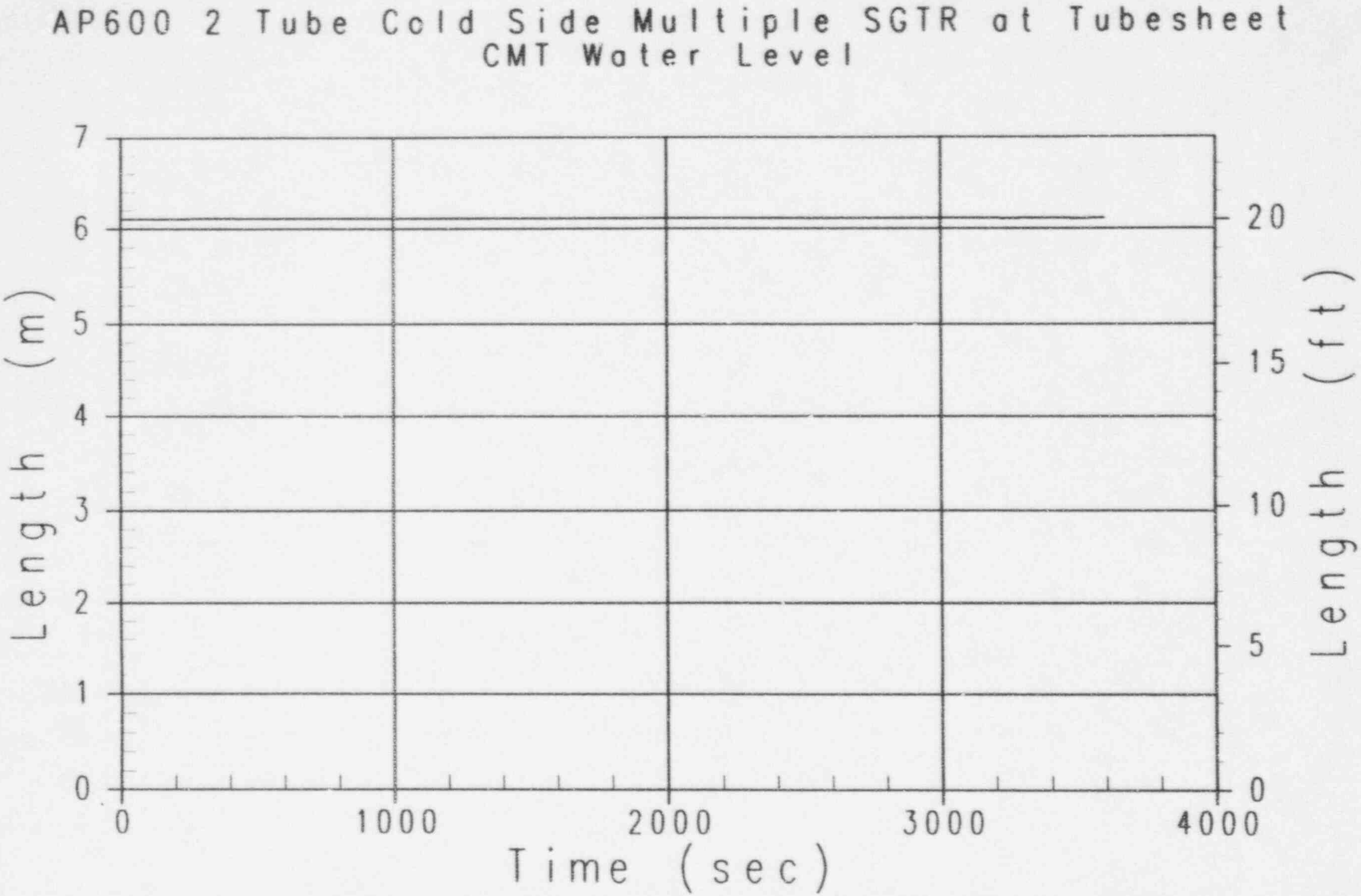

AP600 2 Tube Cold Side Multiple SGTR at Tubesheet
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
Temperature (K)
600
550
500
450
400
350
300
Temperature (F)
600
500
400
300
200
100
0
1000
2000
3000
4000
Time (sec)

Figure 16



AP600 2 Tube Cold Side Multiple SGTR at Tubesheet
CMT Water Level
Length (m)
Length (ft)
Time (sec)
0
1
2
3
4
5
6
7
0
5
10
15
20
0
1000
2000
3000
4000

Figure 17

AP600 2 Tube Cold Side Multiple SGTR at Tubesheet
PRHR Heat Removal

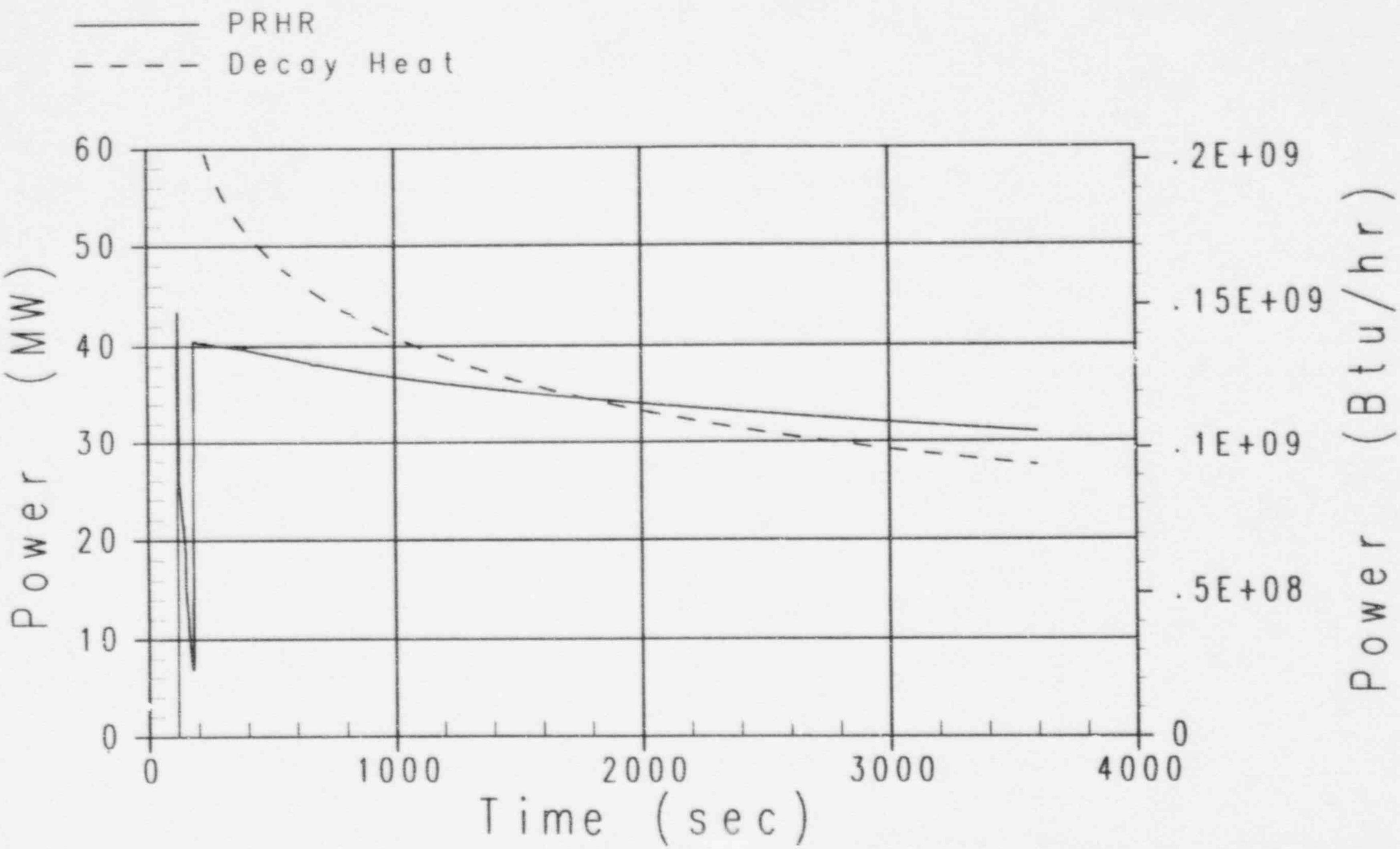


Figure 18

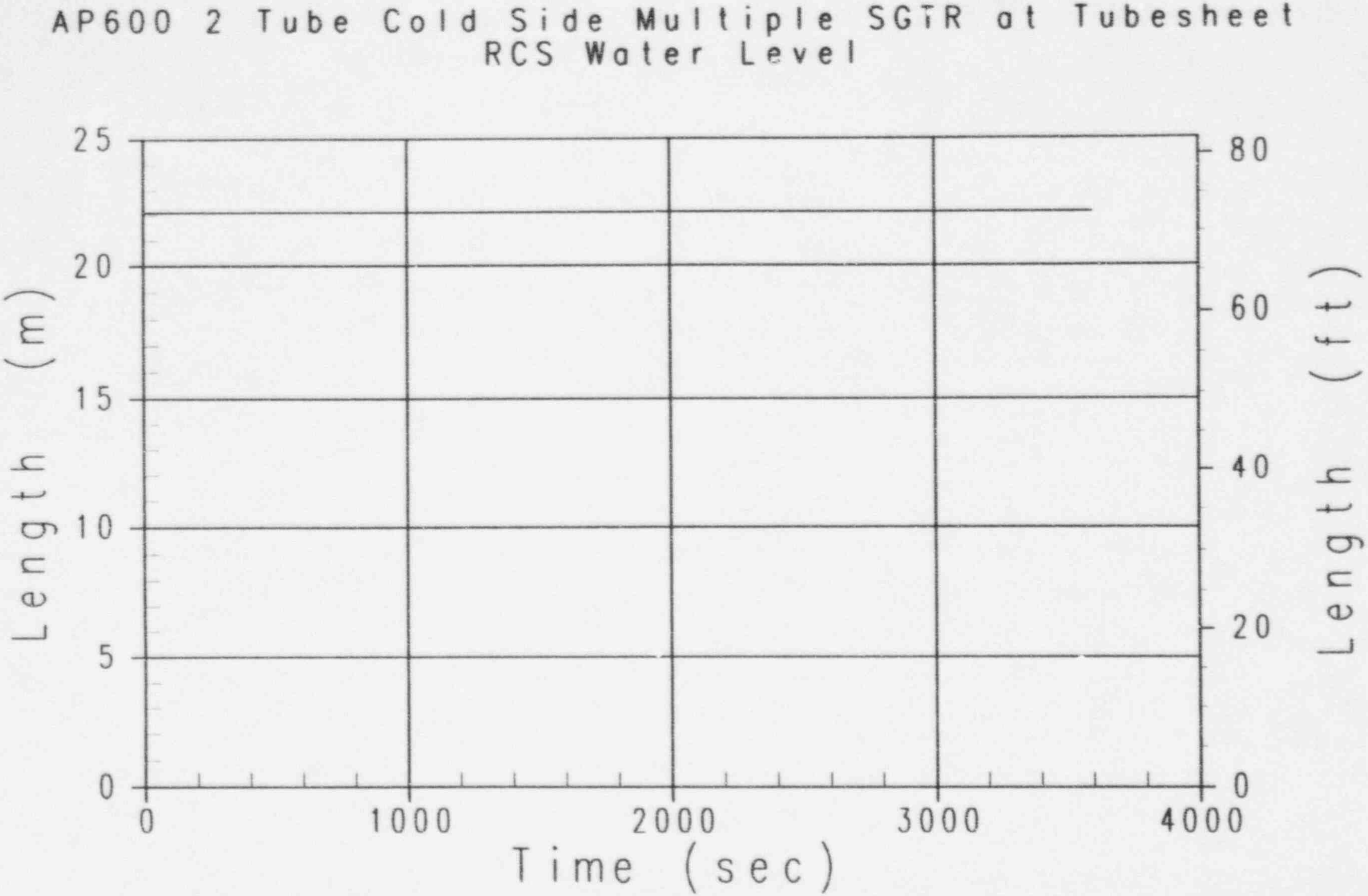

AP600 2 Tube Cold Side Multiple SGTR at Tubesheet
RCS Water Level
25
20
15
10
5
0
80
60
40
20
0
Length (m)
Length (ft)
0
1000
2000
3000
4000
Time (sec)

Figure 19

AP600 3 Tube Cold Side Multiple SGTR at Tubesheet
Tube Rupture Break Flow

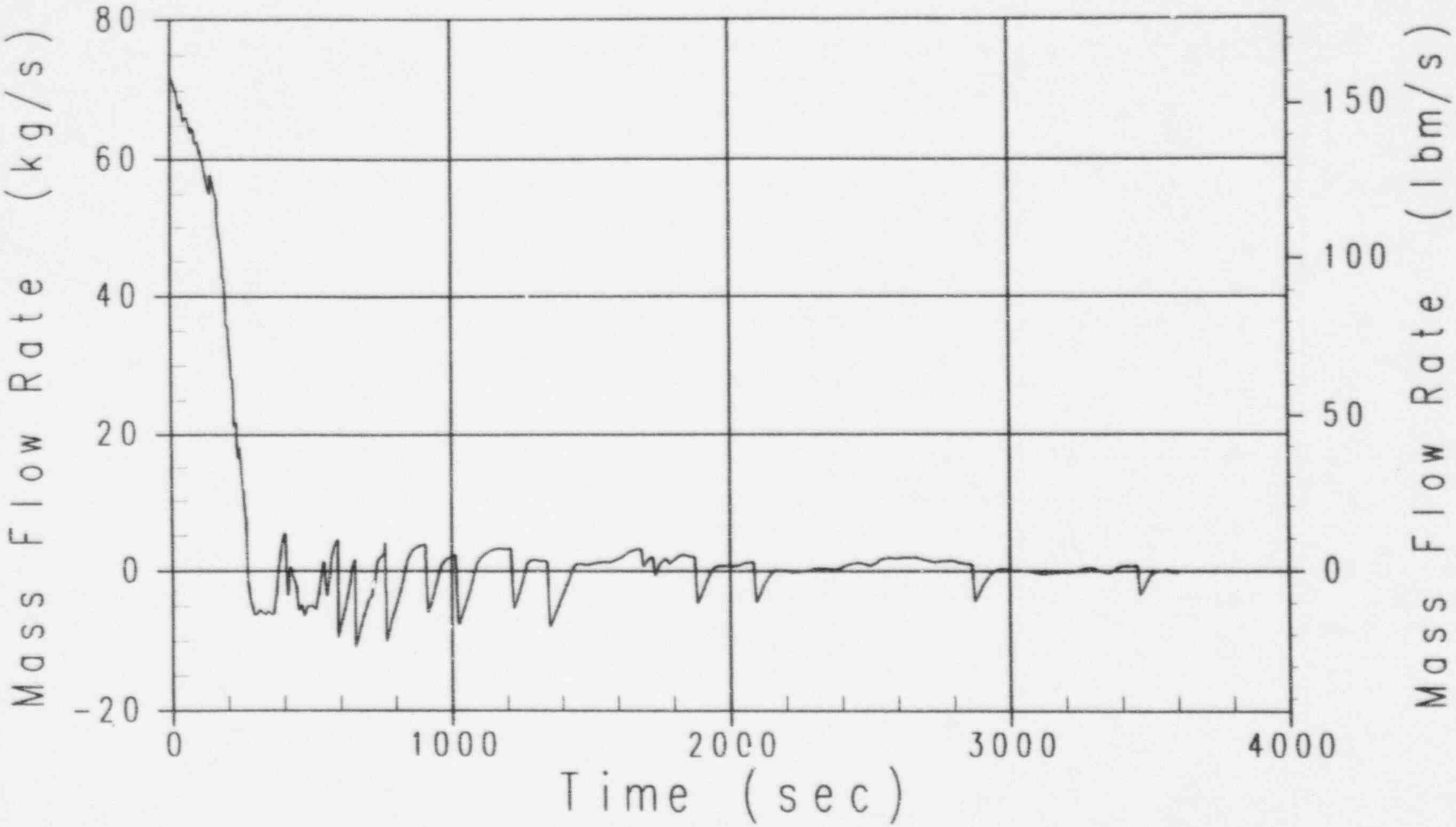
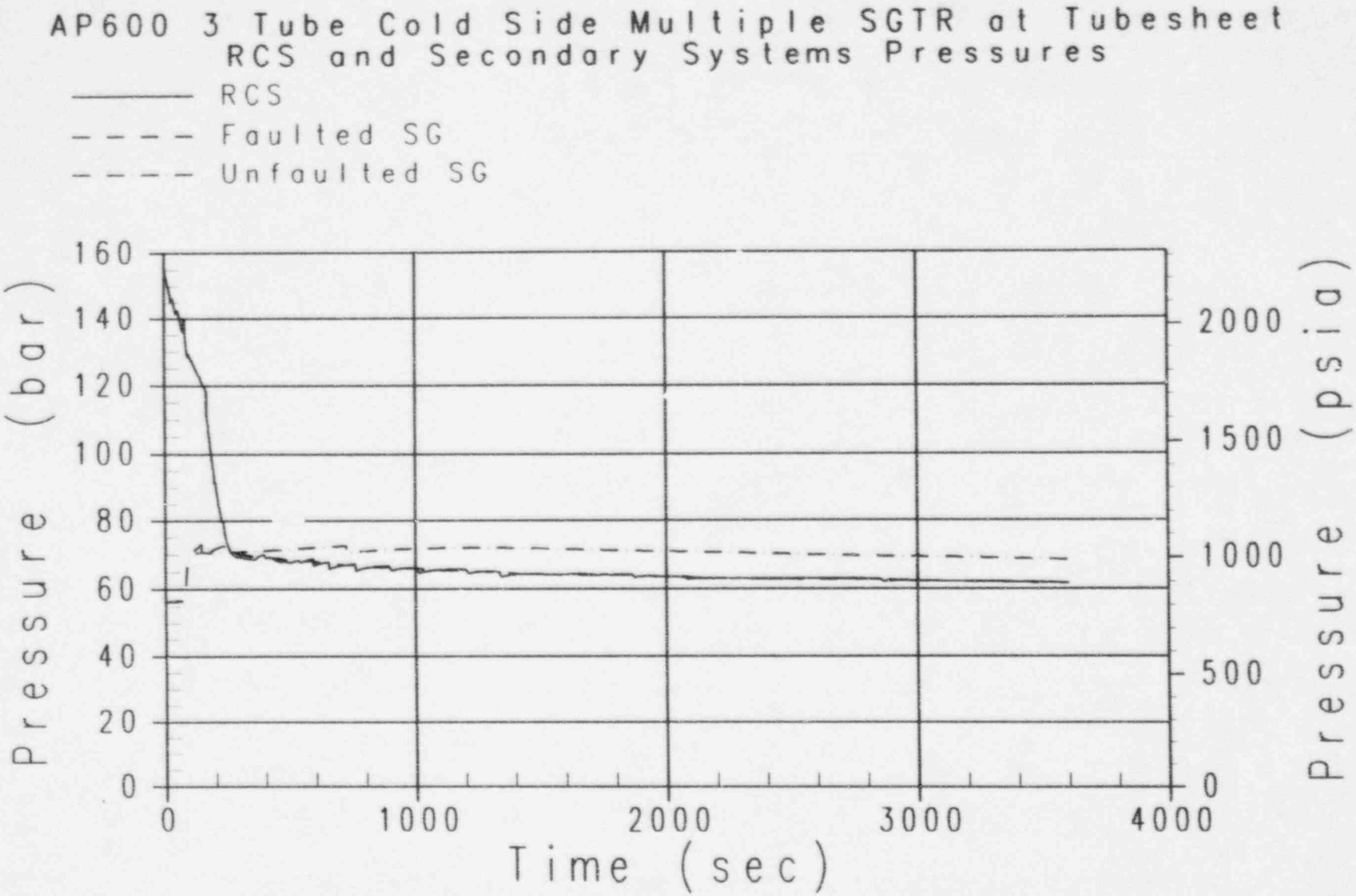


Figure 20



AP600 3 Tube Cold Side Multiple SGTR at Tubesheet
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
Pressure (psia)
Time (sec)
0
20
40
60
80
100
120
140
160
0
500
1000
1500
2000
0
1000
2000
3000
4000

Figure 21

AP600 3 Tube Cold Side Multiple SGTR at Tubesheet
Faulted Steam Generator Pressure

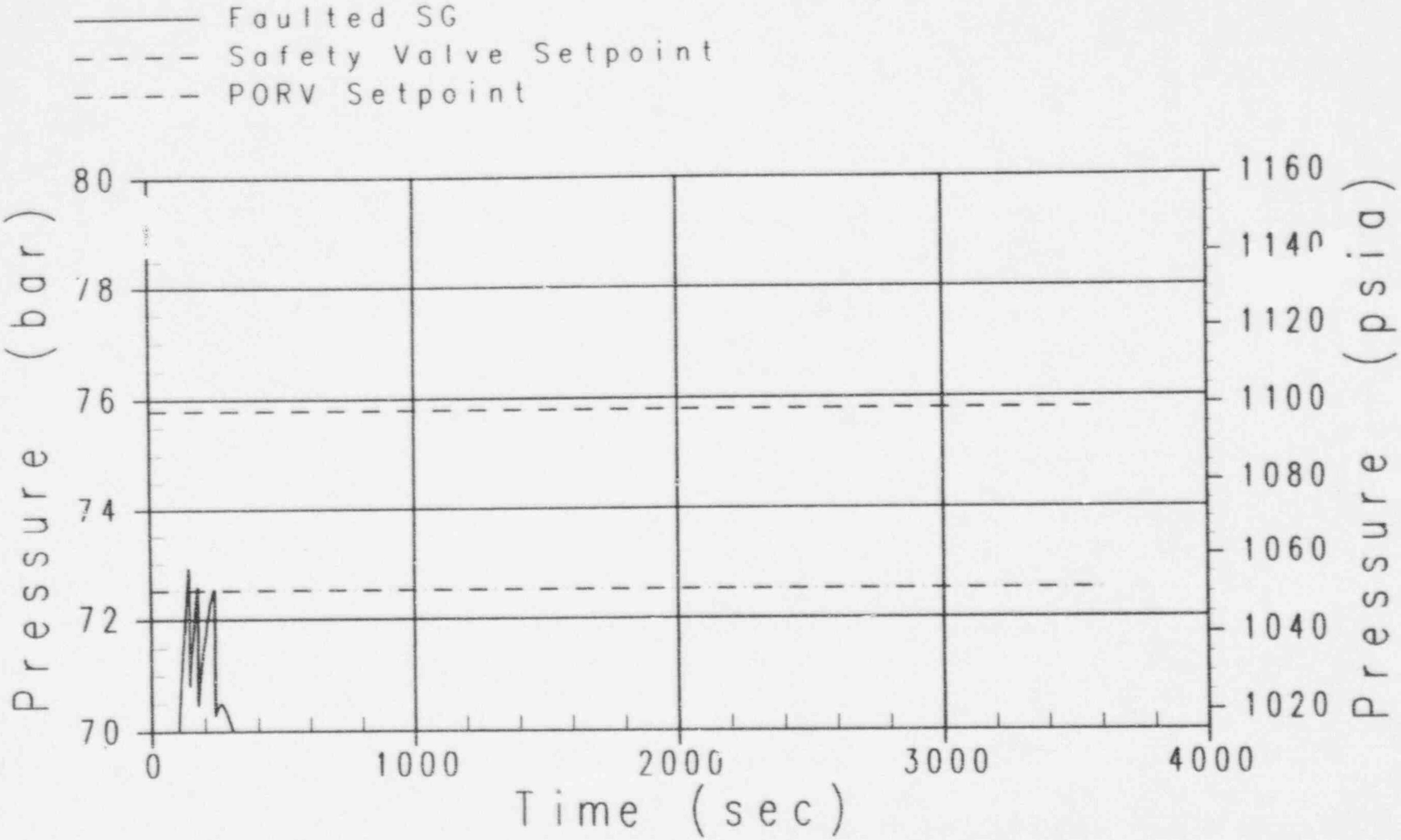


Figure 22

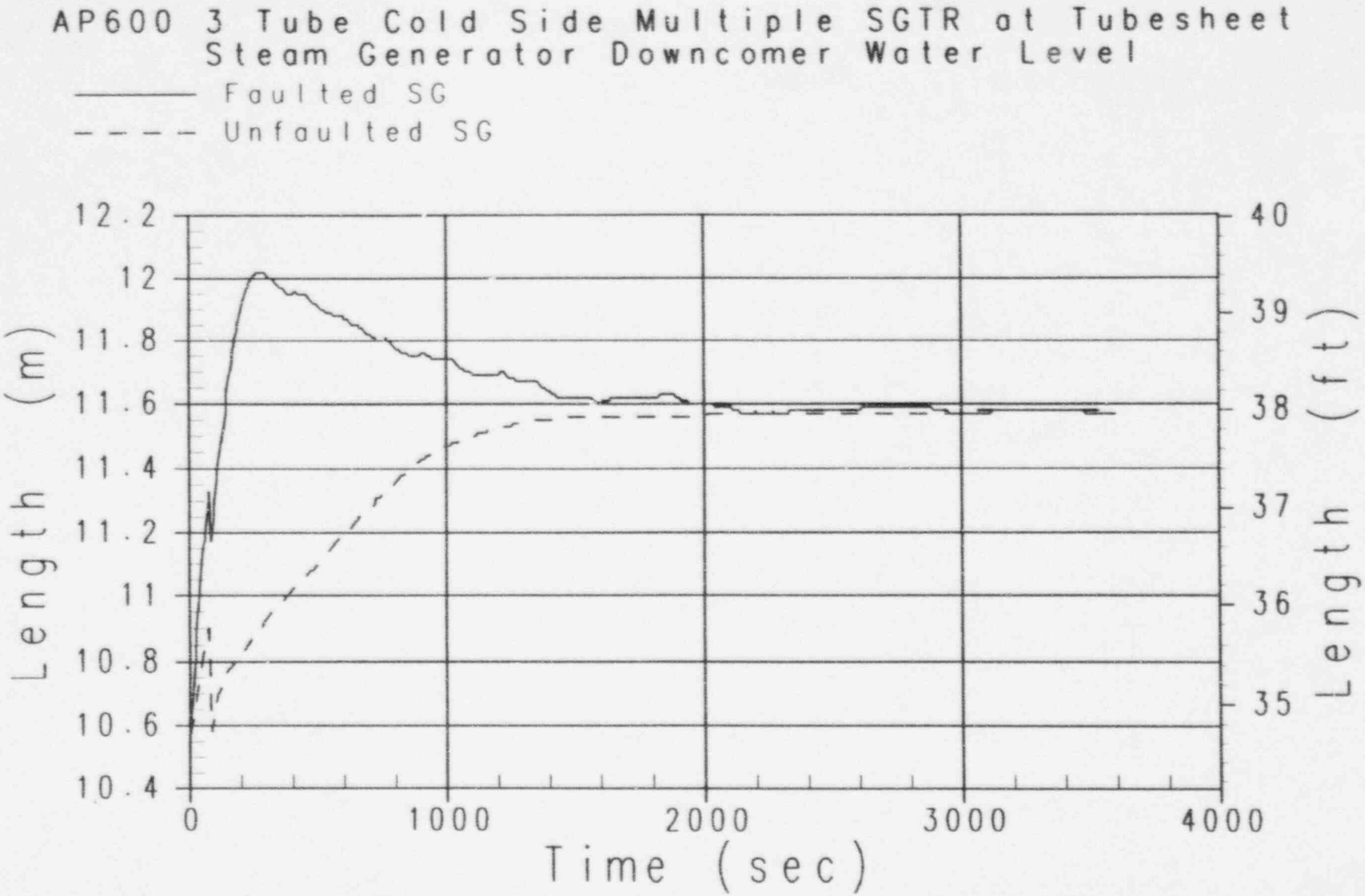

AP600 3 Tube Cold Side Multiple SGTR at Tubesheet
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
Length (m)
Length (ft)
Time (sec)
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
40
39
38
37
36
35
0
1000
2000
3000
4000

Figure 23

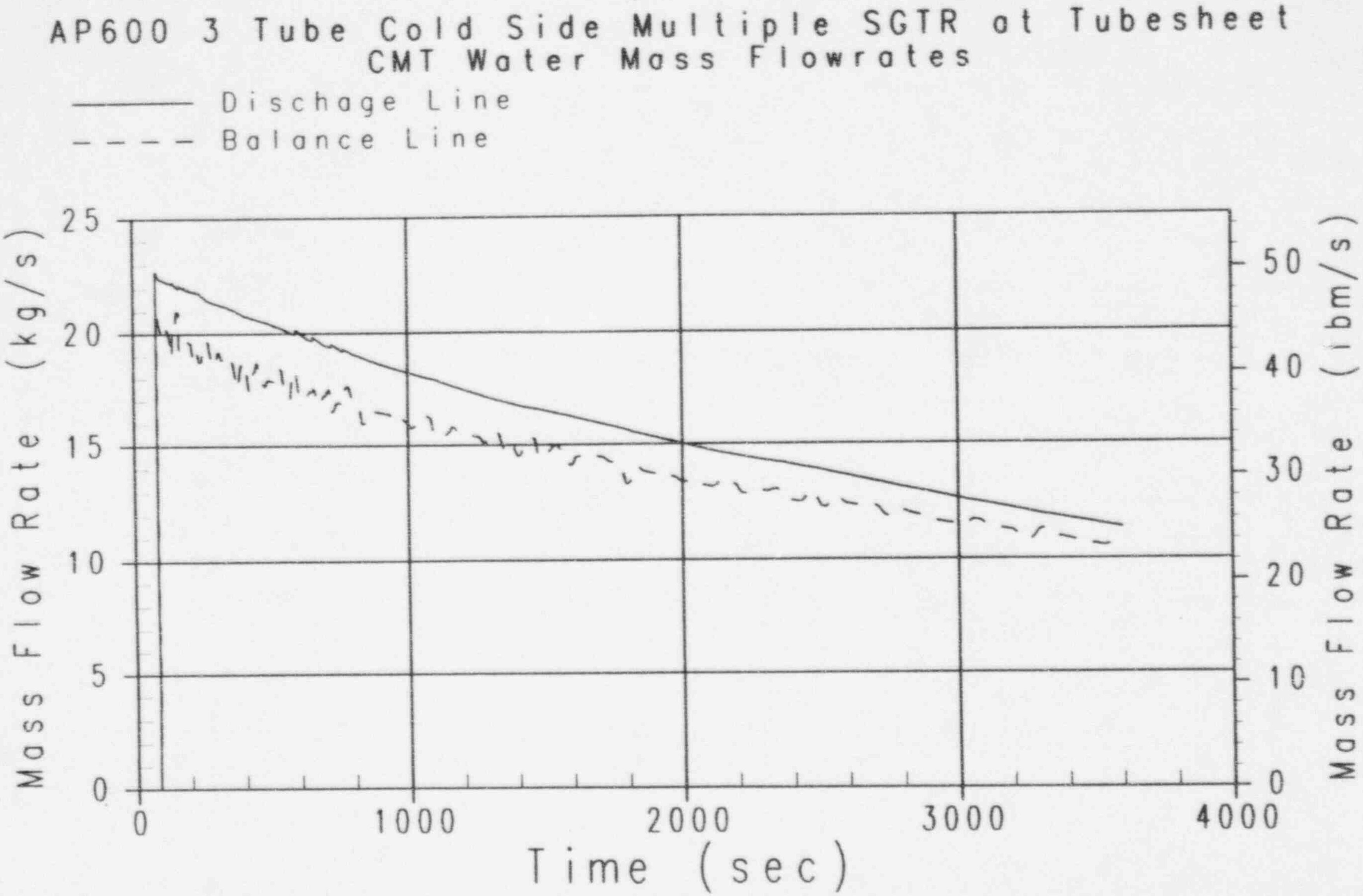

AP600 3 Tube Cold Side Multiple SGTR at Tubesheet
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
5
10
15
20
25
0
10
20
30
40
50
0
1000
2000
3000
4000

Figure 24

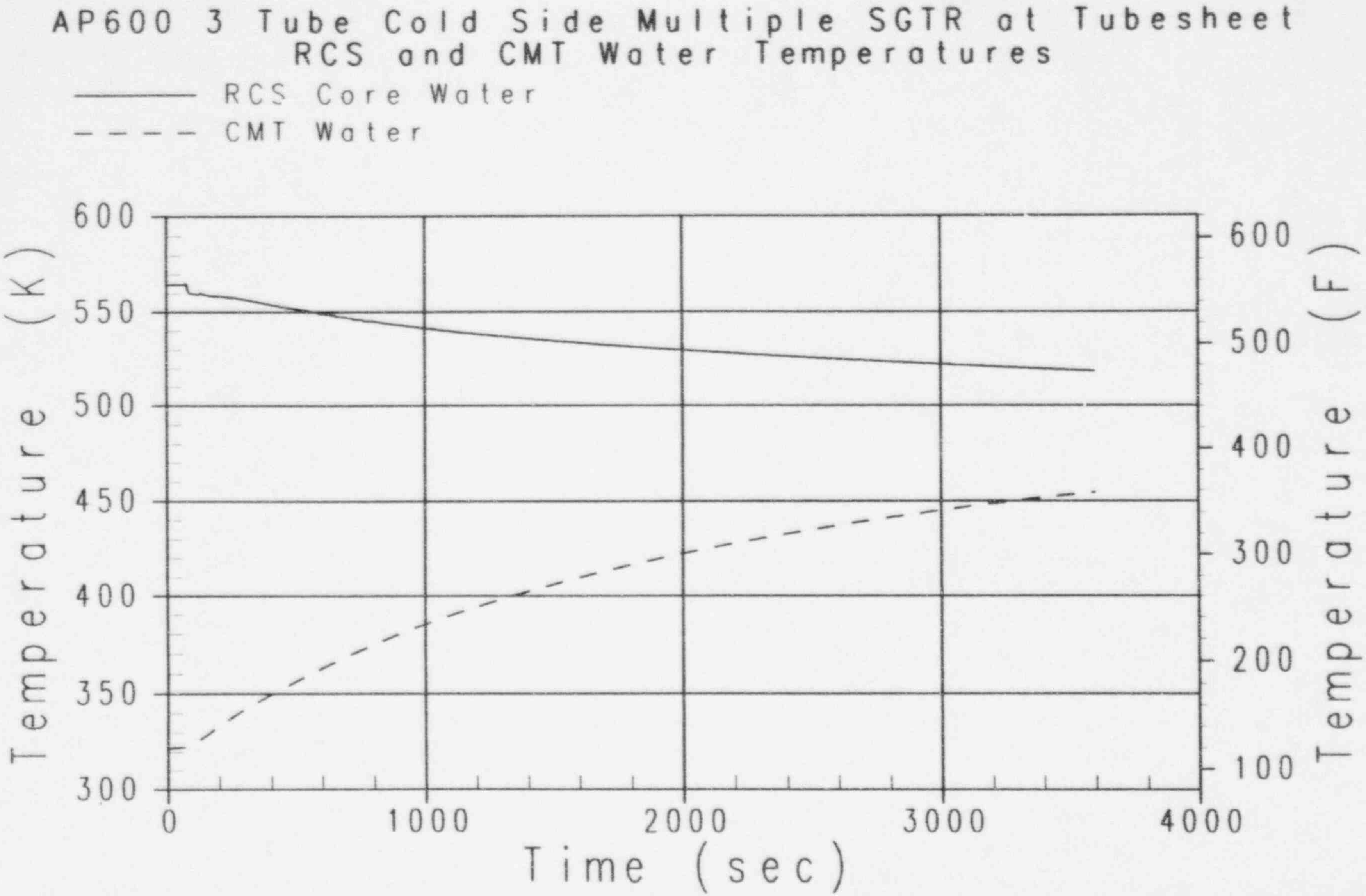

AP600 3 Tube Cold Side Multiple SGTR at Tubesheet
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
600
550
500
450
400
350
300
Temperature (K)
600
500
400
300
200
100
Temperature (F)
0
1000
2000
3000
4000
Time (sec)

Figure 25

AP600 3 Tube Cold Side Multiple SGTR at Tubesheet
CMT Water Level

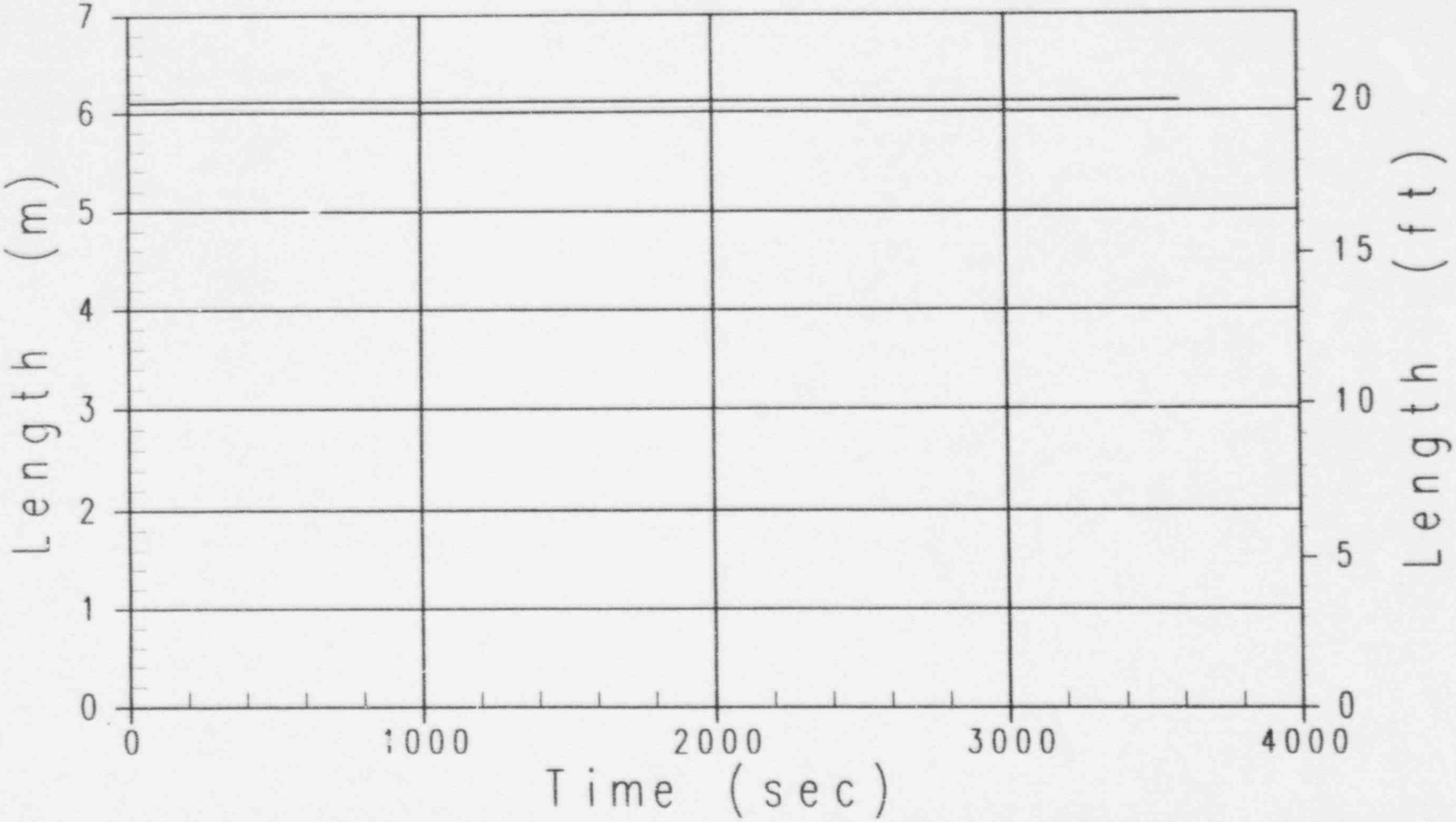


Figure 26

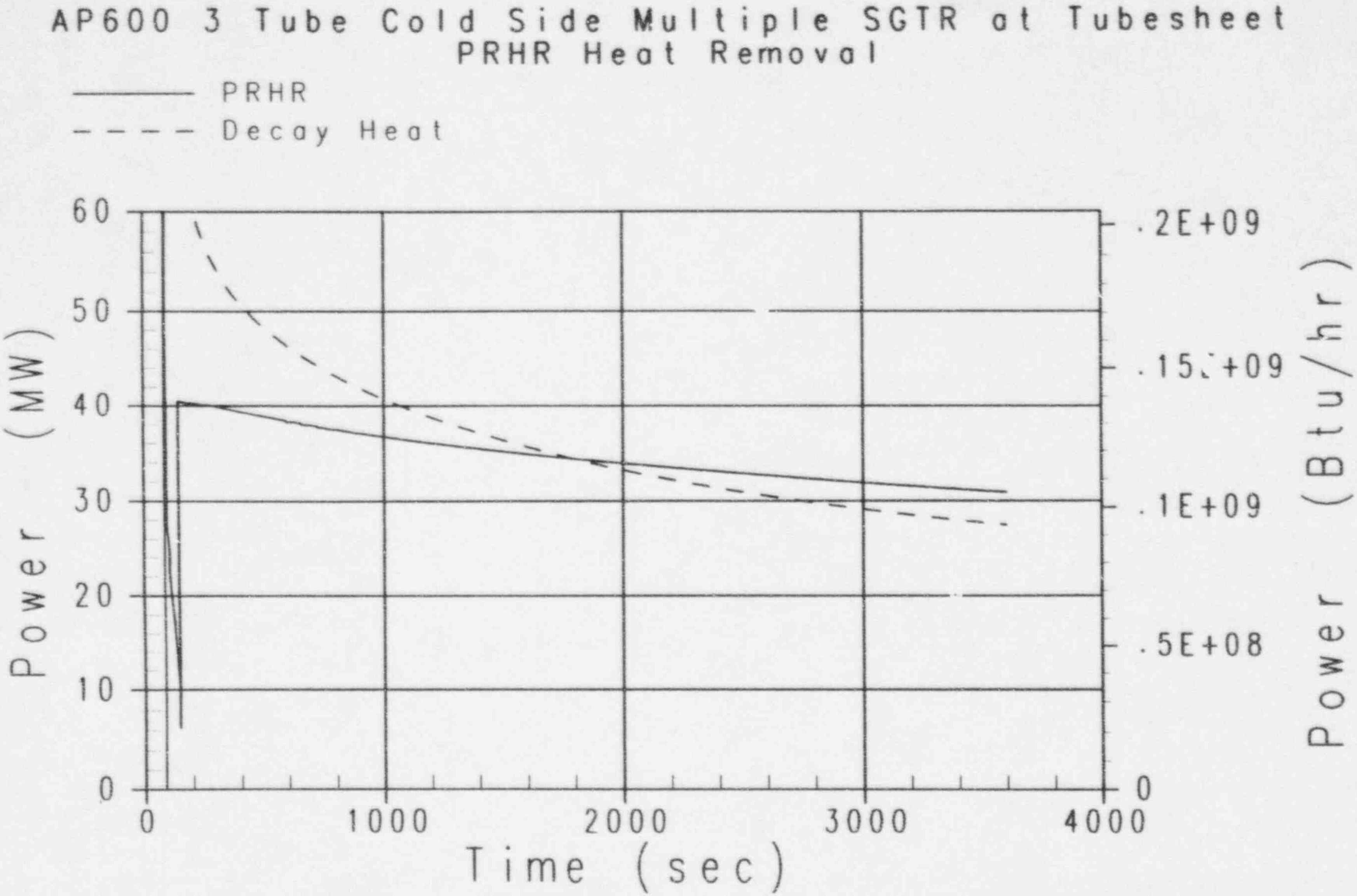

AP600 3 Tube Cold Side Multiple SGTR at Tubesheet
PRHR Heat Removal
PRHR
Decay Heat
Power (MW)
Power (Btu/hr)
Time (sec)
0
10
20
30
40
50
60
1000
2000
3000
4000
.2E+09
.15E+09
.1E+09
.5E+08

Figure 27

AP600 3 Tube Cold Side Multiple SGTR at Tubesheet
RCS Water Level

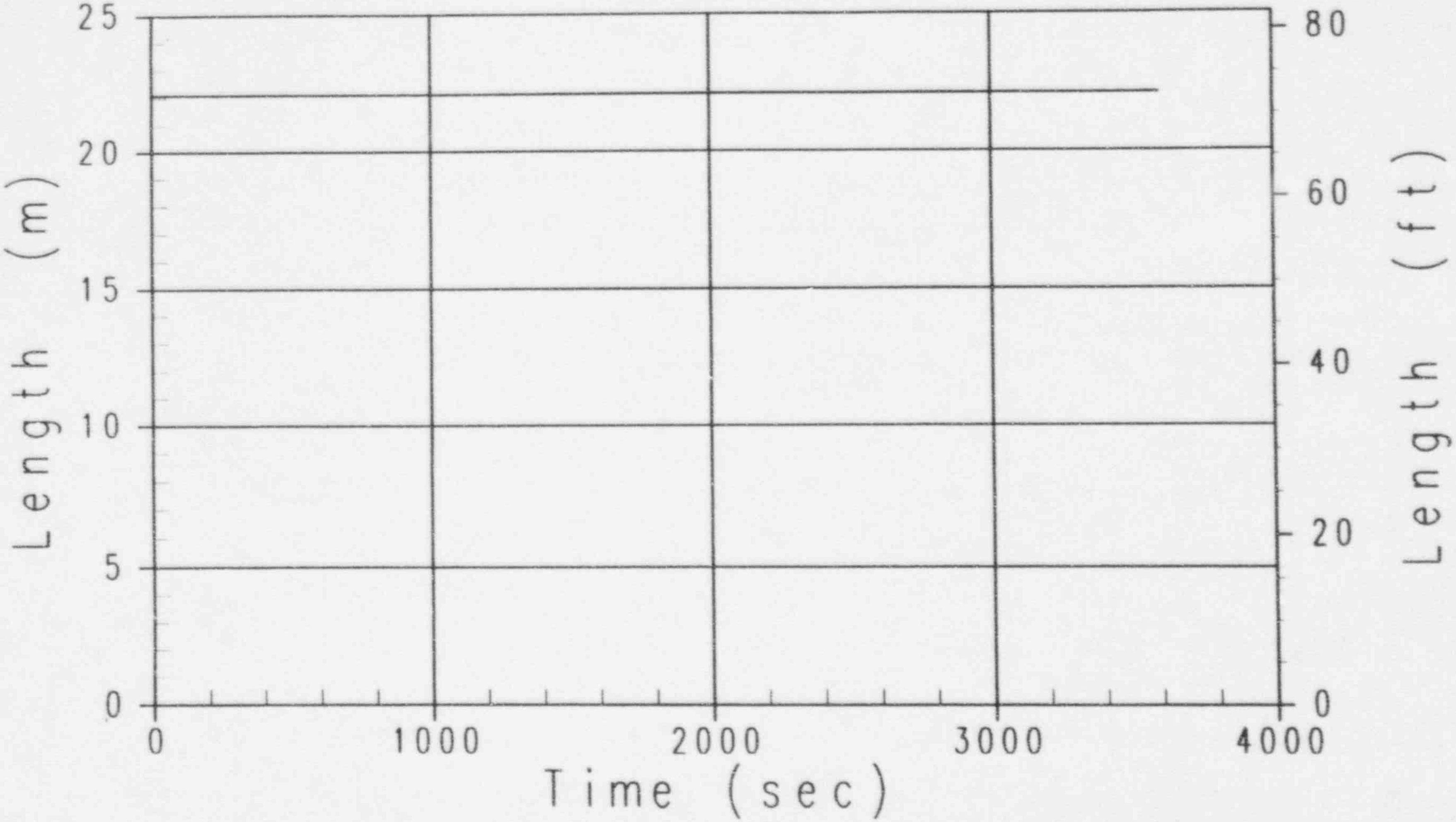


Figure 28

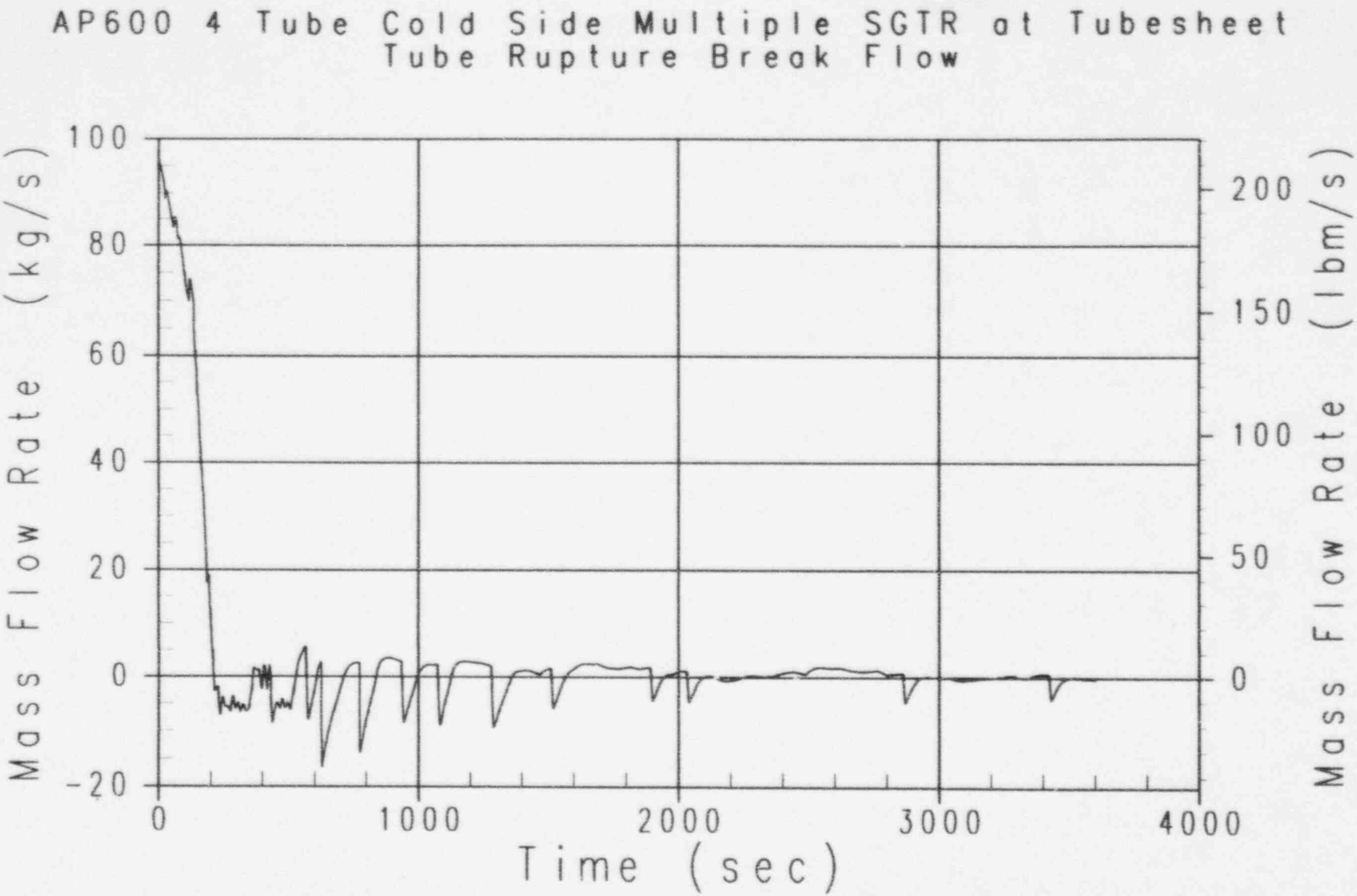
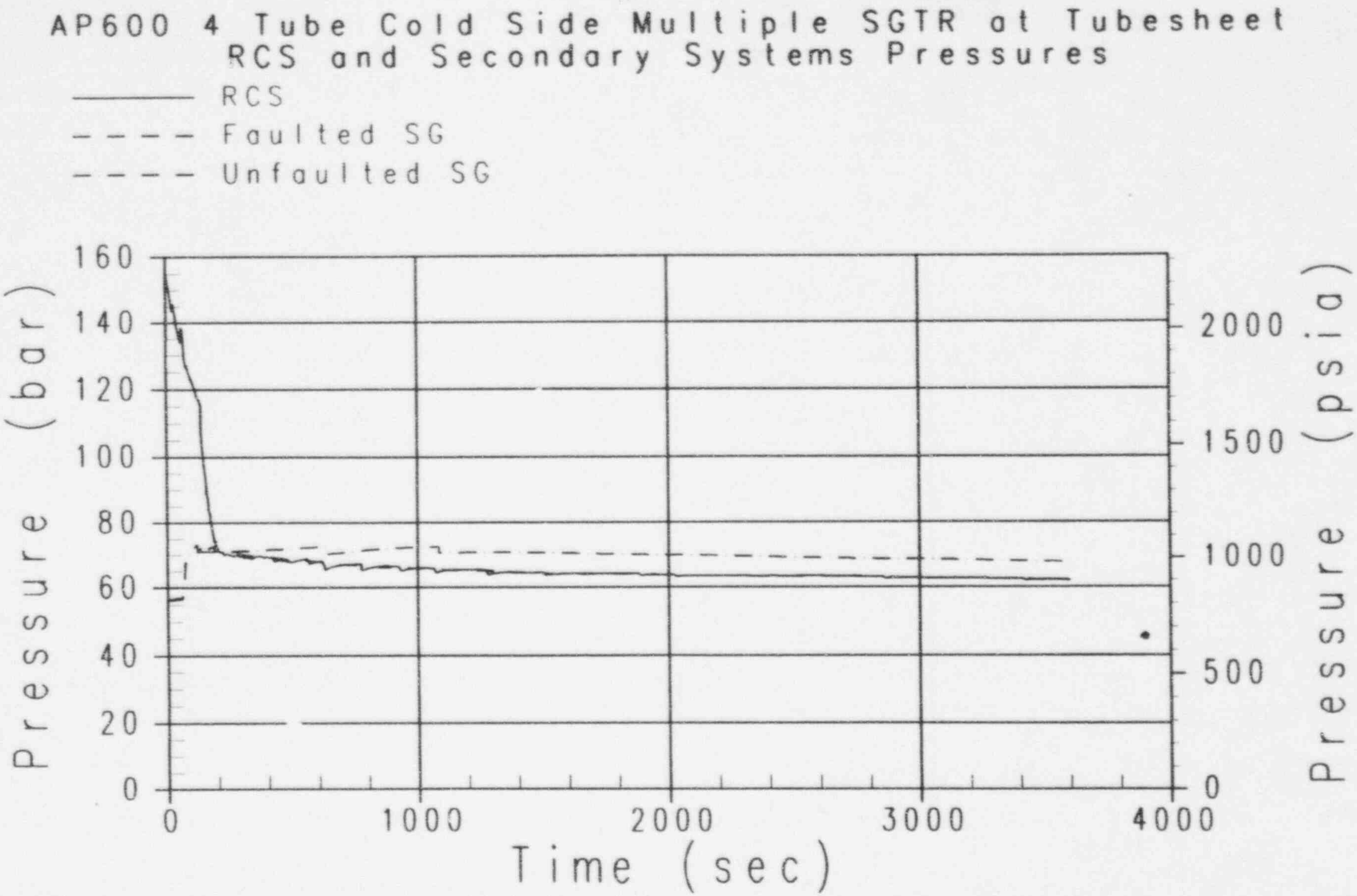

AP600 4 Tube Cold Side Multiple SGTR at Tubesheet
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
100
80
60
40
20
0
-20
200
150
100
50
0
1000
2000
3000
4000

Figure 29



AP600 4 Tube Cold Side Multiple SGTR at Tubesheet
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
Pressure (psia)
Time (sec)
0
20
40
60
80
100
120
140
160
500
1000
1500
2000
1000
2000
3000
4000

Figure 30

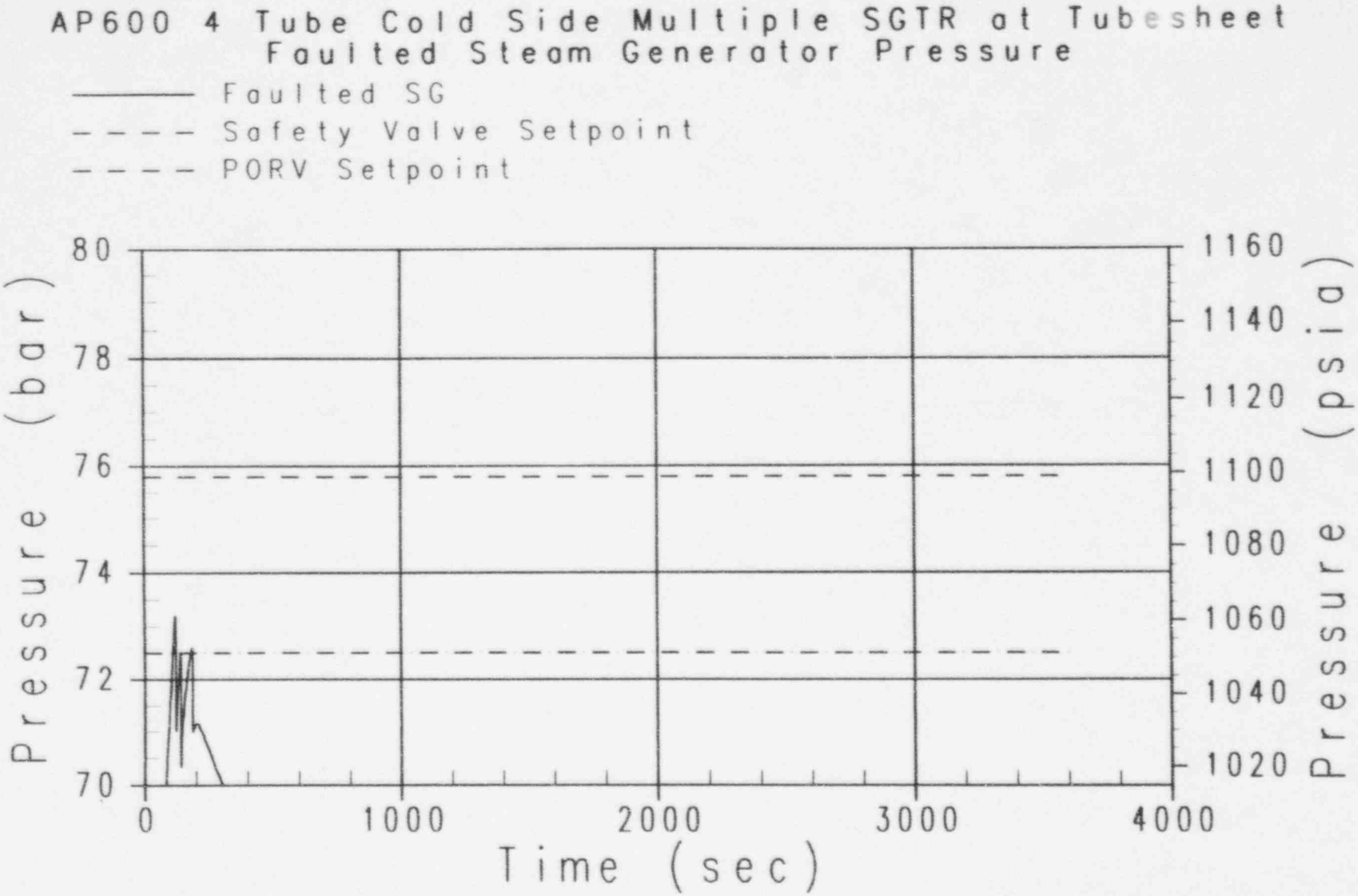
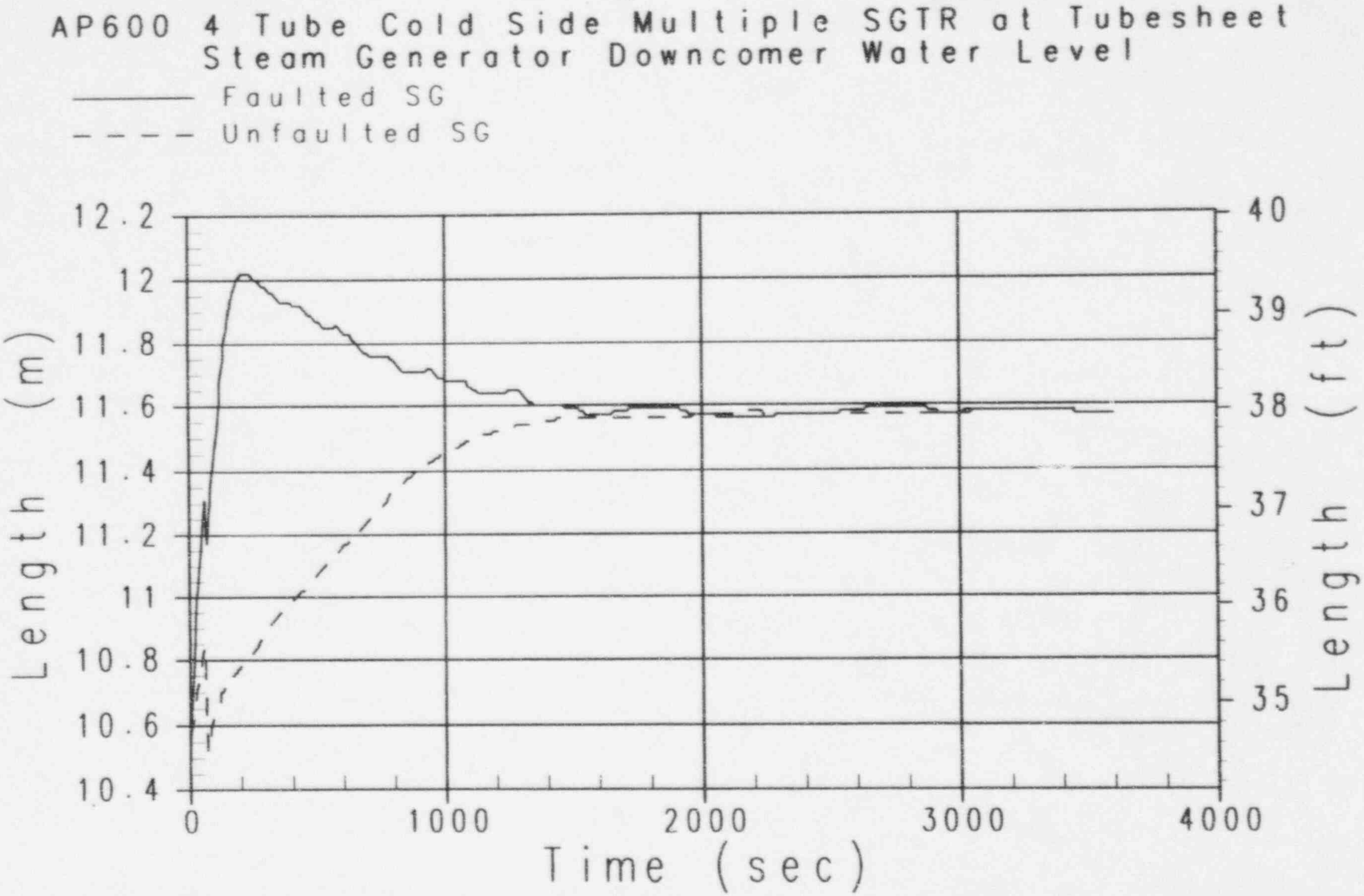

AP600 4 Tube Cold Side Multiple SGTR at Tubesheet
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
PORV Setpoint
Pressure (bar)
Pressure (psia)
Time (sec)
80
78
76
74
72
70
1160
1140
1120
1100
1080
1060
1040
1020
0
1000
2000
3000
4000

Figure 31



AP600 4 Tube Cold Side Multiple SGTR at Tubesheet
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
Length (m)
40
39
38
37
36
35
Length (ft)
0
1000
2000
3000
4000
Time (sec)

Figure 32

AP600 4 Tube Cold Side Multiple SGTR at Tubesheet
CMT Water Mass Flowrates

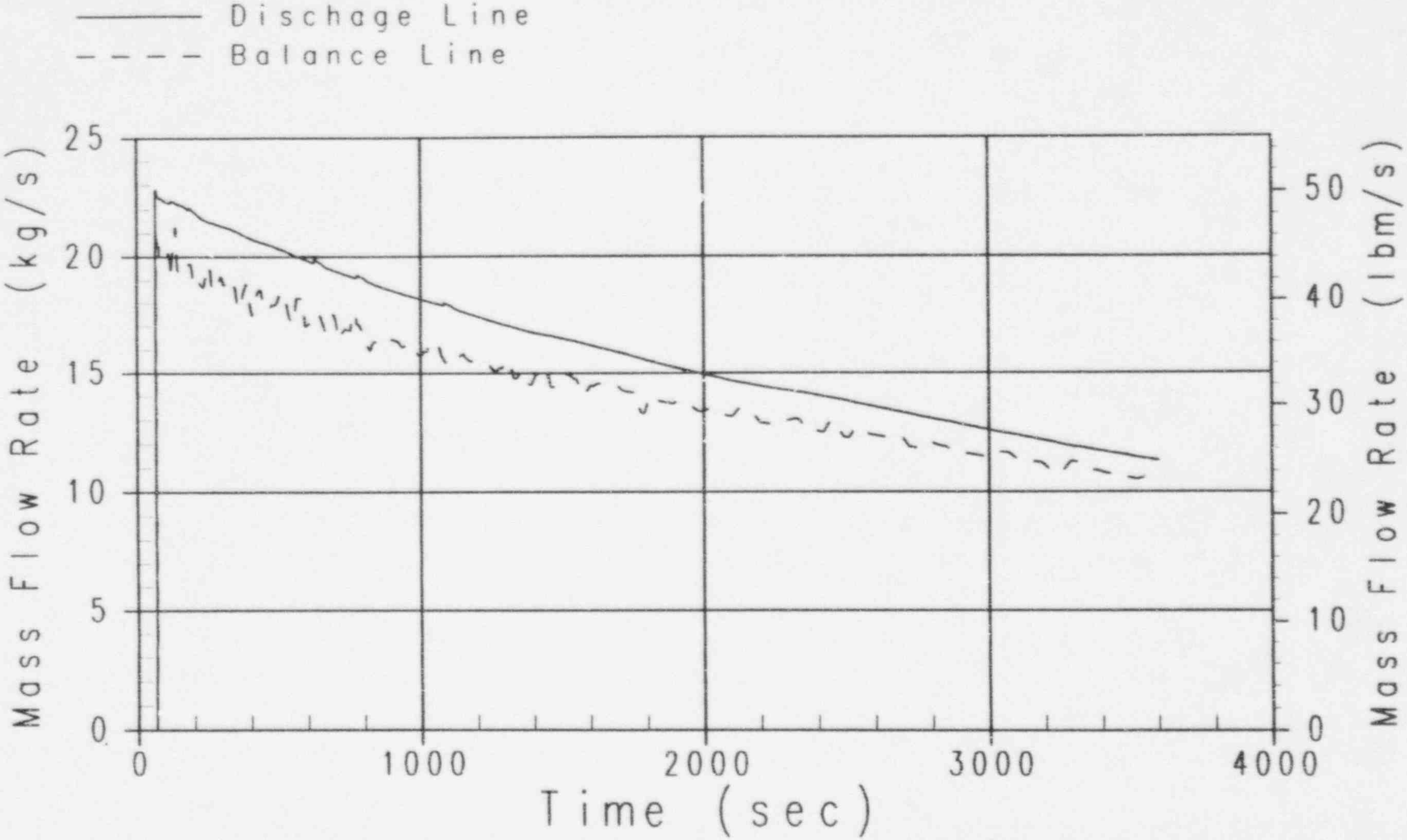


Figure 33

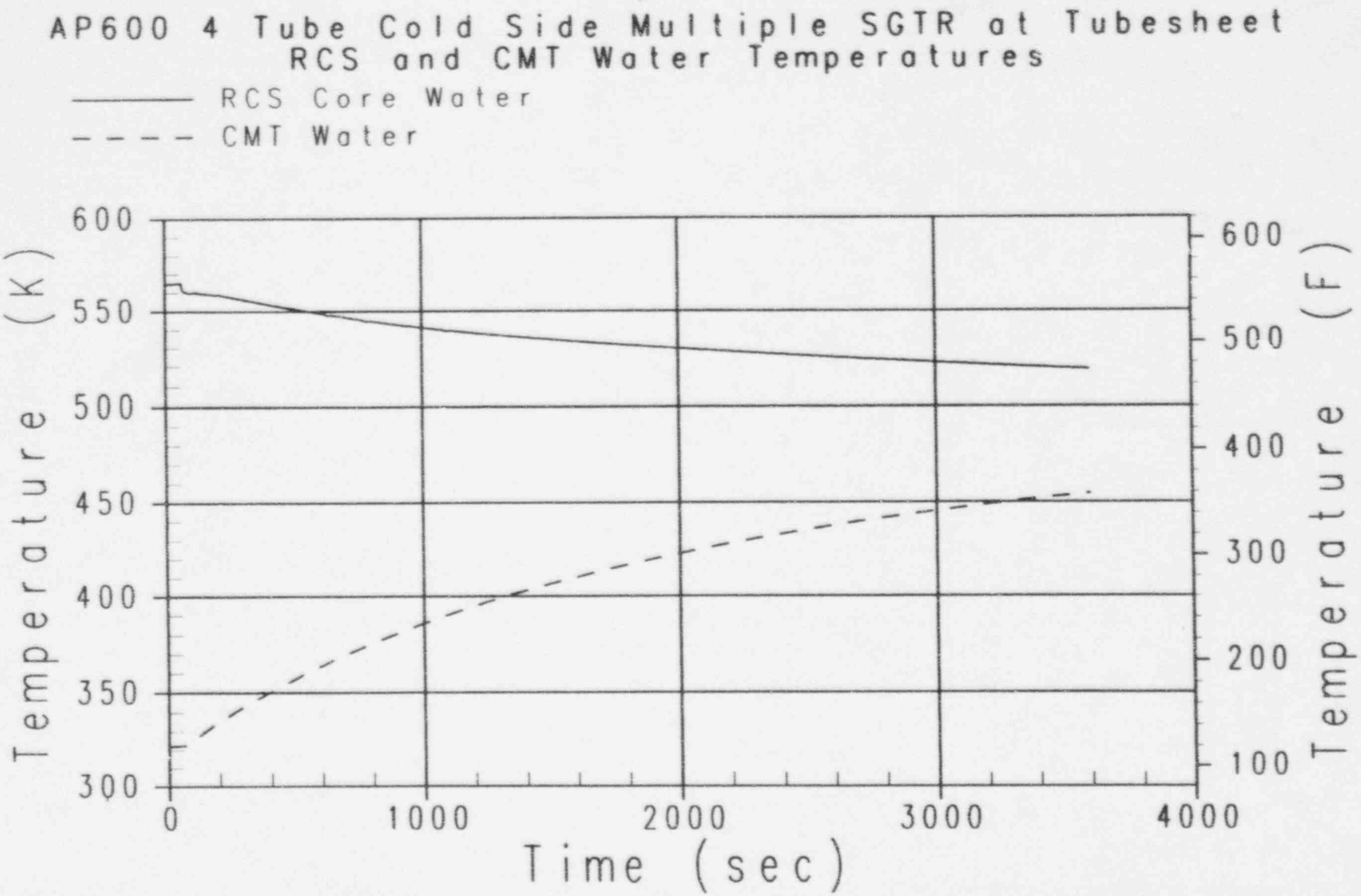
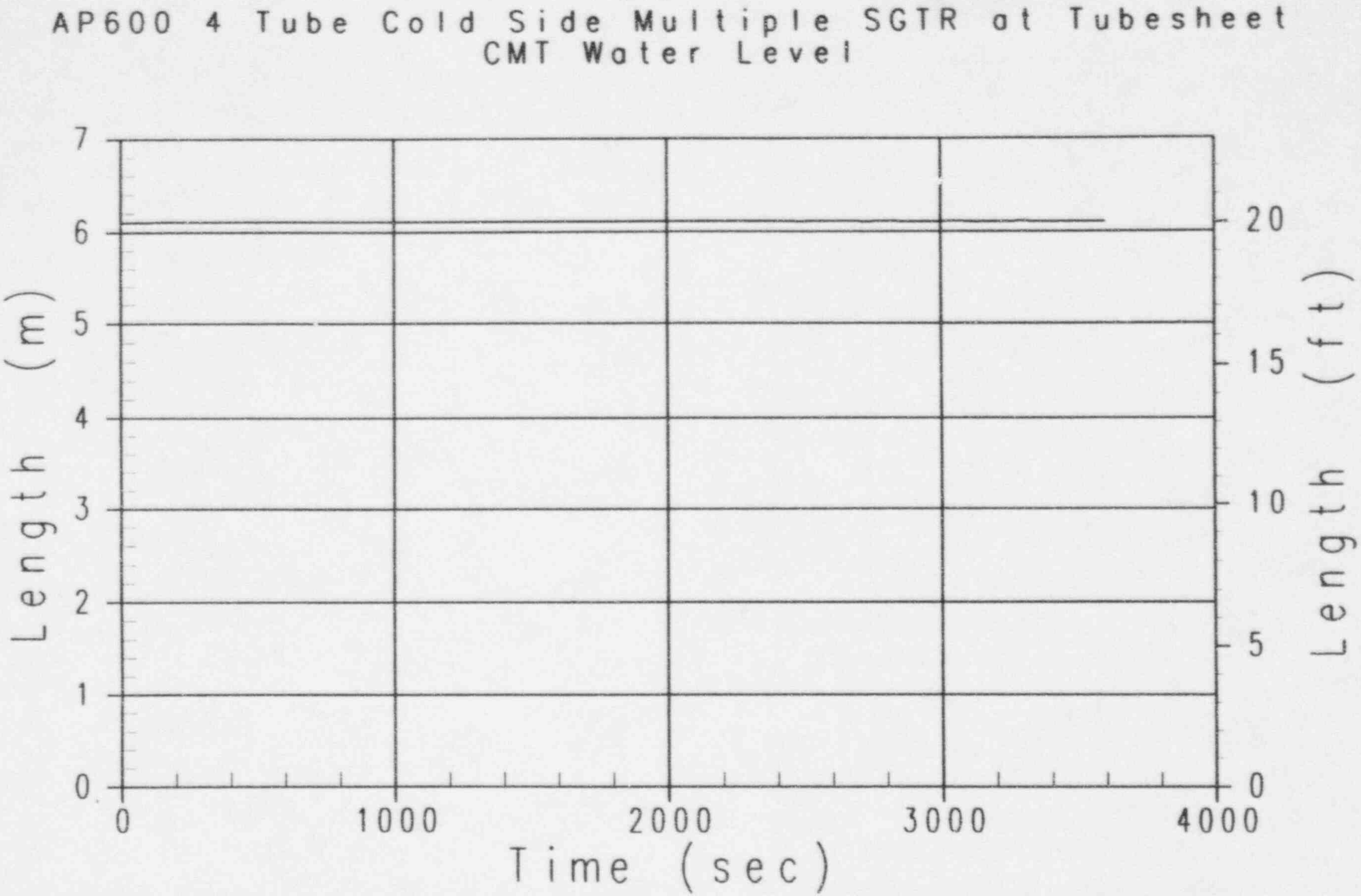

AP600 4 Tube Cold Side Multiple SGTR at Tubesheet
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
600
550
500
450
400
350
300
Temperature (K)
600
500
400
300
200
100
Temperature (F)
0
1000
2000
3000
4000
Time (sec)

Figure 34



AP600 4 Tube Cold Side Multiple SGTR at Tubesheet
CMT Water Level
Length (m)
Length (ft)
Time (sec)
0
1
2
3
4
5
6
7
0
5
10
15
20
1000
2000
3000
4000

Figure 35

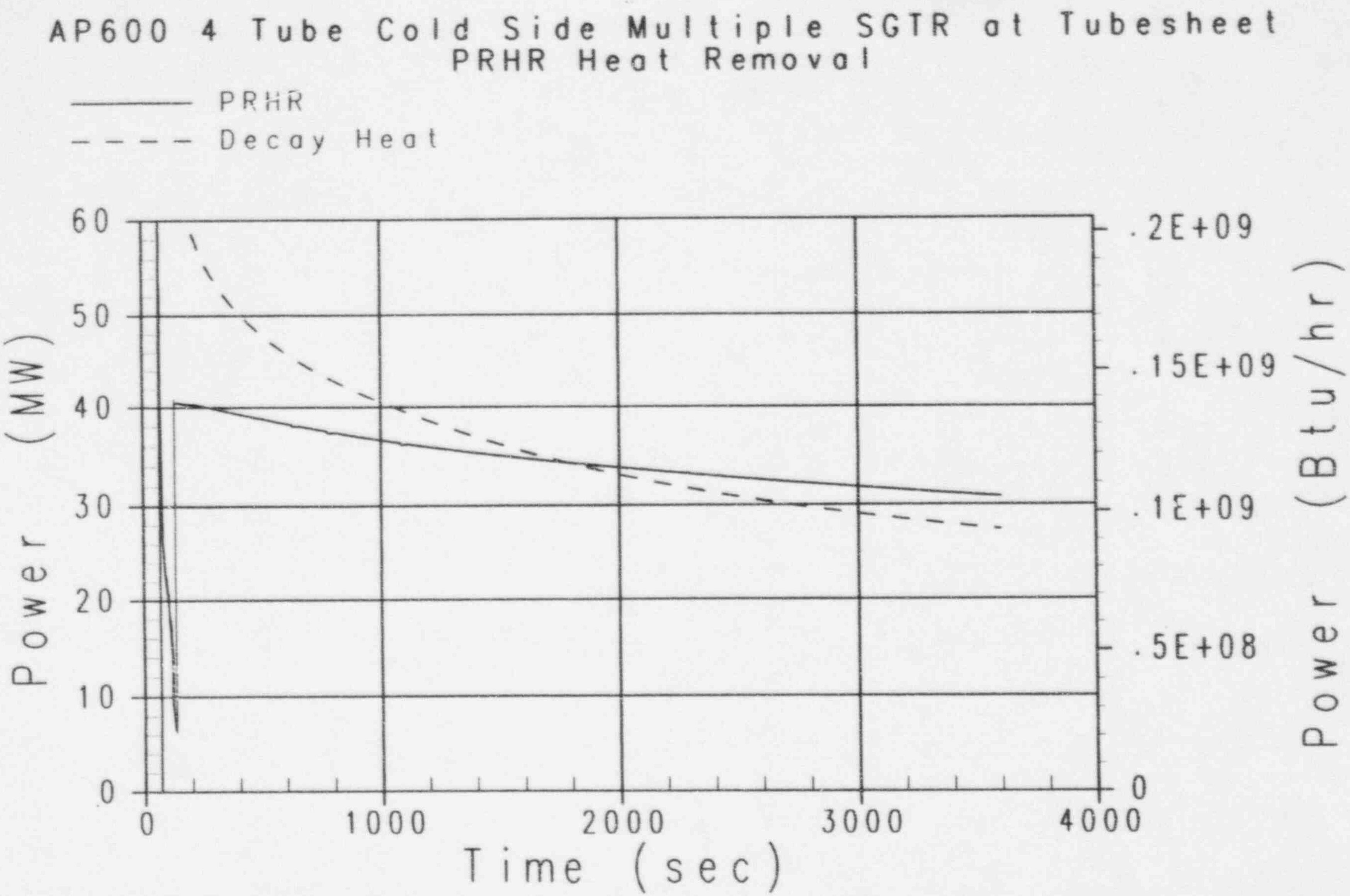

AP600 4 Tube Cold Side Multiple SGTR at Tubesheet
PRHR Heat Removal
PRHR
Decay Heat
Power (MW)
Power (Btu/hr)
Time (sec)
0
10
20
30
40
50
60
0
.5E+08
.1E+09
.15E+09
.2E+09
0
1000
2000
3000
4000

Figure 36

AP600 4 Tube Cold Side Multiple SGTR at Tubesheet
RCS Water Level

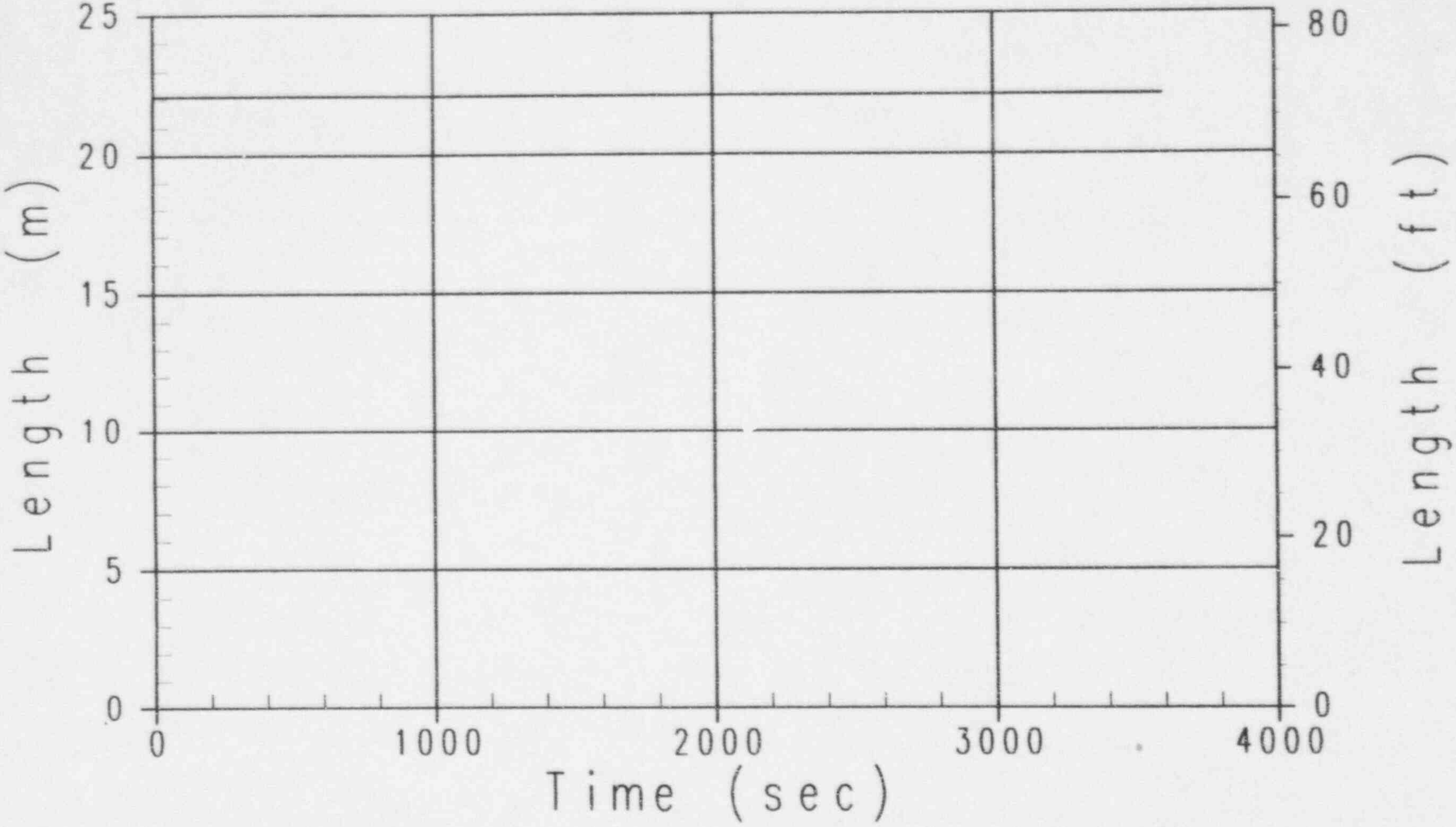


Figure 37

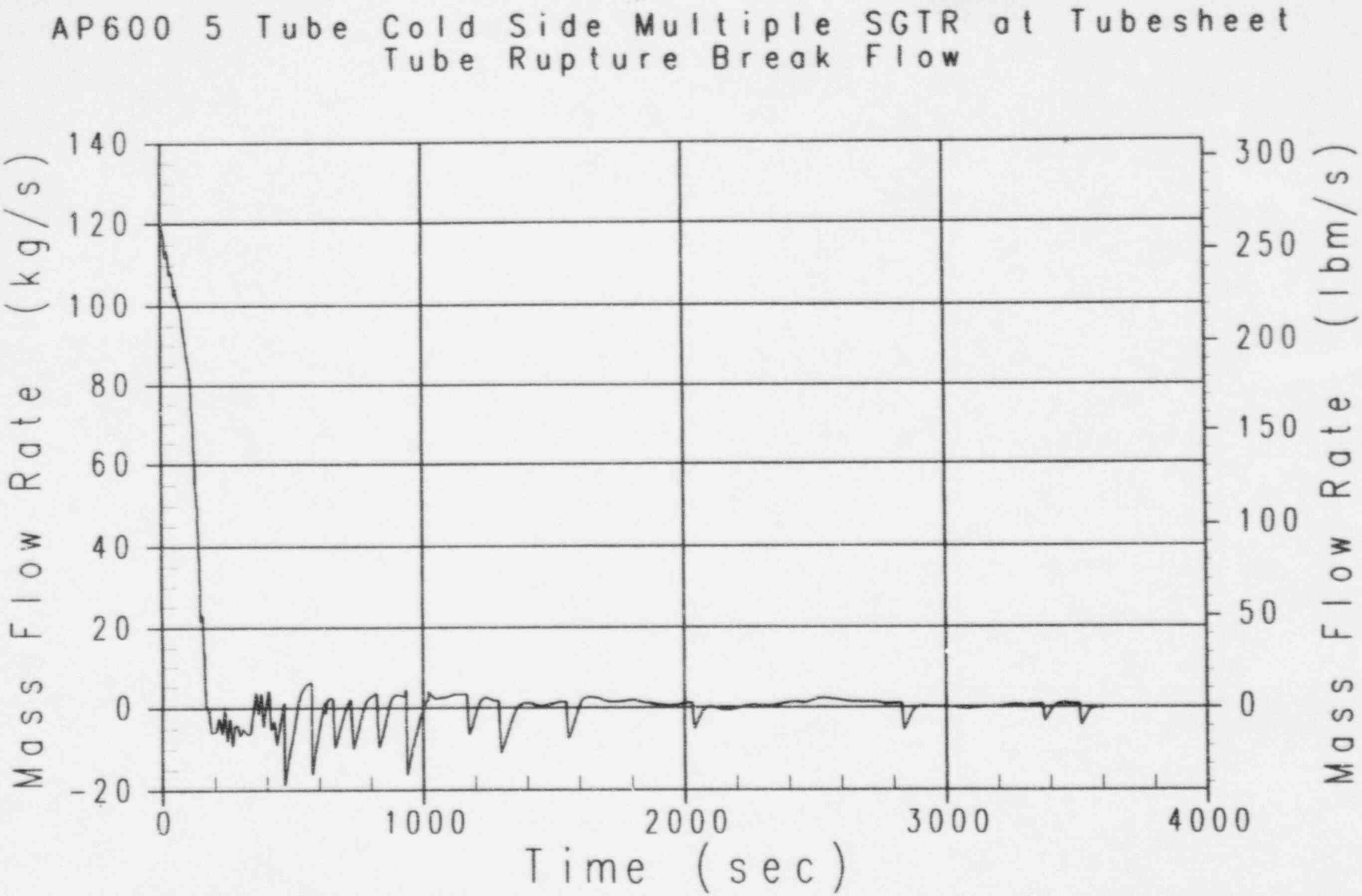

AP600 5 Tube Cold Side Multiple SGTR at Tubesheet
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
140
120
100
80
60
40
20
0
-20
0
1000
2000
3000
4000
Time (sec)
300
250
200
150
100
50
0
Mass Flow Rate (lbm/s)

Figure 38

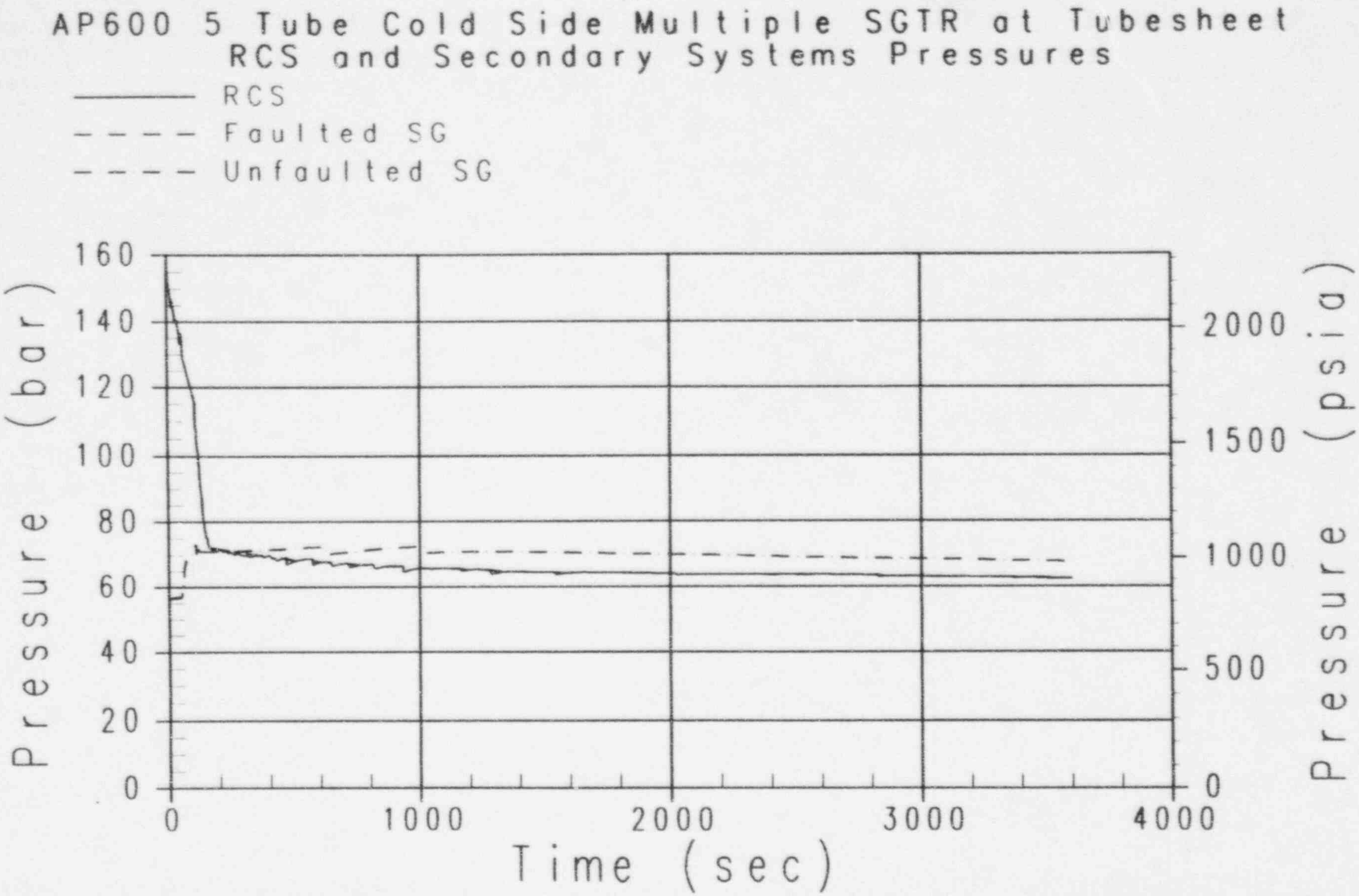
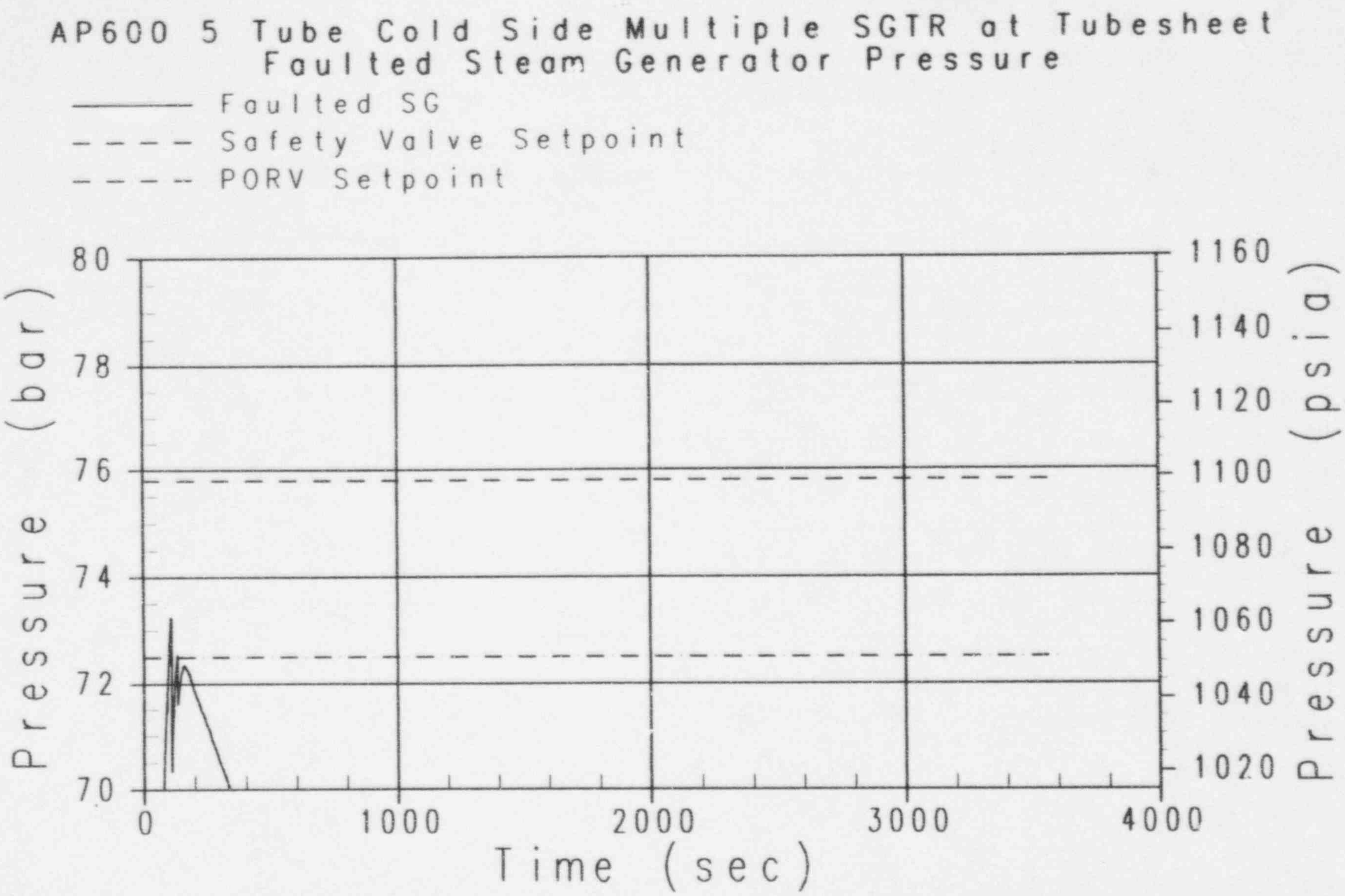

AP600 5 Tube Cold Side Multiple SGTR at Tubesheet
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
160
140
120
100
80
60
40
20
0
Pressure (bar)
2000
1500
1000
500
0
Pressure (psia)
0
1000
2000
3000
4000
Time (sec)

Figure 39



AP600 5 Tube Cold Side Multiple SGTR at Tubesheet
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
PORV Setpoint
80
78
76
74
72
70
1160
1140
1120
1100
1080
1060
1040
1020
Pressure (bar)
Pressure (psia)
0
1000
2000
3000
4000
Time (sec)

Figure 40

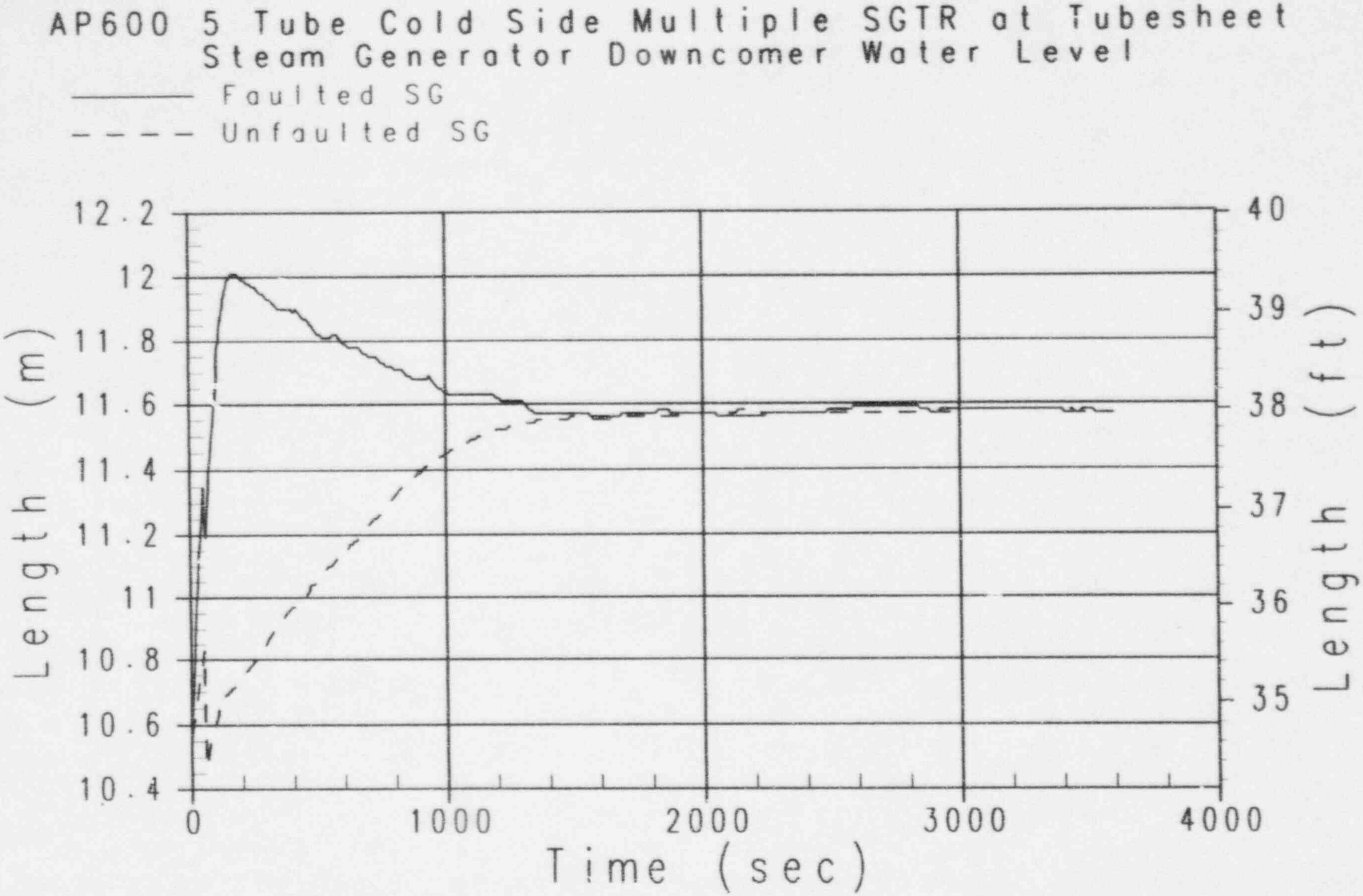

AP600 5 Tube Cold Side Multiple SGTR at Tubesheet
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
Length (m)
40
39
38
37
36
35
Length (ft)
0
1000
2000
3000
4000
Time (sec)

Figure 41

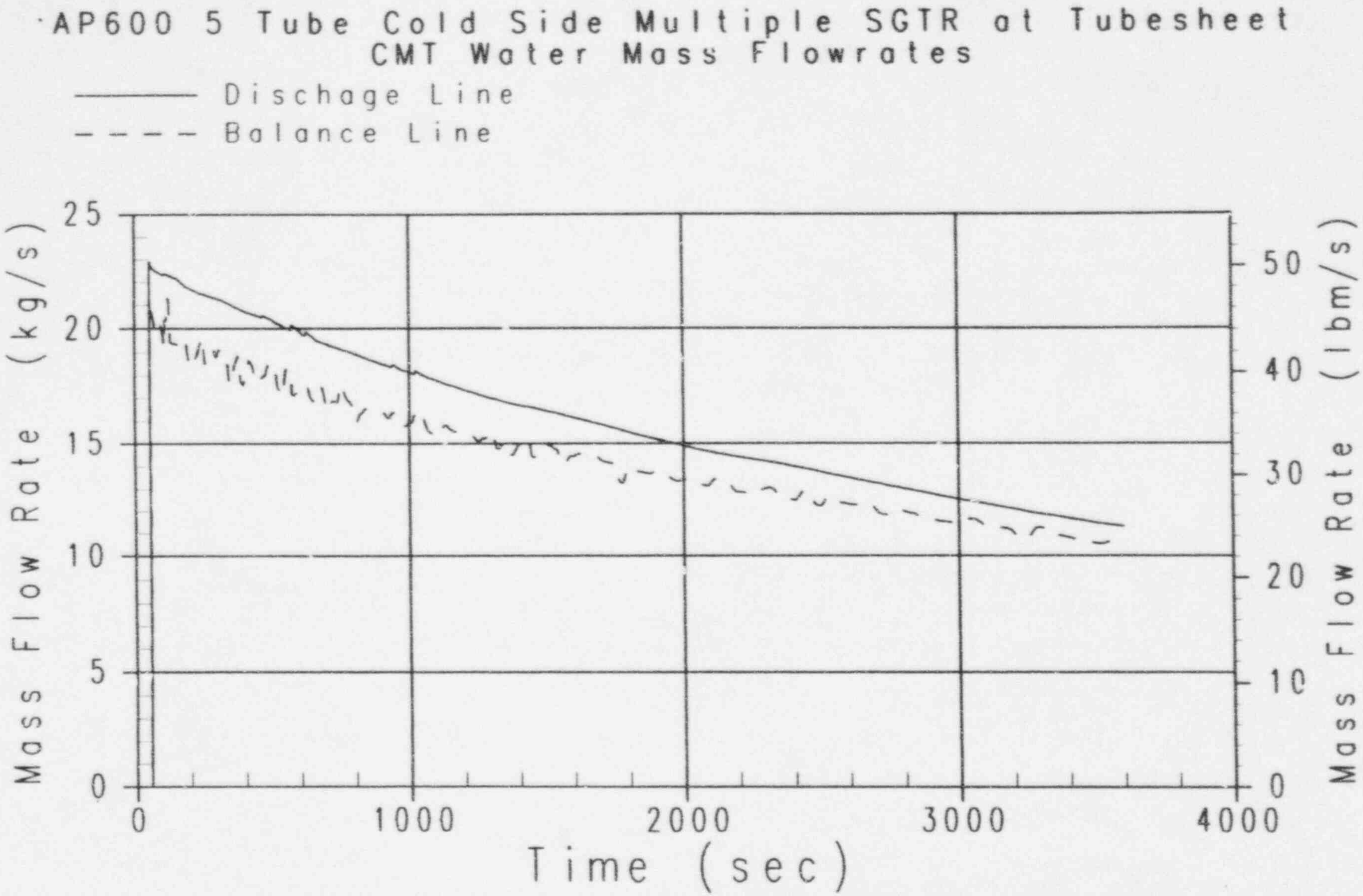
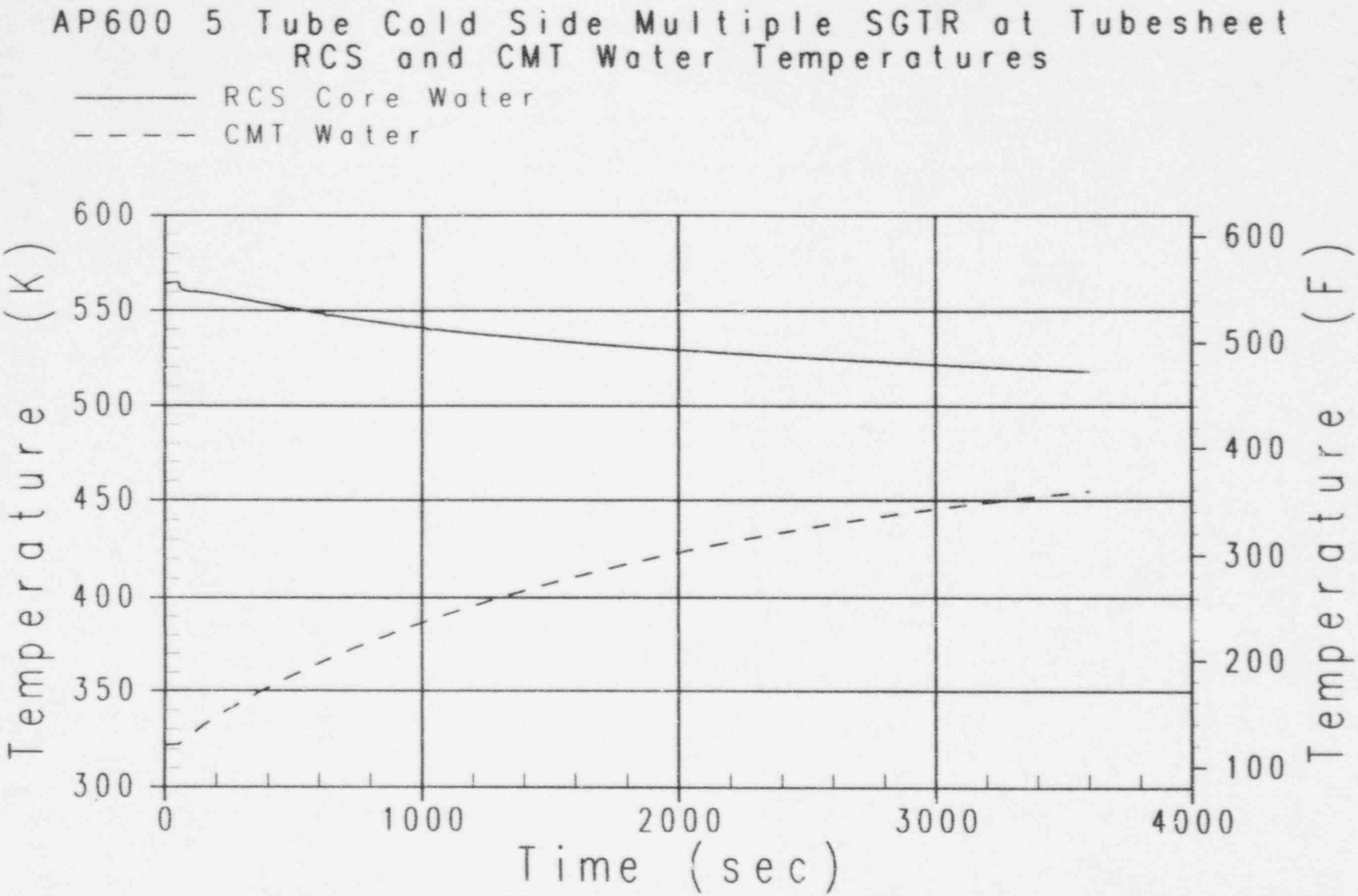

AP600 5 Tube Cold Side Multiple SGTR at Tubesheet
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
5
10
15
20
25
0
10
20
30
40
50
0
1000
2000
3000
4000

Figure 42



AP600 5 Tube Cold Side Multiple SGTR at Tubesheet
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
600
550
500
450
400
350
300
Temperature (K)
600
500
400
300
200
100
Temperature (F)
0
1000
2000
3000
4000
Time (sec)

Figure 43

AP600 5 Tube Cold Side Multiple SGTR at Tubesheet
CMT Water Level

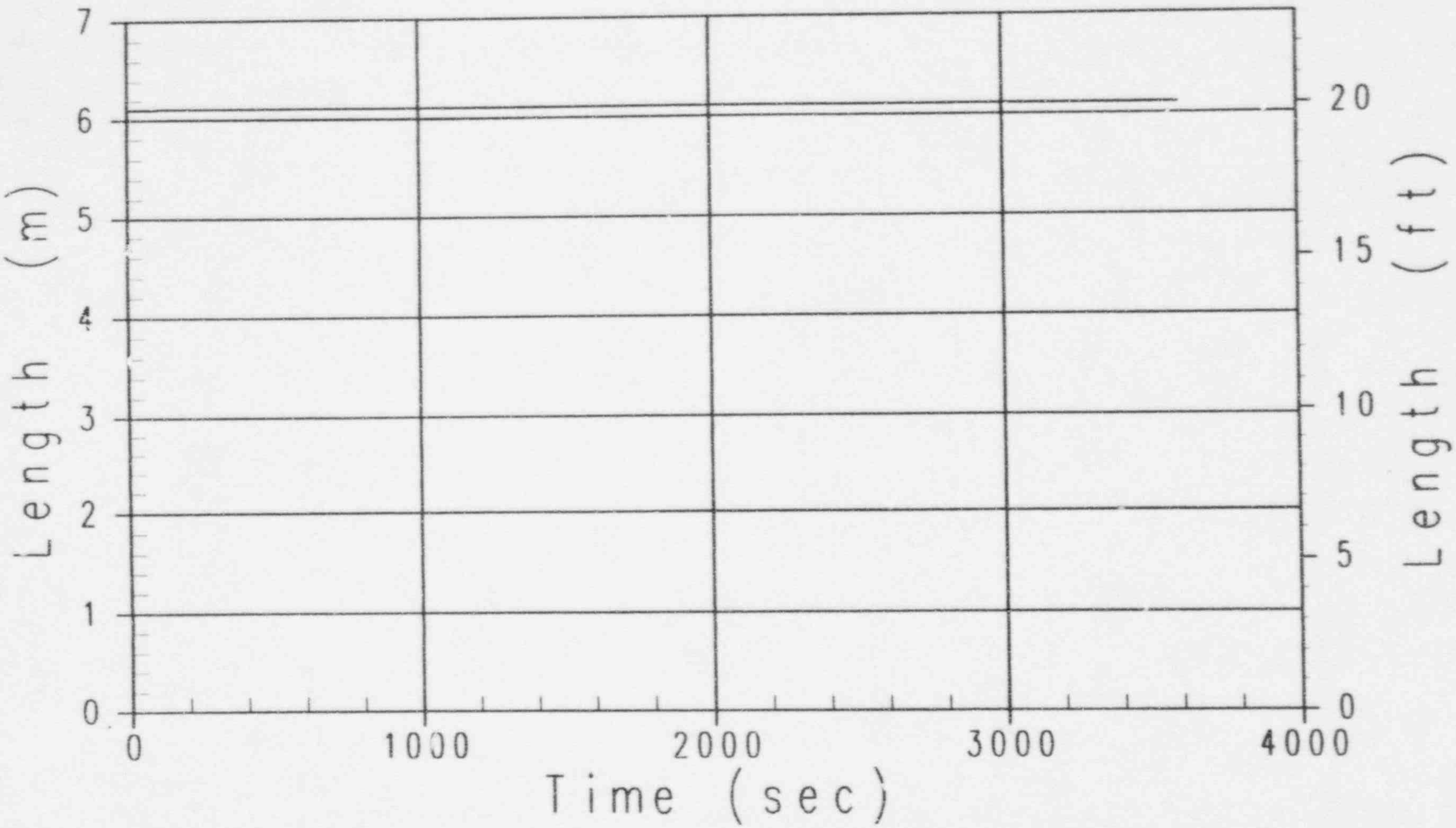


Figure 44

AP600 5 Tube Cold Side Multiple SGTR at Tubesheet
PRHR Heat Removal

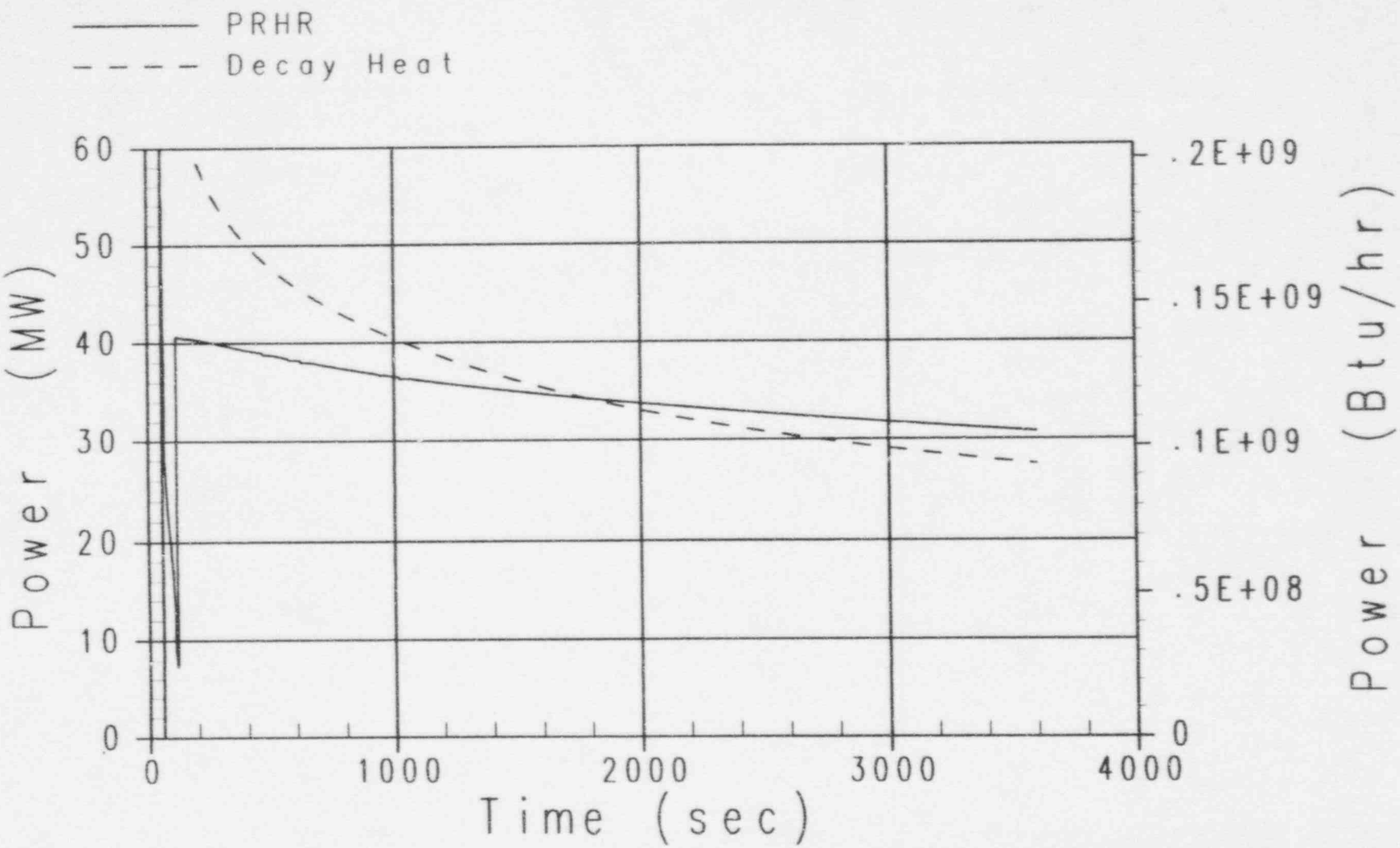


Figure 45

AP600 5 Tube Cold Side Multiple SGTR at Tubesheet
RCS Water Level

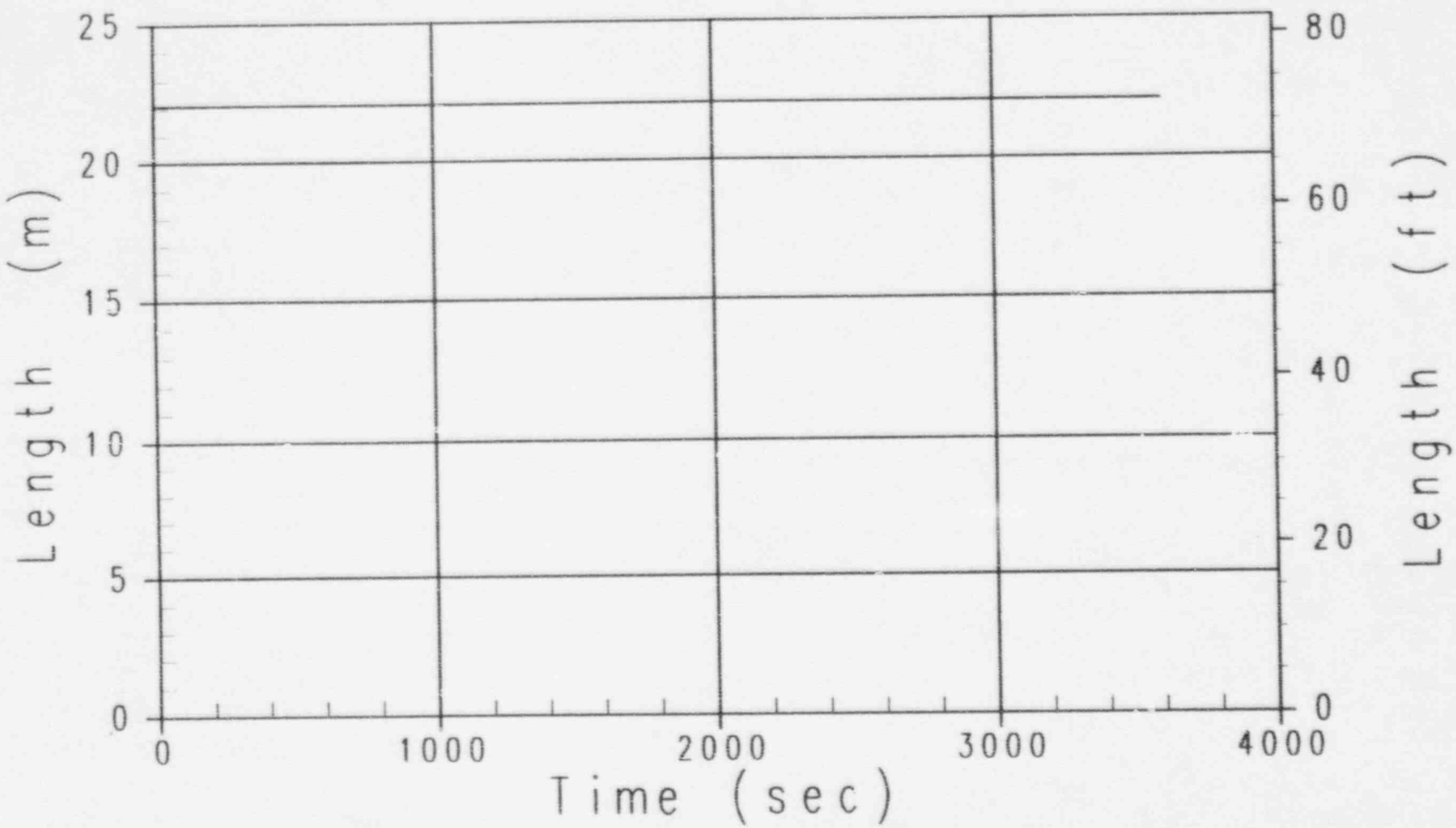


Figure 46

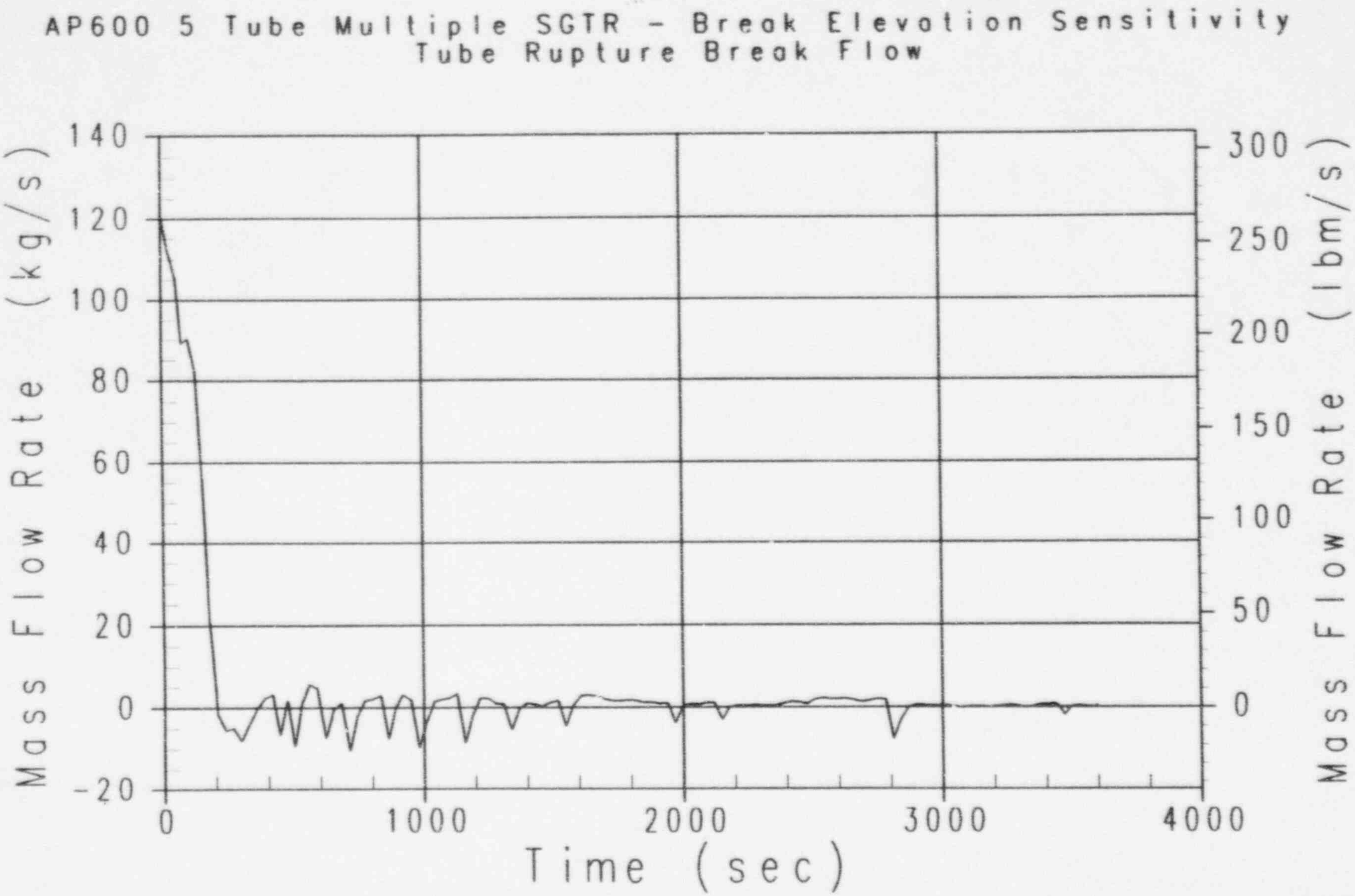

AP600 5 Tube Multiple SGTR - Break Elevation Sensitivity
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
140
120
100
80
60
40
20
0
-20
300
250
200
150
100
50
0
1000
2000
3000
4000

Figure 47

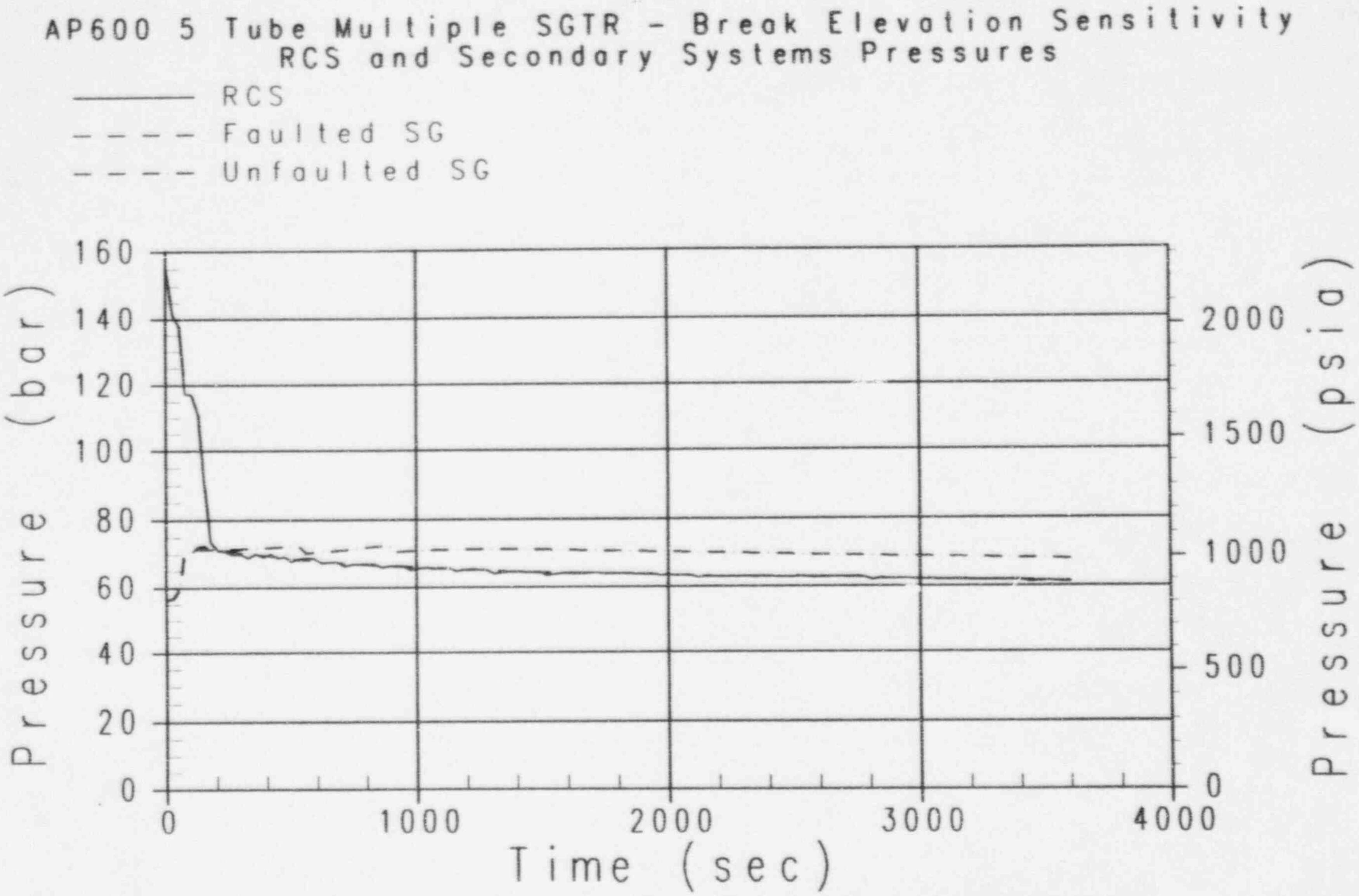

AP600 5 Tube Multiple SGTR - Break Elevation Sensitivity
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
Pressure (psia)
Time (sec)
160
140
120
100
80
60
40
20
0
2000
1500
1000
500
0
1000
2000
3000
4000

Figure 48

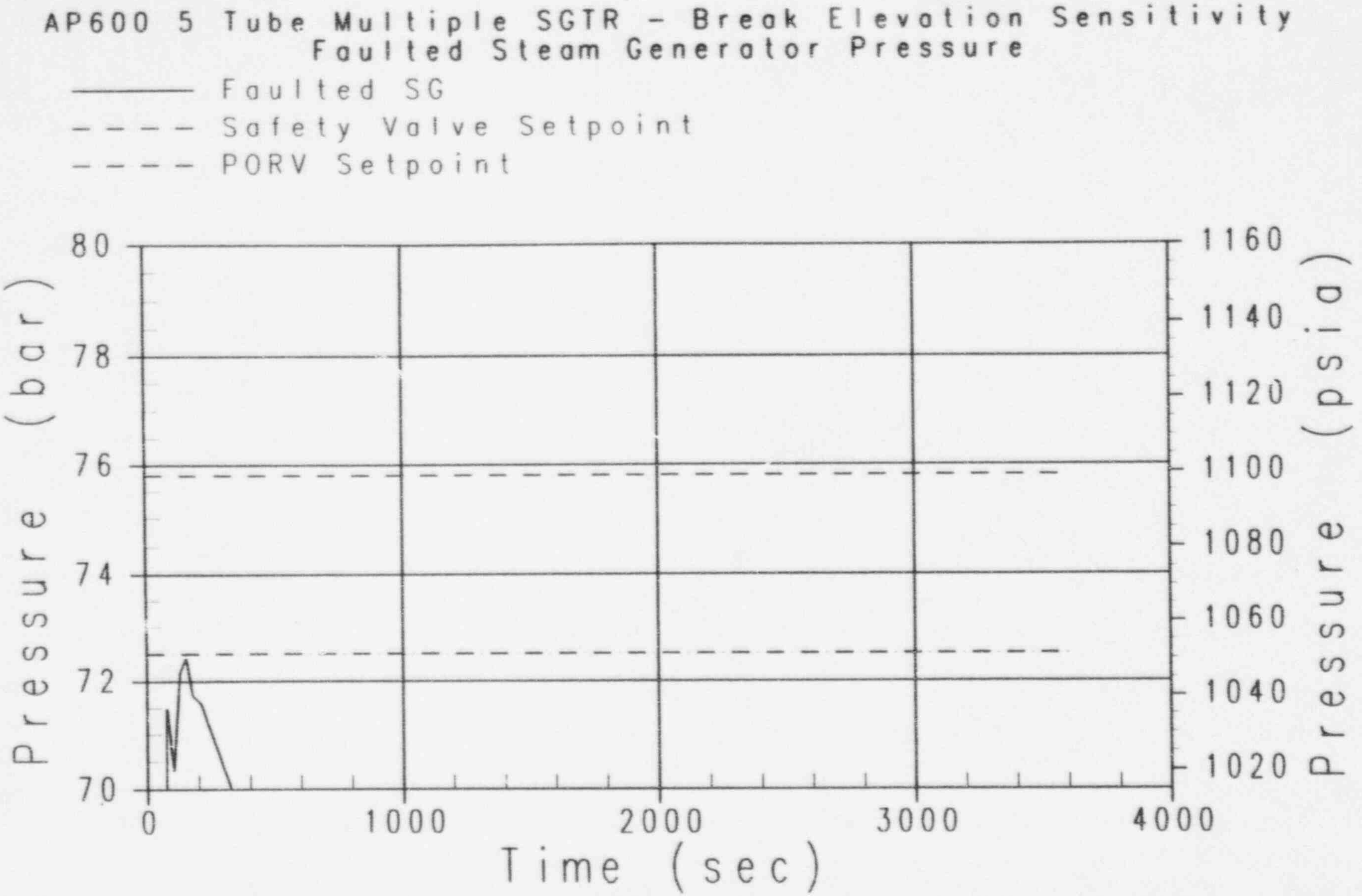

AP600 5 Tube Multiple SGTR - Break Elevation Sensitivity
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
PORV Setpoint
Pressure (bar)
80
78
76
74
72
70
Pressure (psia)
1160
1140
1120
1100
1080
1060
1040
1020
0
1000
2000
3000
4000
Time (sec)

Figure 49

AP600 5 Tube Multiple SGTR - Break Elevation Sensitivity
Steam Generator Downcomer Water Level

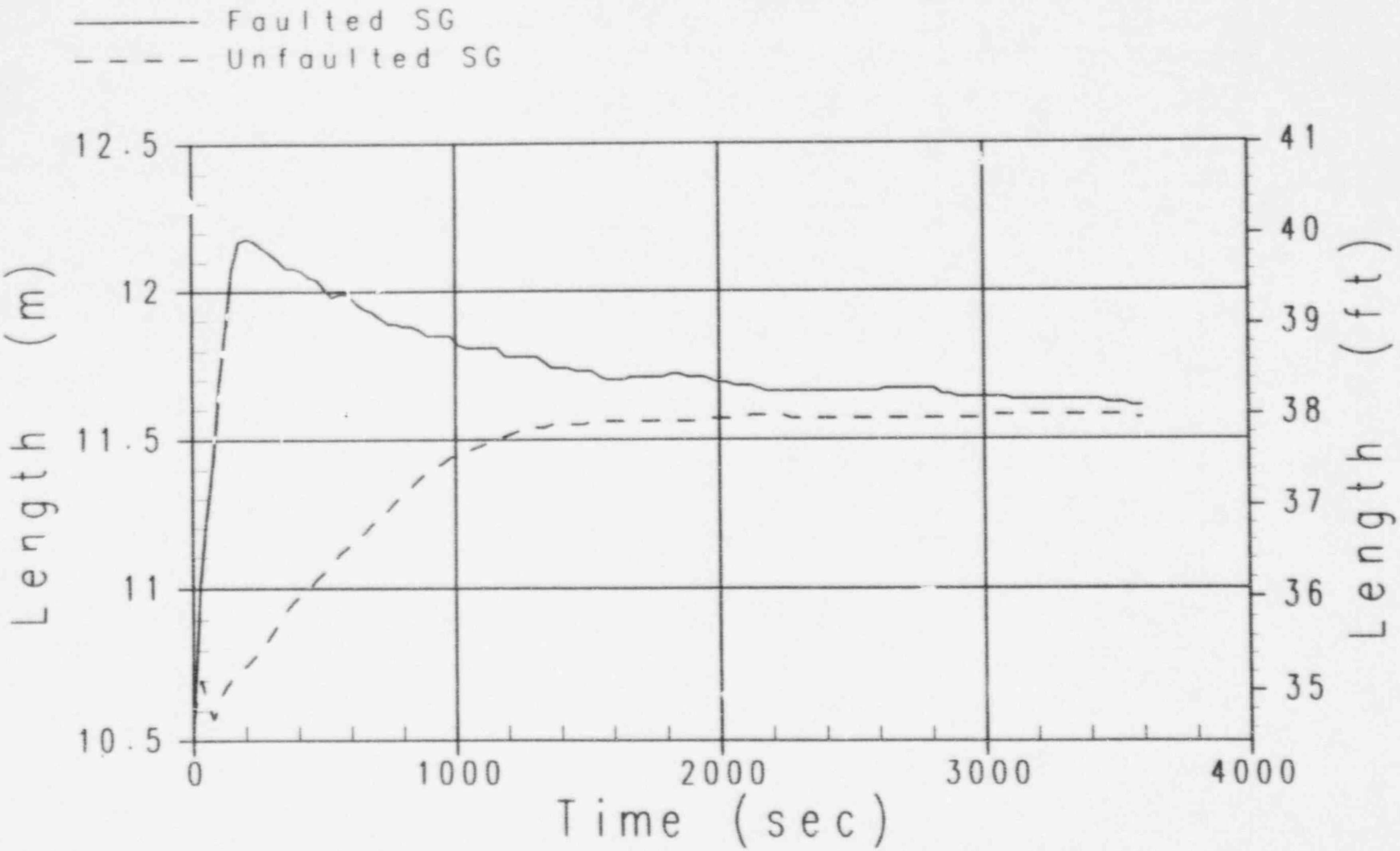


Figure 50

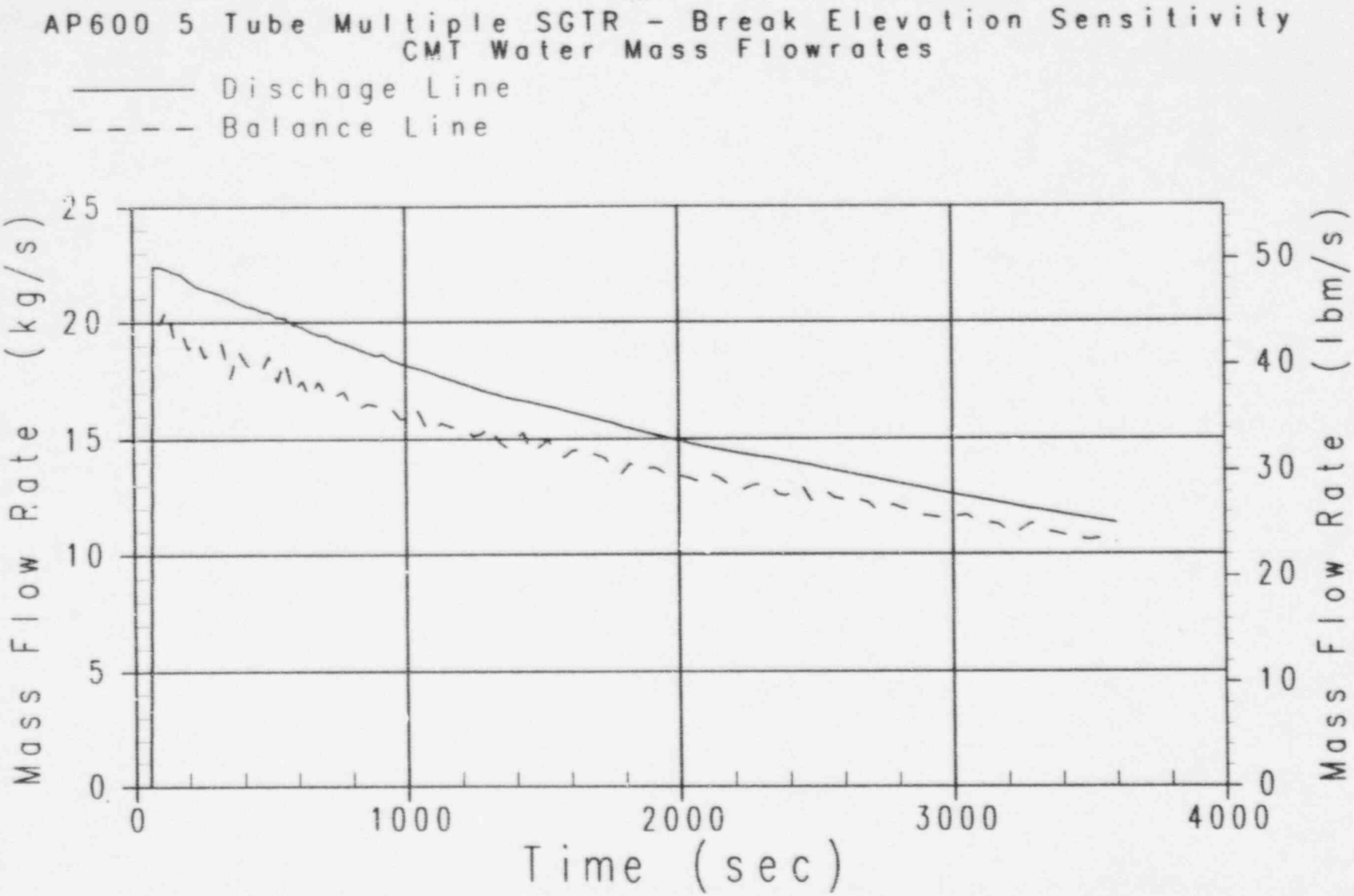

AP600 5 Tube Multiple SGTR - Break Elevation Sensitivity
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
5
10
15
20
25
0
10
20
30
40
50
0
1000
2000
3000
4000

Figure 51

AP600 5 Tube Multiple SGTR - Break Elevation Sensitivity
RCS and CMT Water Temperatures

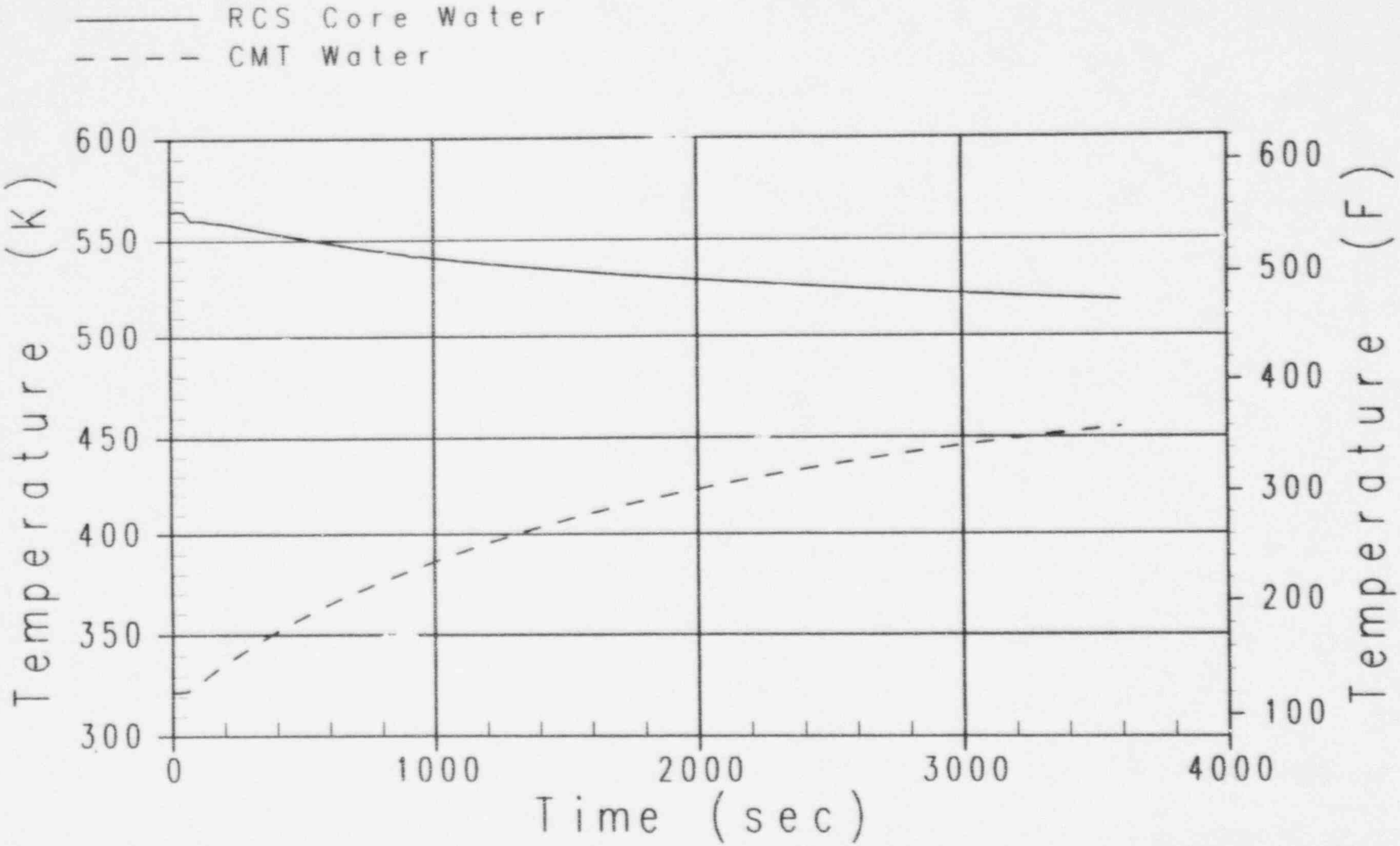


Figure 52

AP600 5 Tube Multiple SGTR - Break Elevation Sensitivity
CMT Water Level

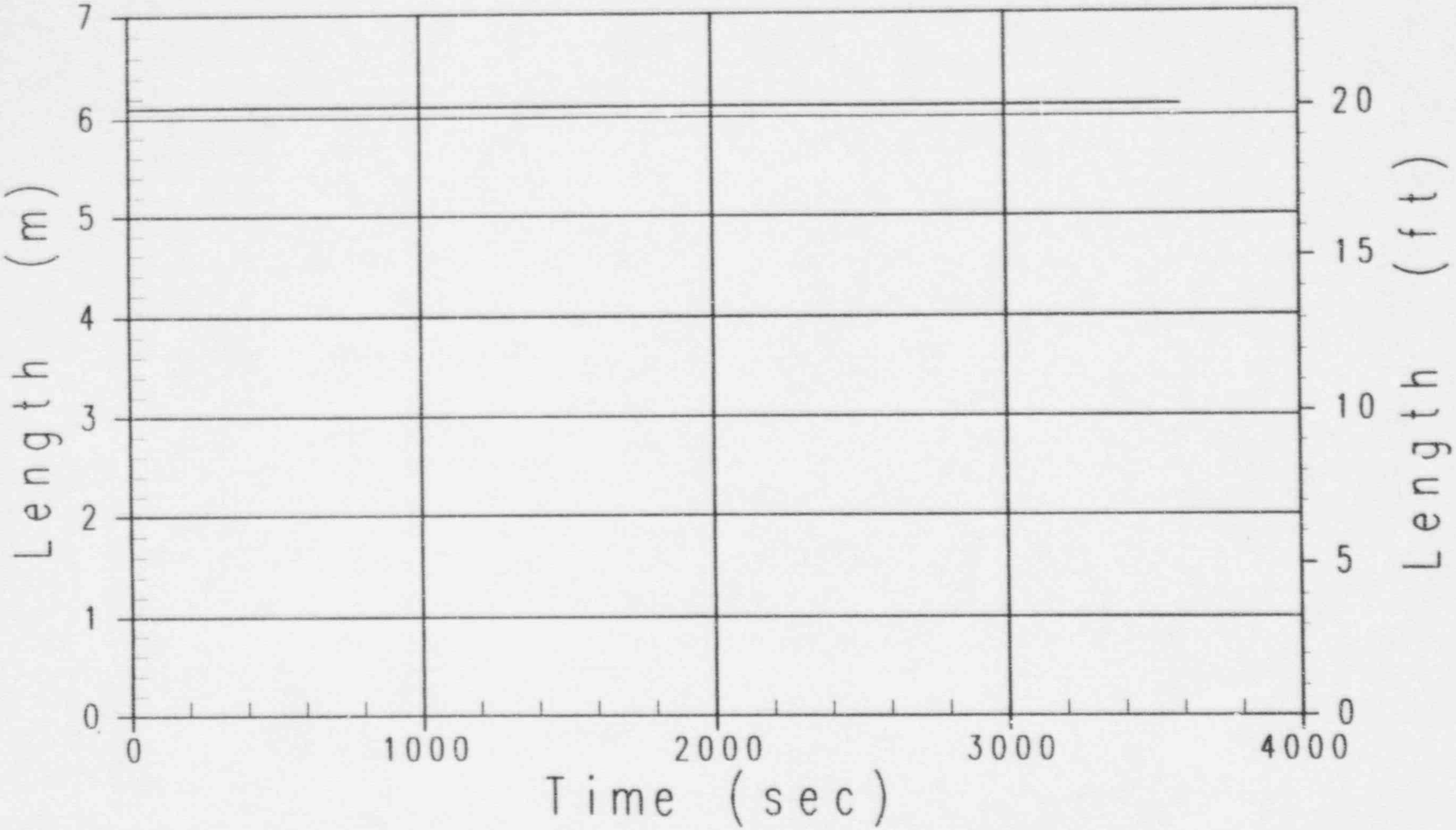


Figure 53

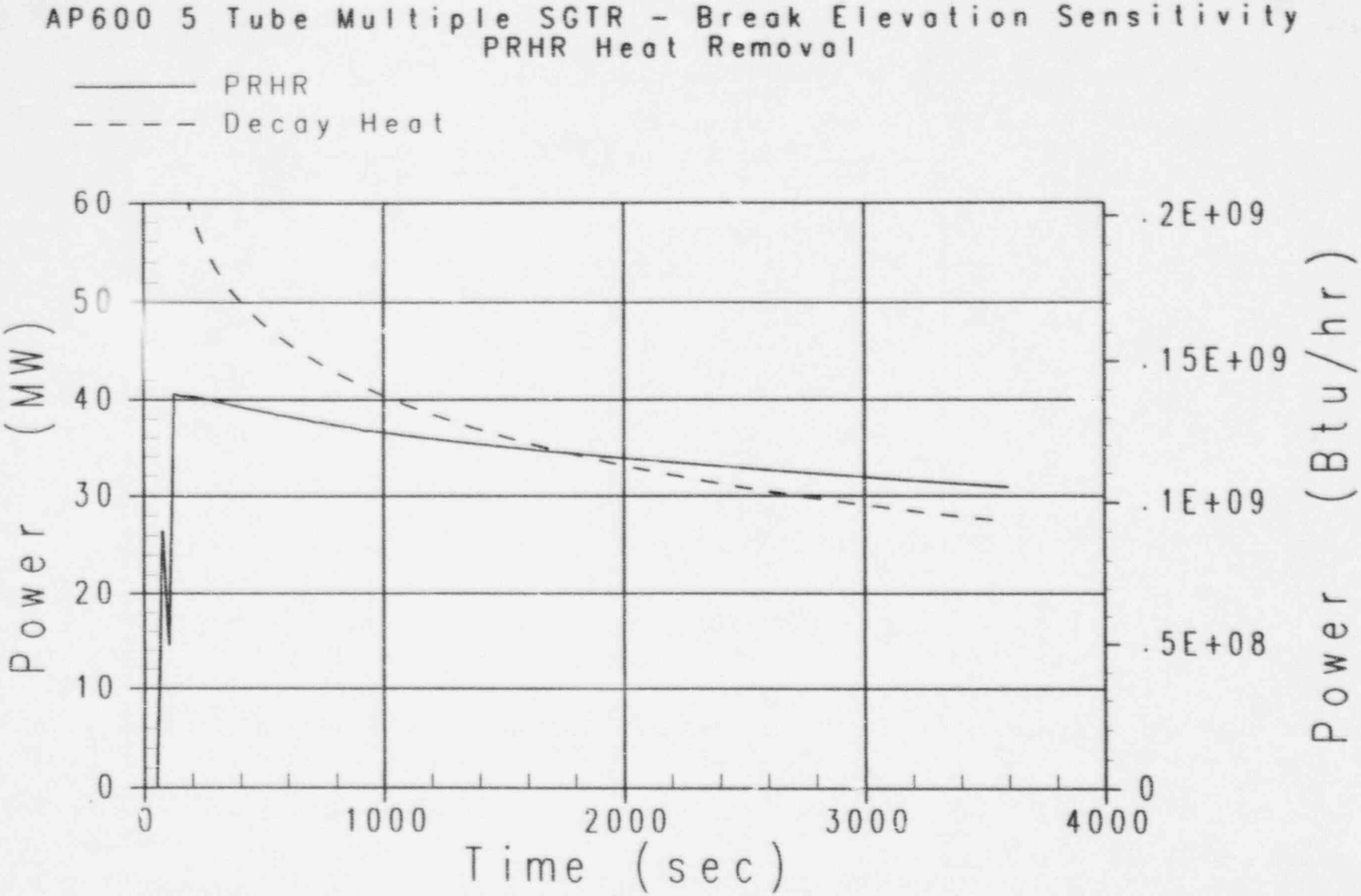

AP600 5 Tube Multiple SGTR - Break Elevation Sensitivity
PRHR Heat Removal
PRHR
Decay Heat
Power (MW)
Power (Btu/hr)
Time (sec)
0
10
20
30
40
50
60
0
1000
2000
3000
4000
.5E+08
.1E+09
.15E+09
.2E+09

Figure 54

AP600 5 Tube Multiple SGTR - Break Elevation Sensitivity
RCS Water Level

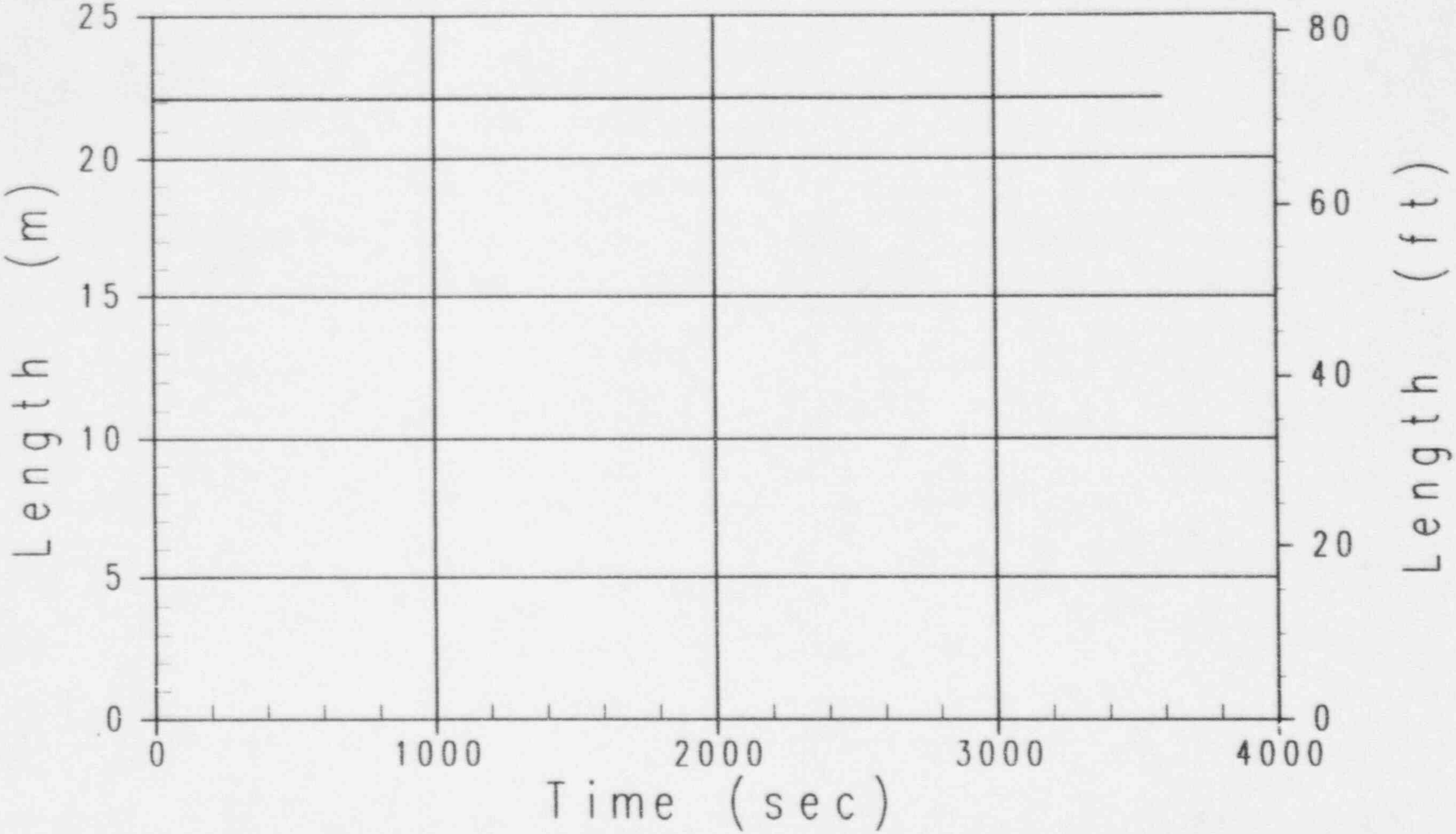


Figure 55

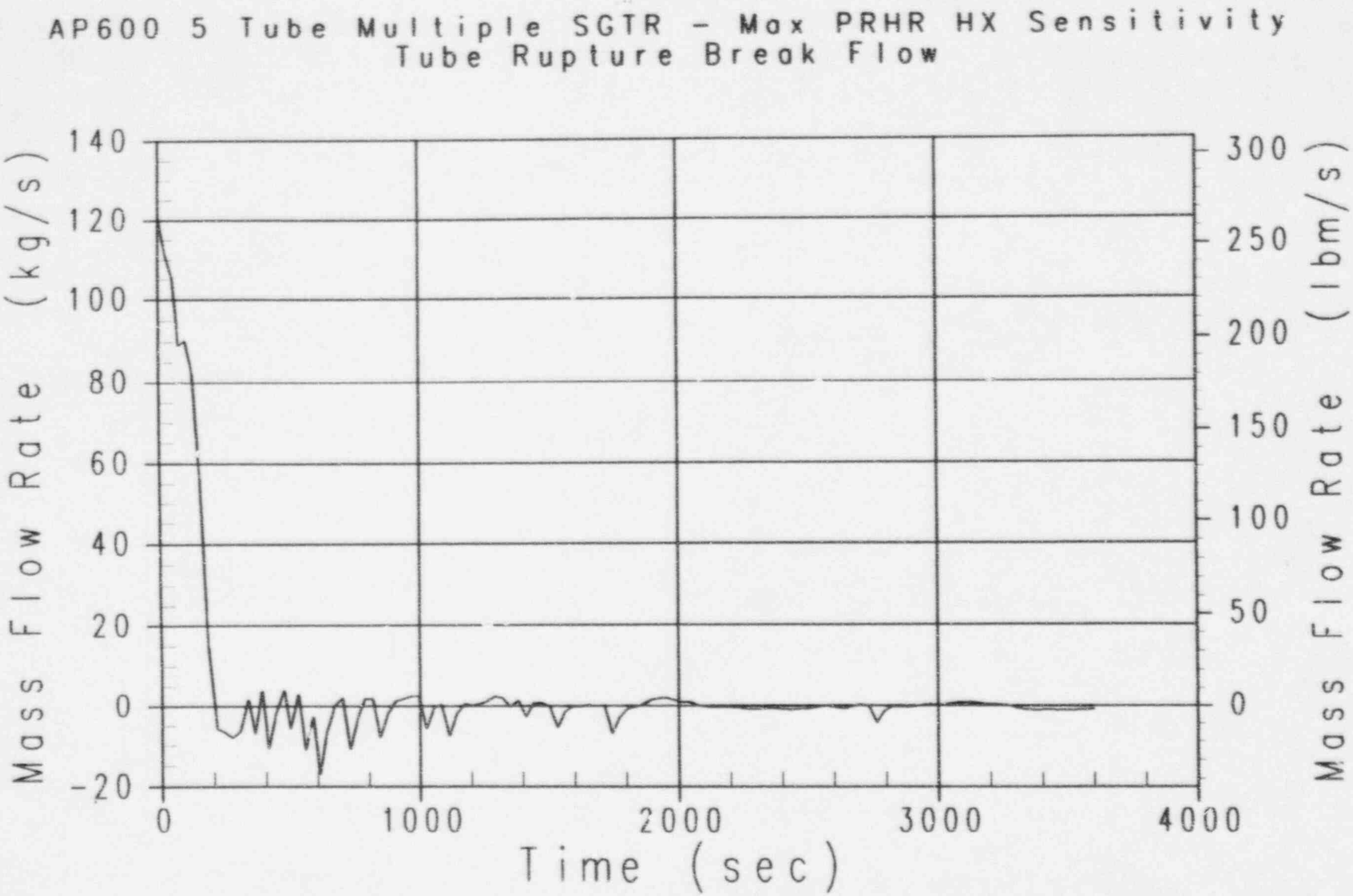
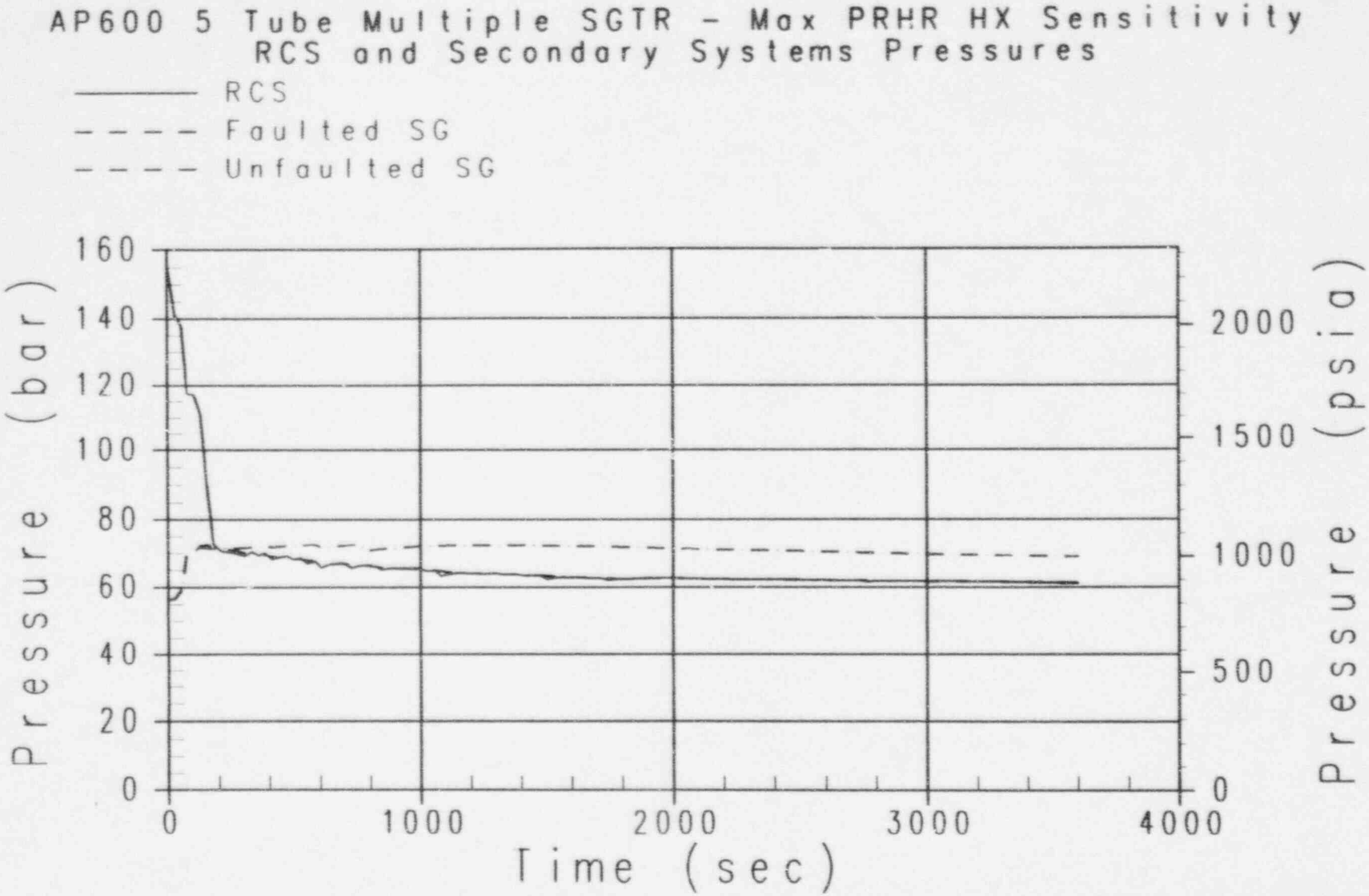
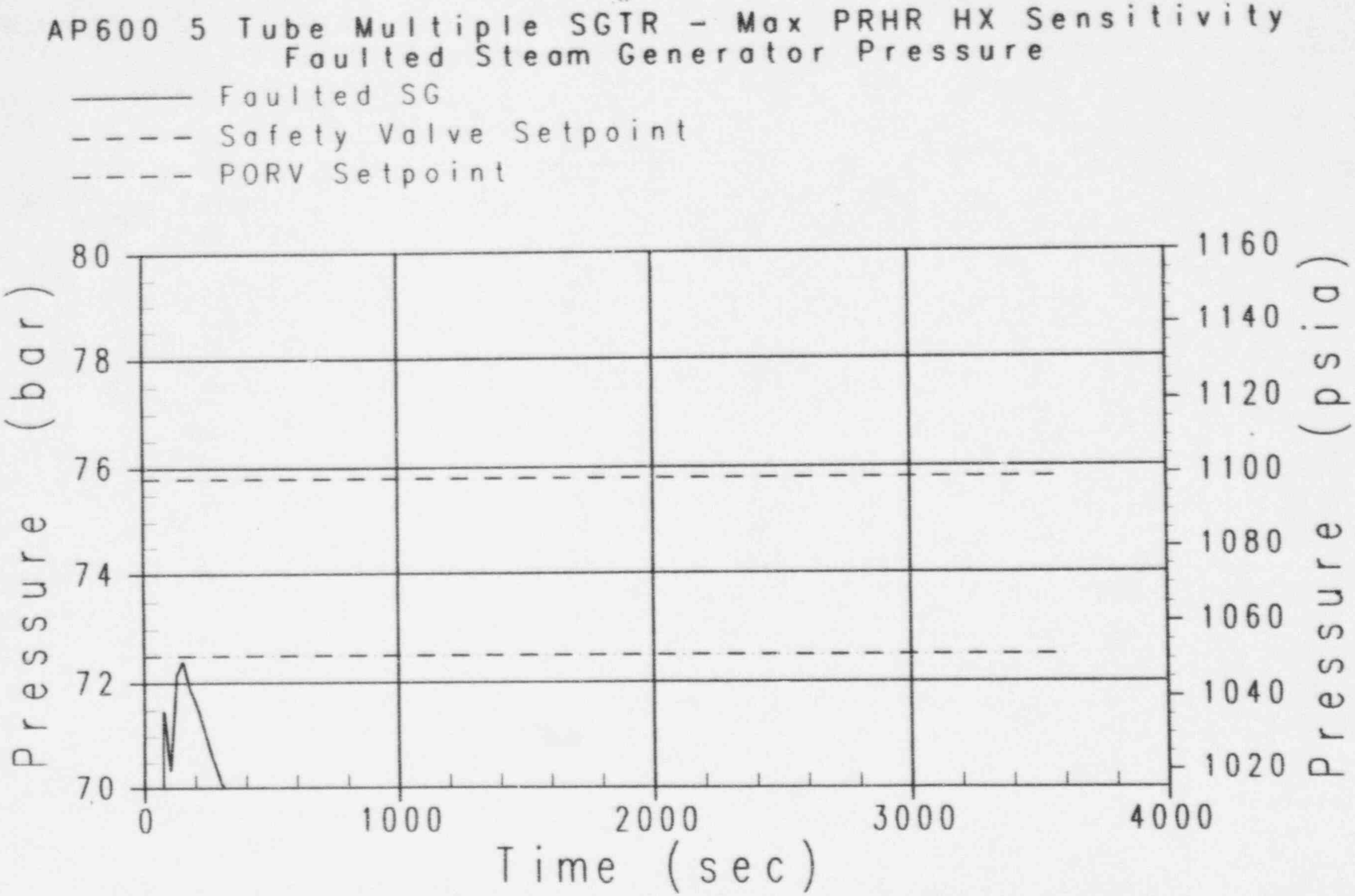

AP600 5 Tube Multiple SGTR - Max PRHR HX Sensitivity
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
140
120
100
80
60
40
20
0
-20
Mass Flow Rate (lbm/s)
300
250
200
150
100
50
0
0
1000
2000
3000
4000
Time (sec)

Figure 56



AP600 5 Tube Multiple SGTR - Max PRHR HX Sensitivity
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
160
140
120
100
80
60
40
20
0
Pressure (psia)
2000
1500
1000
500
0
0
1000
2000
3000
4000
Time (sec)

Figure 57



AP600 5 Tube Multiple SGTR - Max PRHR HX Sensitivity
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
PORV Setpoint
Pressure (bar)
80
78
76
74
72
70
Pressure (psia)
1160
1140
1120
1100
1080
1060
1040
1020
0
1000
2000
3000
4000
Time (sec)

Figure 58

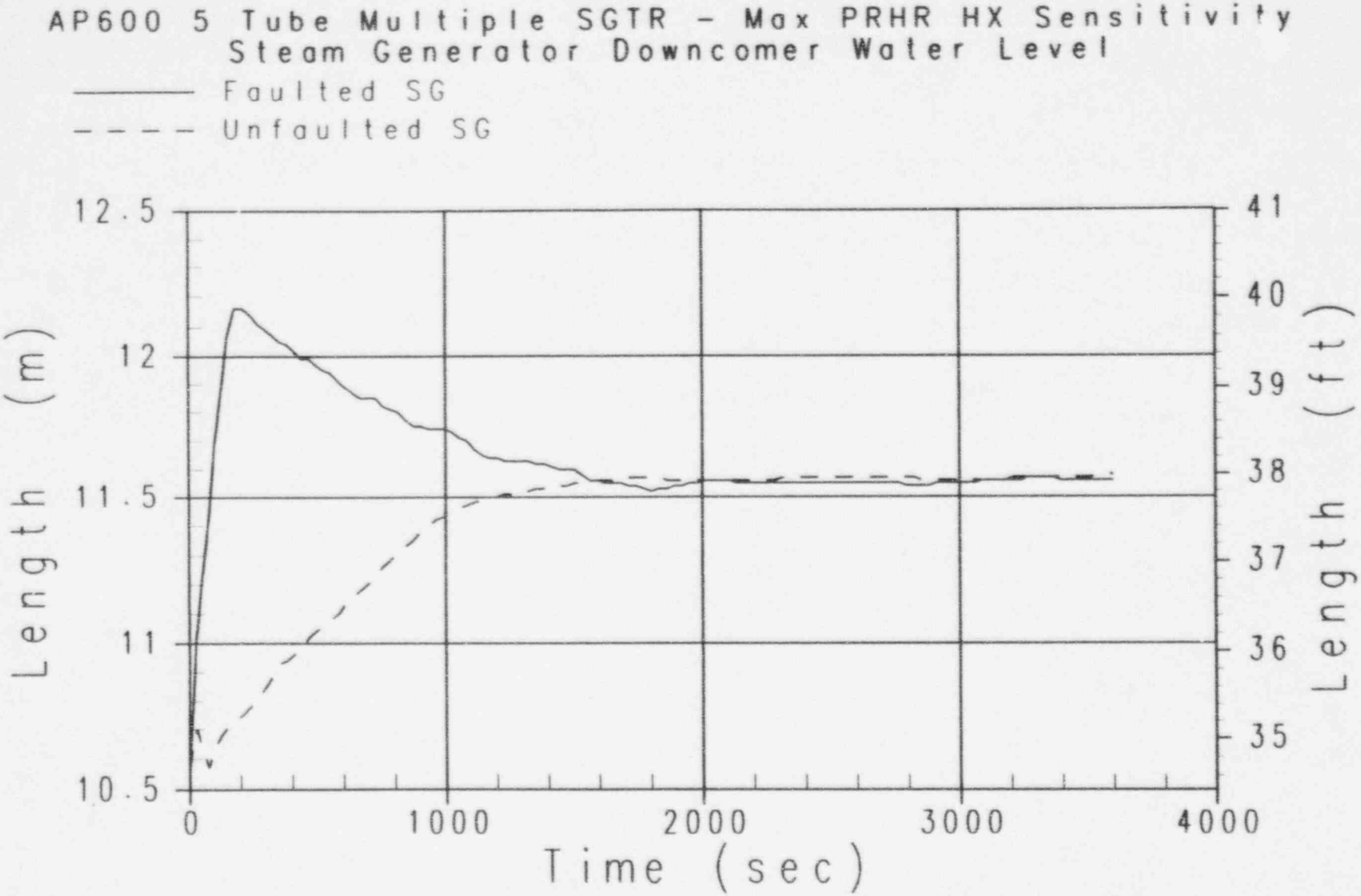
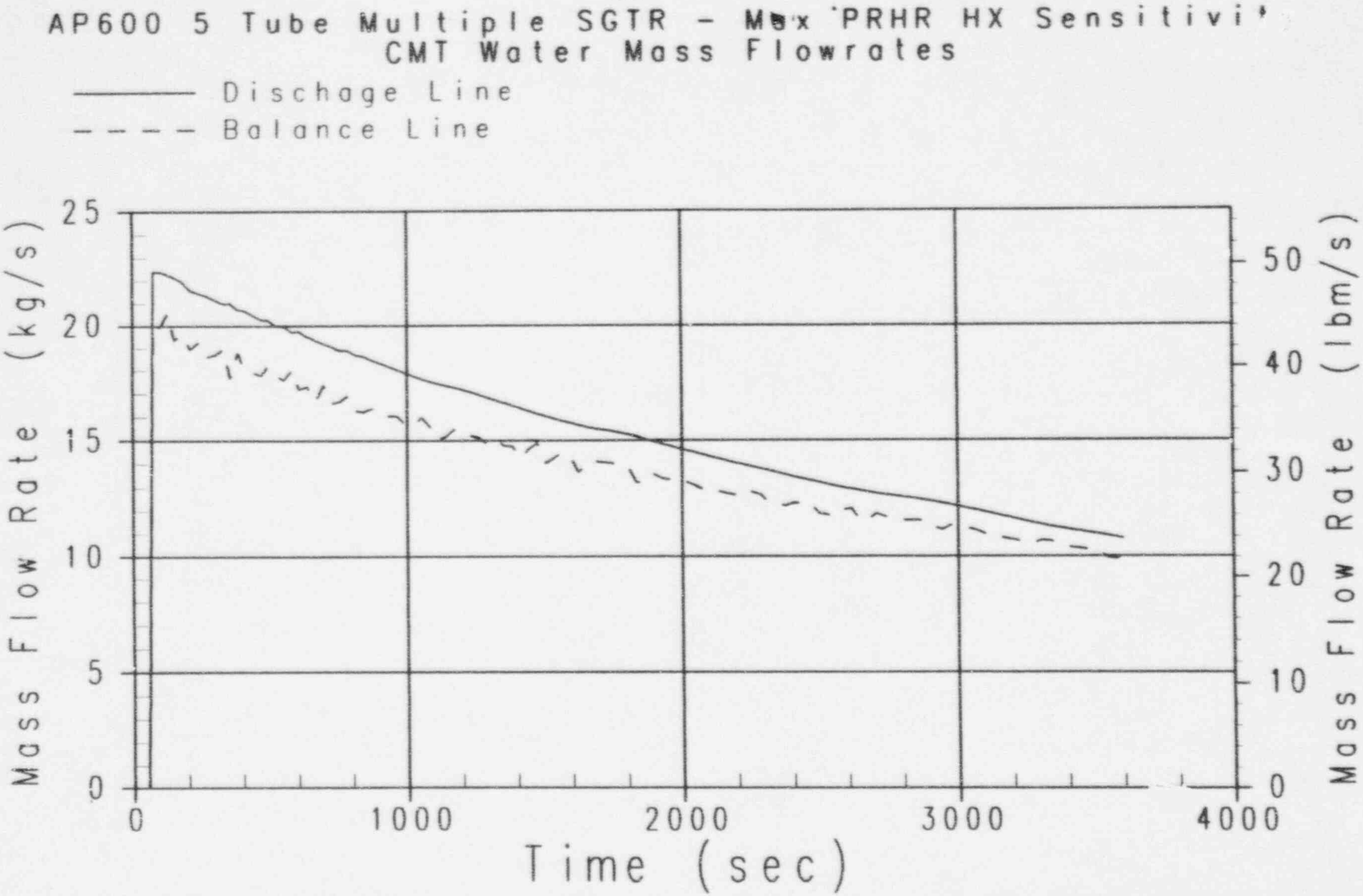

AP600 5 Tube Multiple SGTR - Max PRHR HX Sensitivity
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
12.5
12
11.5
11
10.5
41
40
39
38
37
36
35
0
1000
2000
3000
4000
Length (m)
Length (ft)
Time (sec)

Figure 59



AP600 5 Tube Multiple SGTR - Max PRHR HX Sensitivi
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
5
10
15
20
25
0
10
20
30
40
50
0
1000
2000
3000
4000

Figure 60

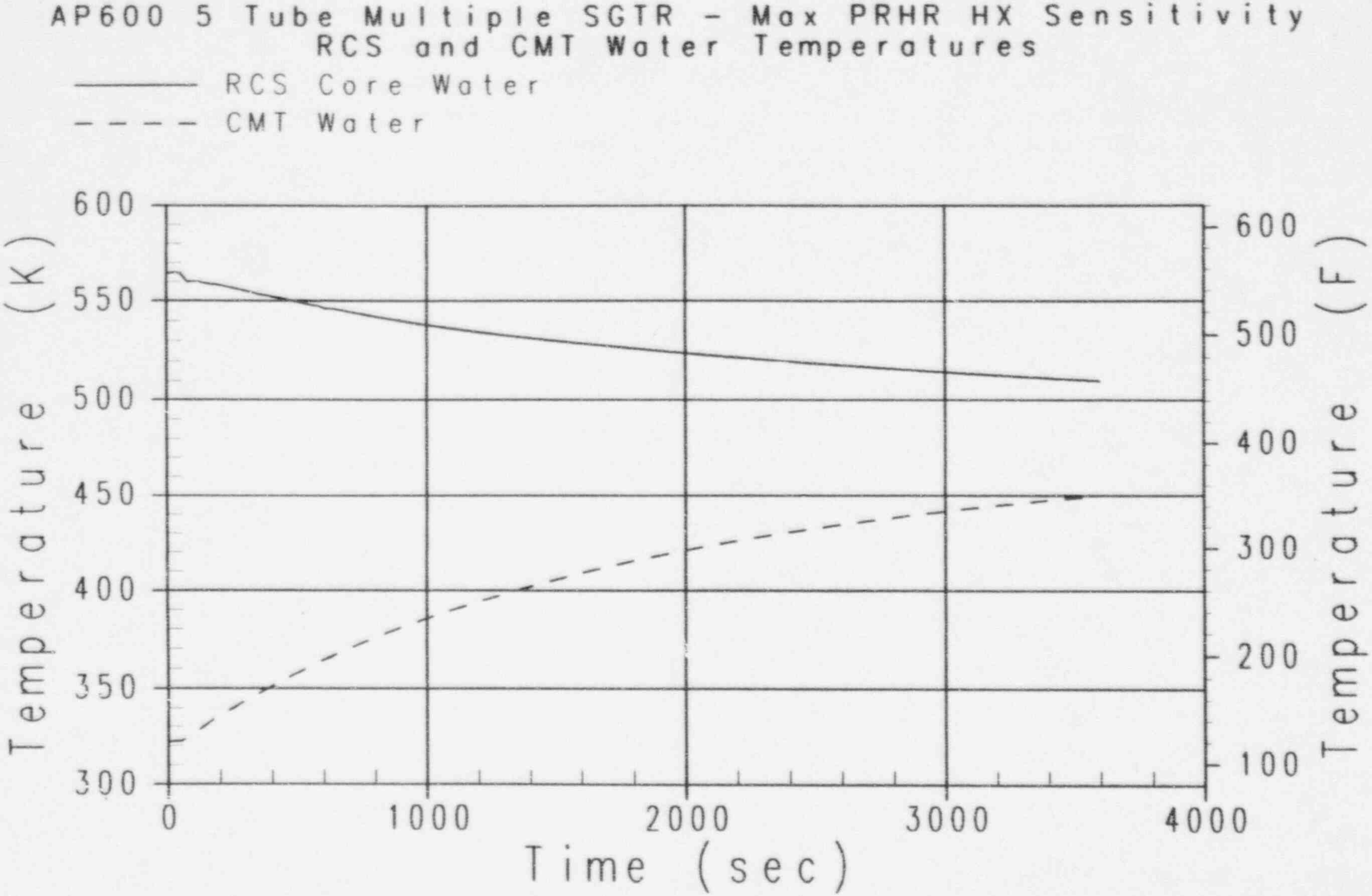
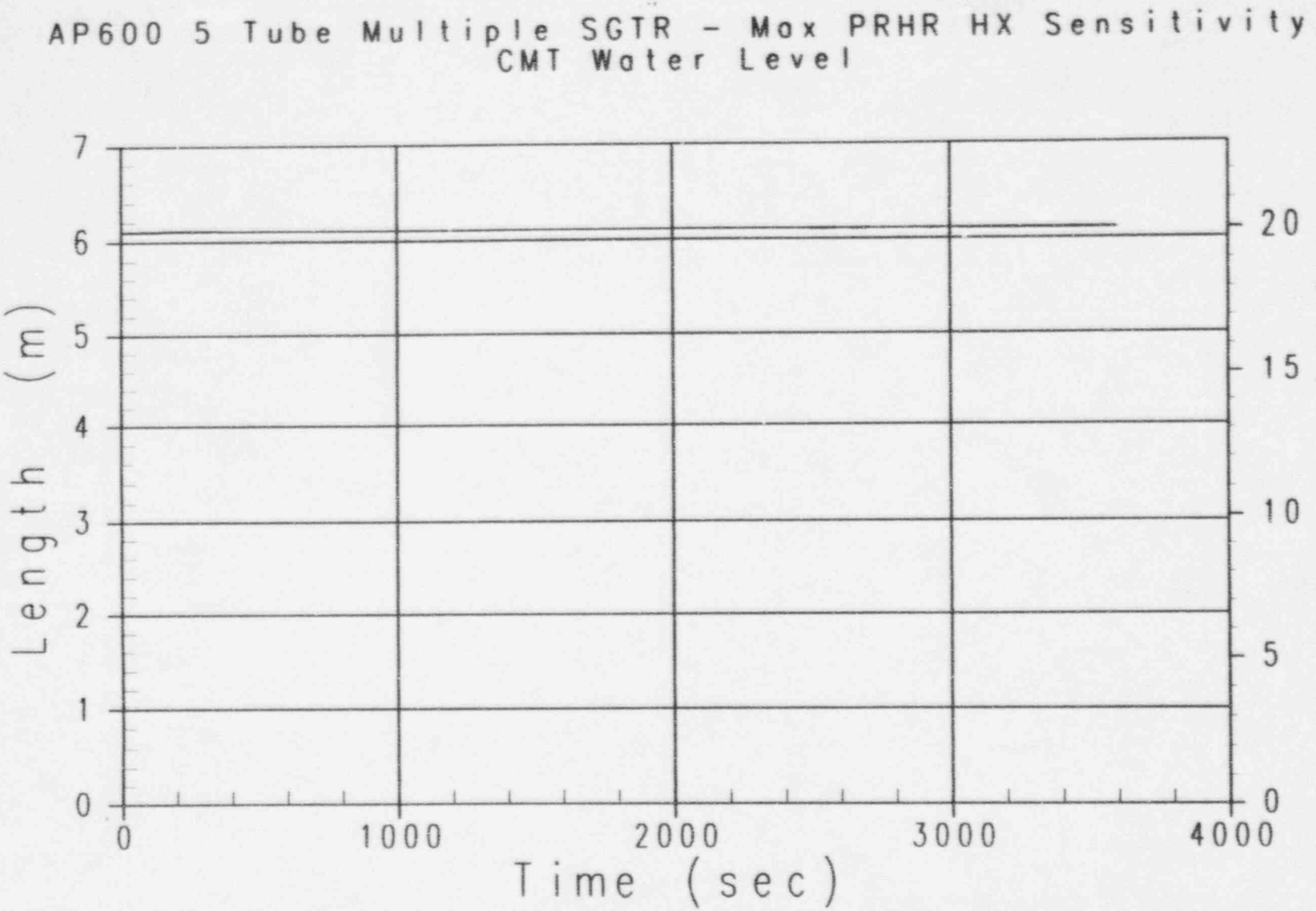

AP600 5 Tube Multiple SGTR - Max PRHR HX Sensitivity
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
Temperature (K)
Temperature (F)
Time (sec)
600
550
500
450
400
350
300
0
1000
2000
3000
4000
100
200
300
400
500
600

Figure 61



AP600 5 Tube Multiple SGTR - Mox PRHR HX Sensitivity
CMT Water Level
Length (m)
Length (ft)
Time (sec)
0
1
2
3
4
5
6
7
0
5
10
15
20
0
1000
2000
3000
4000

Figure 62

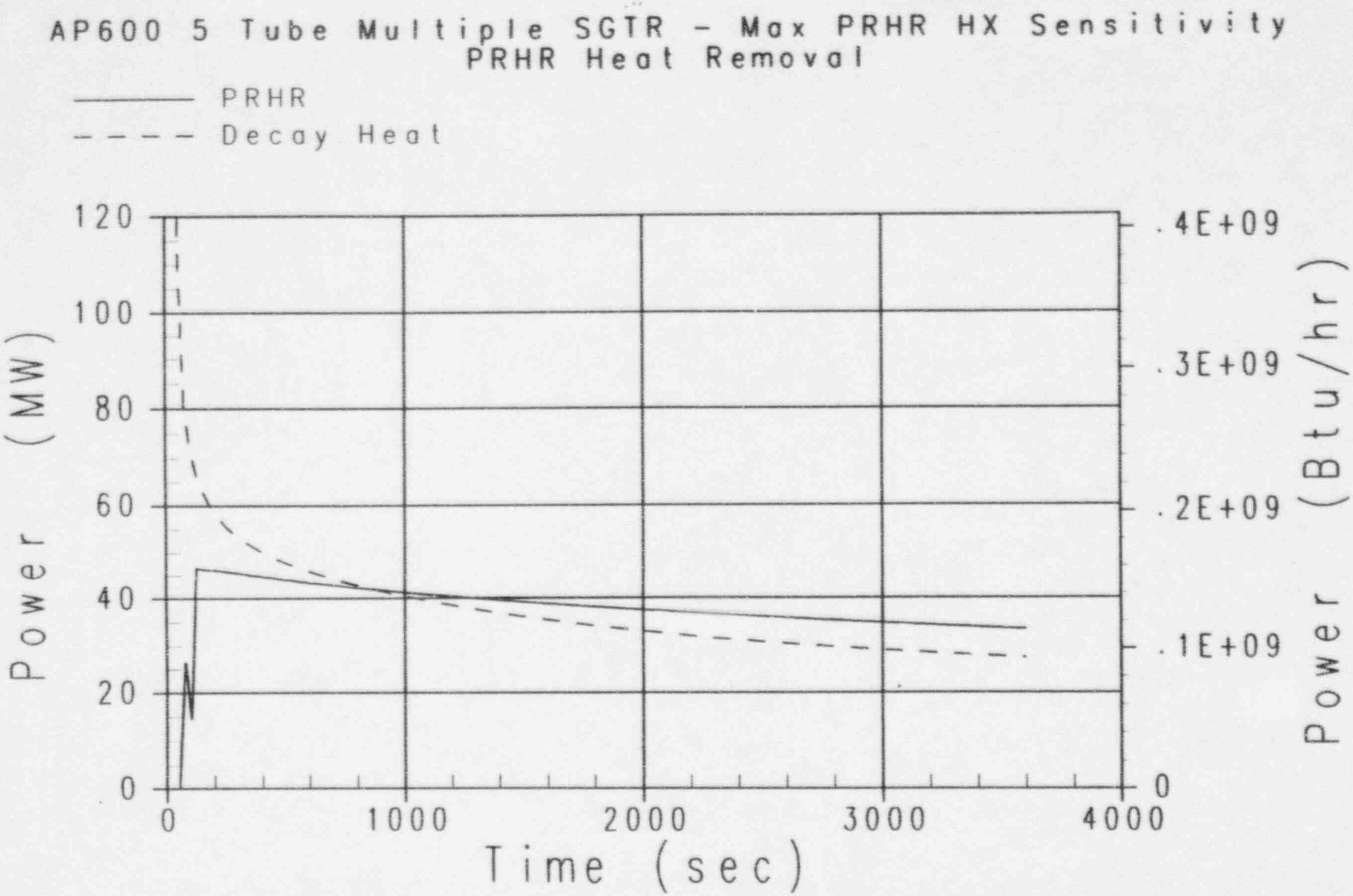

AP600 5 Tube Multiple SGTR - Max PRHR HX Sensitivity
PRHR Heat Removal
PRHR
Decay Heat
Power (MW)
Power (Btu/hr)
Time (sec)
0
20
40
60
80
100
120
1000
2000
3000
4000
.1E+09
.2E+09
.3E+09
.4E+09

Figure 63

AP600 5 Tube Multiple SGTR - Max PRHR HX Sensitivity
RCS Water Level

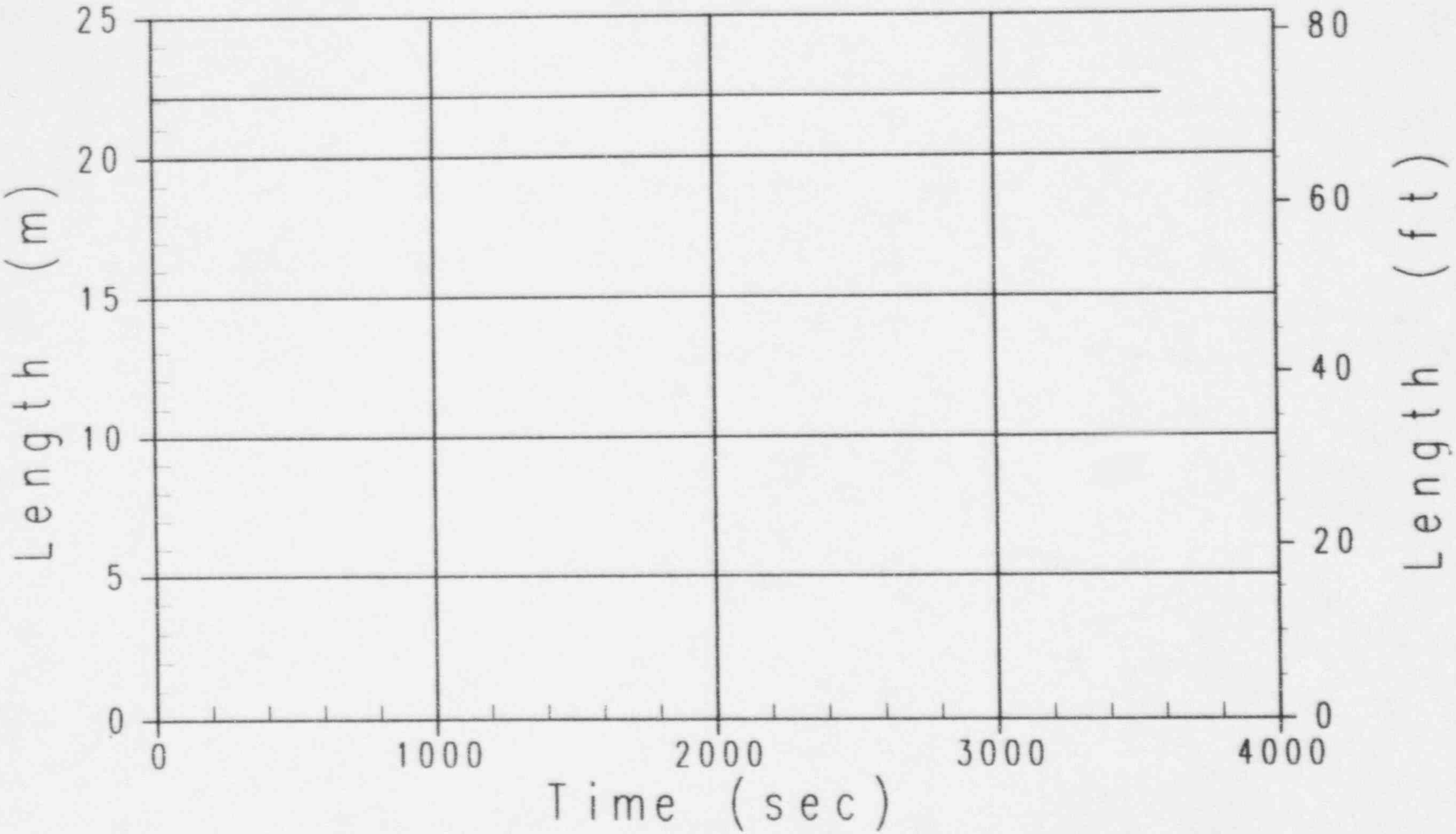


Figure 64

AP600 5 Tube Multiple SGTR - Min PRHR HX Sensitivity
Tube Rupture Break Flow

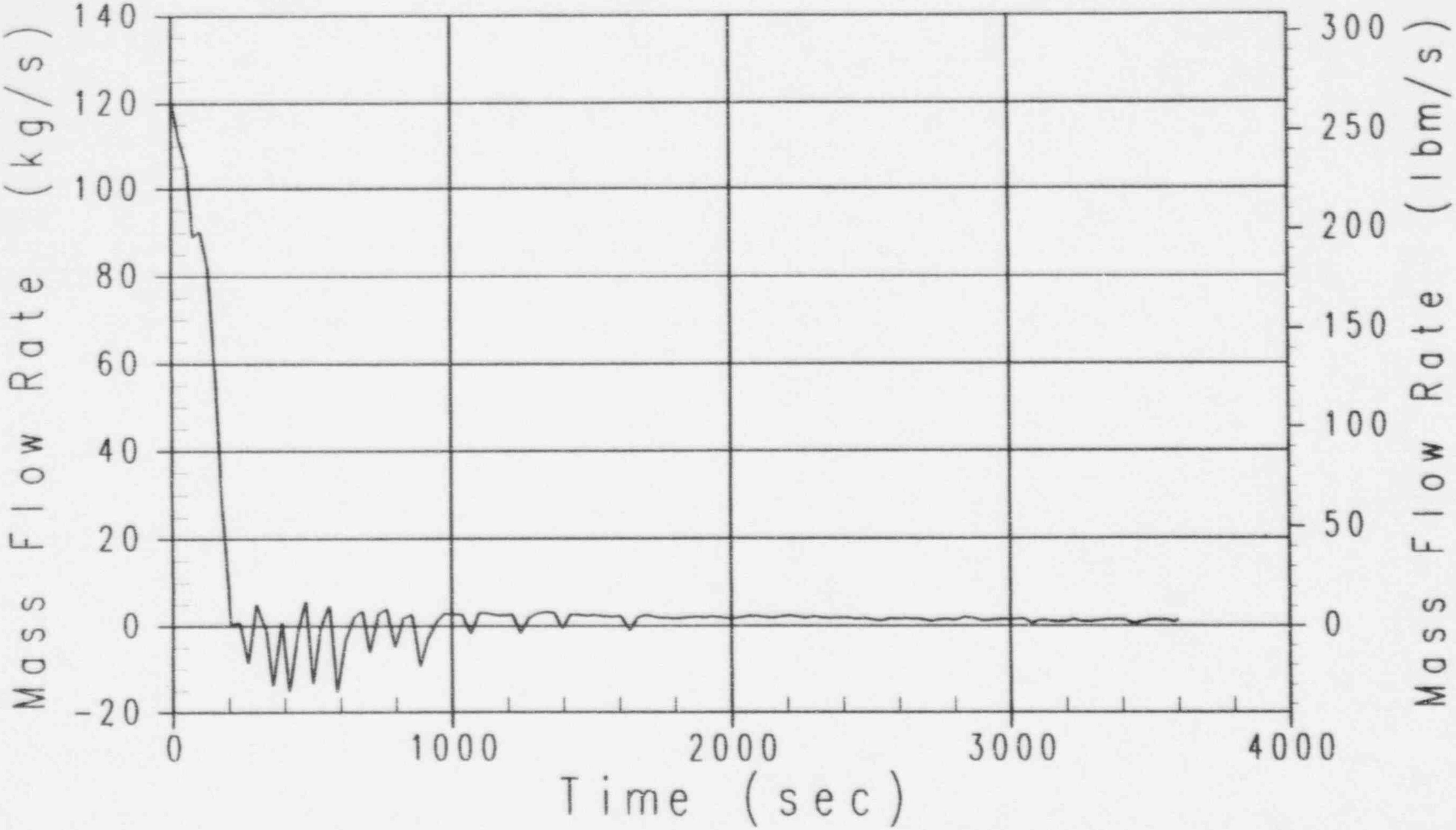


Figure 65

AP600 5 Tube Multiple SGTR - Min PRHR HX Sensitivity
RCS and Secondary Systems Pressures

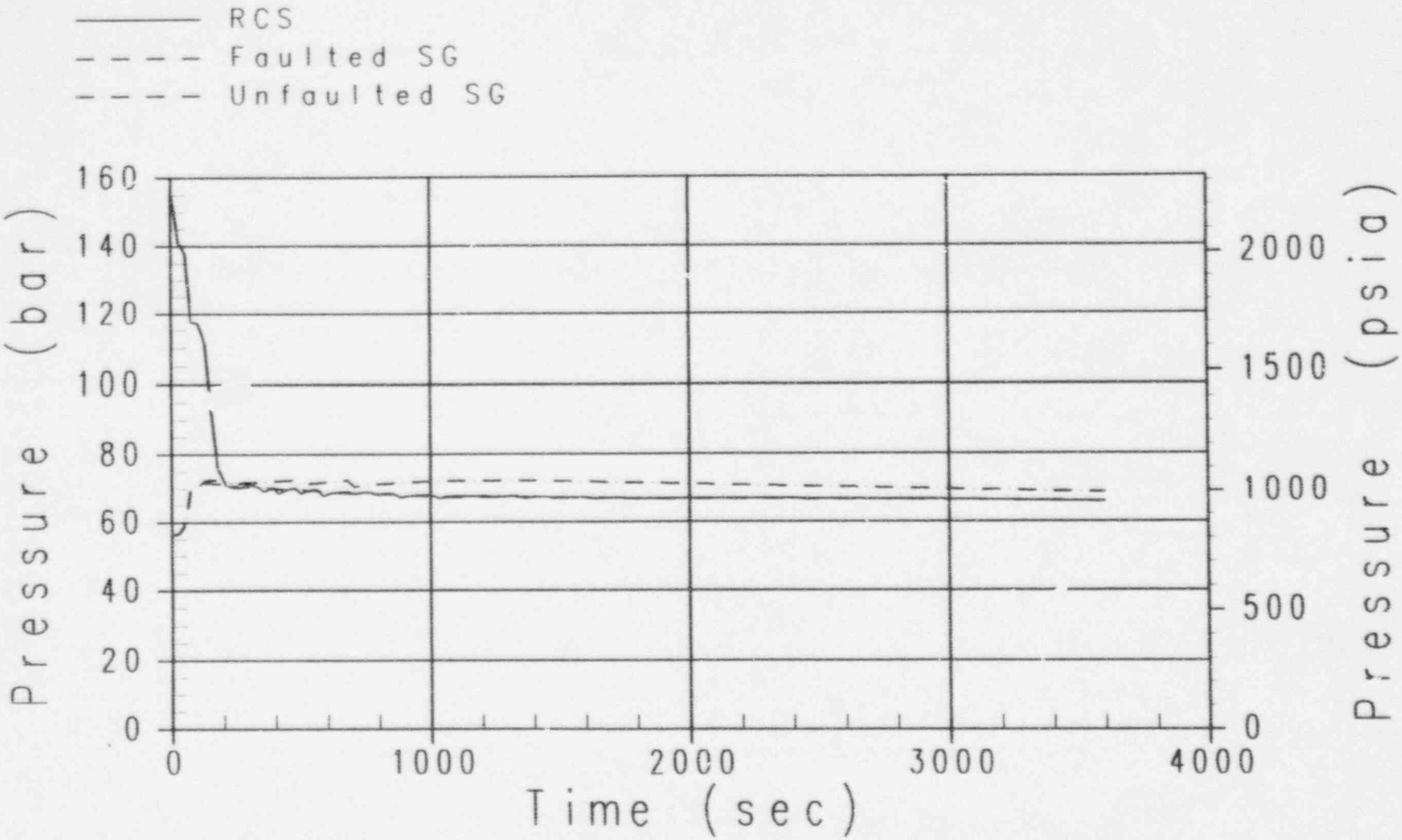


Figure 66

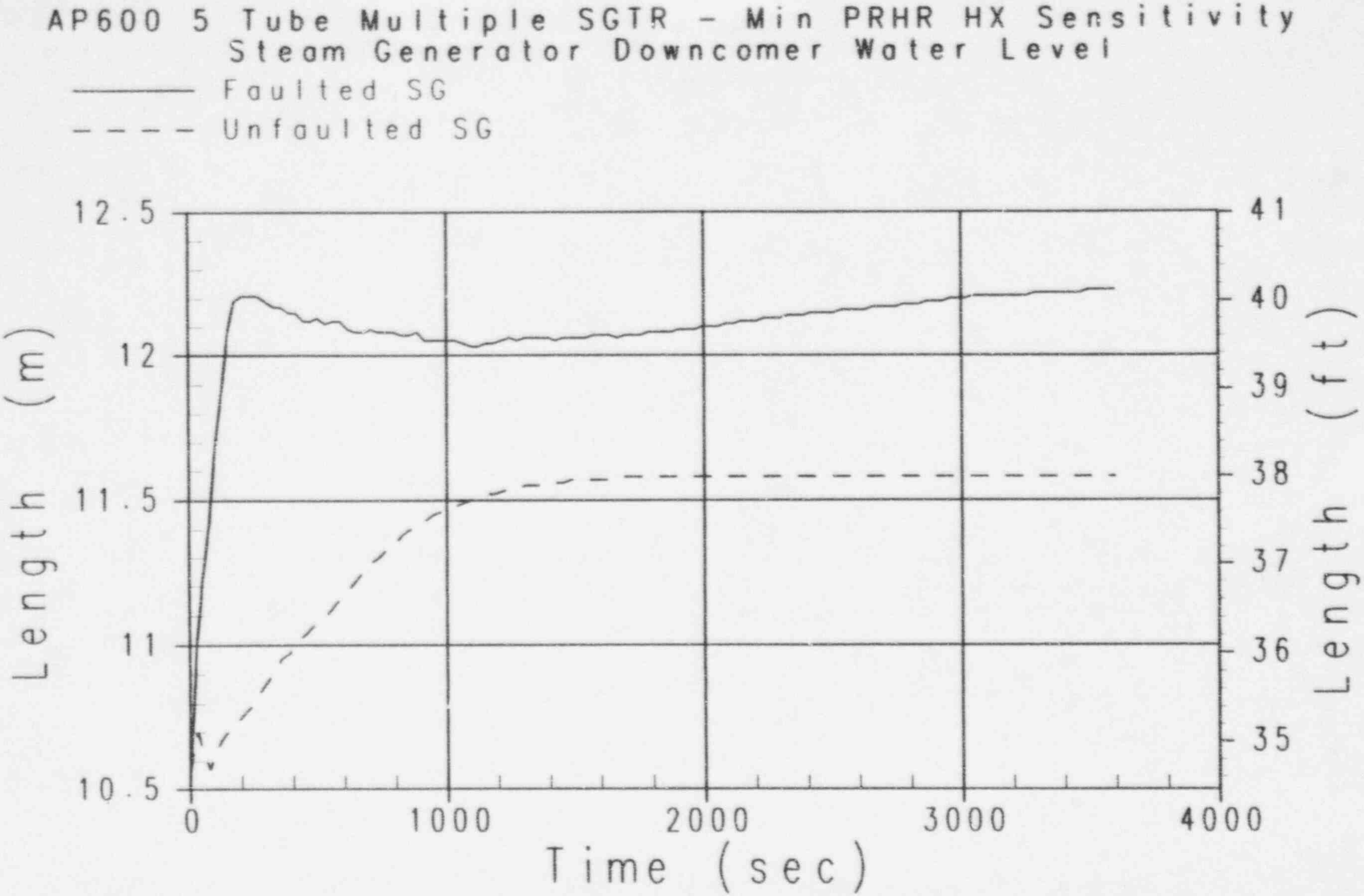

AP600 5 Tube Multiple SGTR - Min PRHR HX Sensitivity
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
12.5
12
11.5
11
10.5
41
40
39
38
37
36
35
0
1000
2000
3000
4000
Time (sec)
Length (m)
Length (ft)

Figure 67

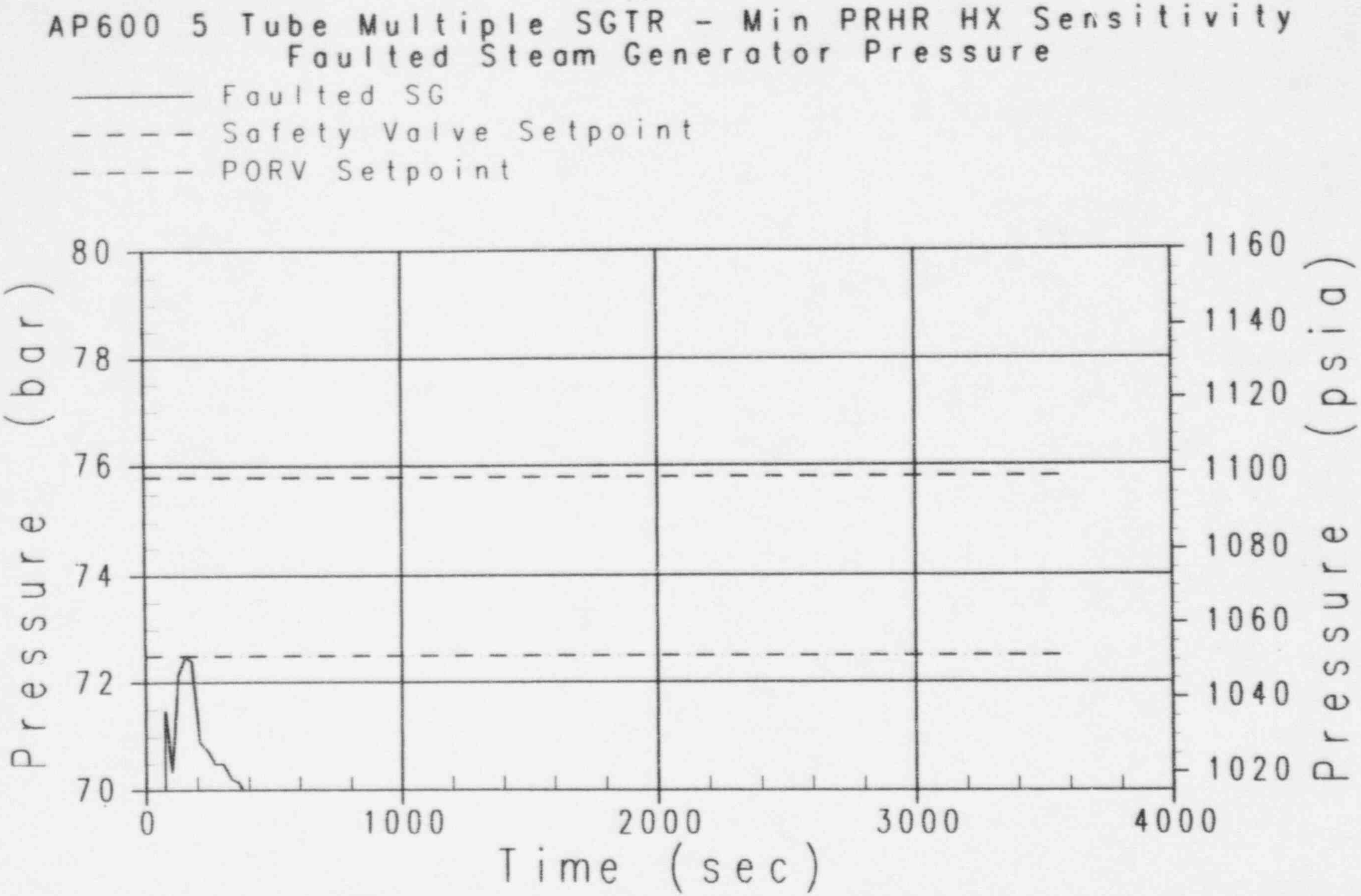

AP600 5 Tube Multiple SGTR - Min PRHR HX Sensitivity
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
PORV Setpoint
Pressure (bar)
80
78
76
74
72
70
Pressure (psia)
1160
1140
1120
1100
1080
1060
1040
1020
0
1000
2000
3000
4000
Time (sec)

Figure 68

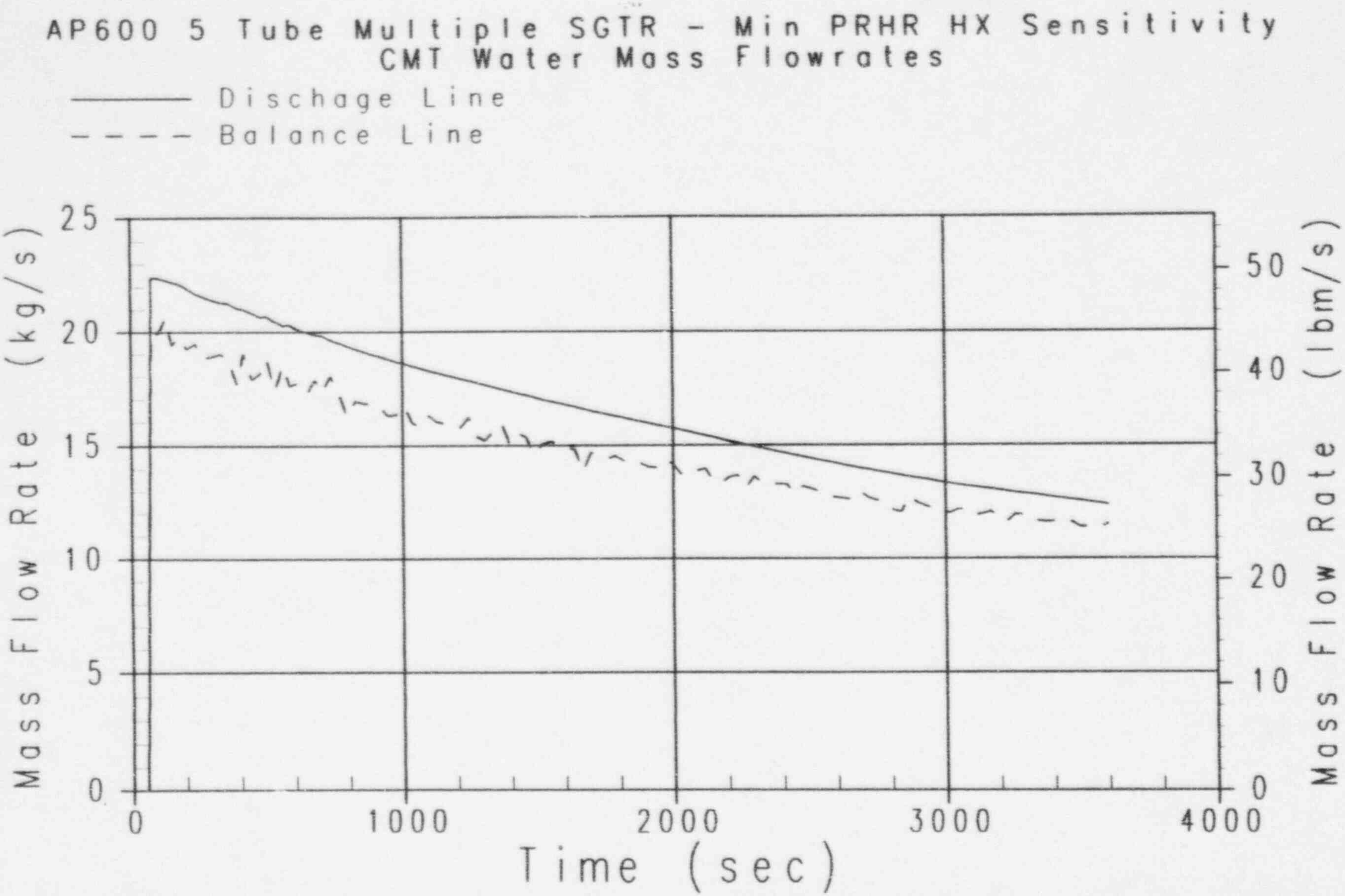

AP600 5 Tube Multiple SGTR - Min PRHR HX Sensitivity
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
5
10
15
20
25
0
10
20
30
40
50
0
1000
2000
3000
4000

Figure 69

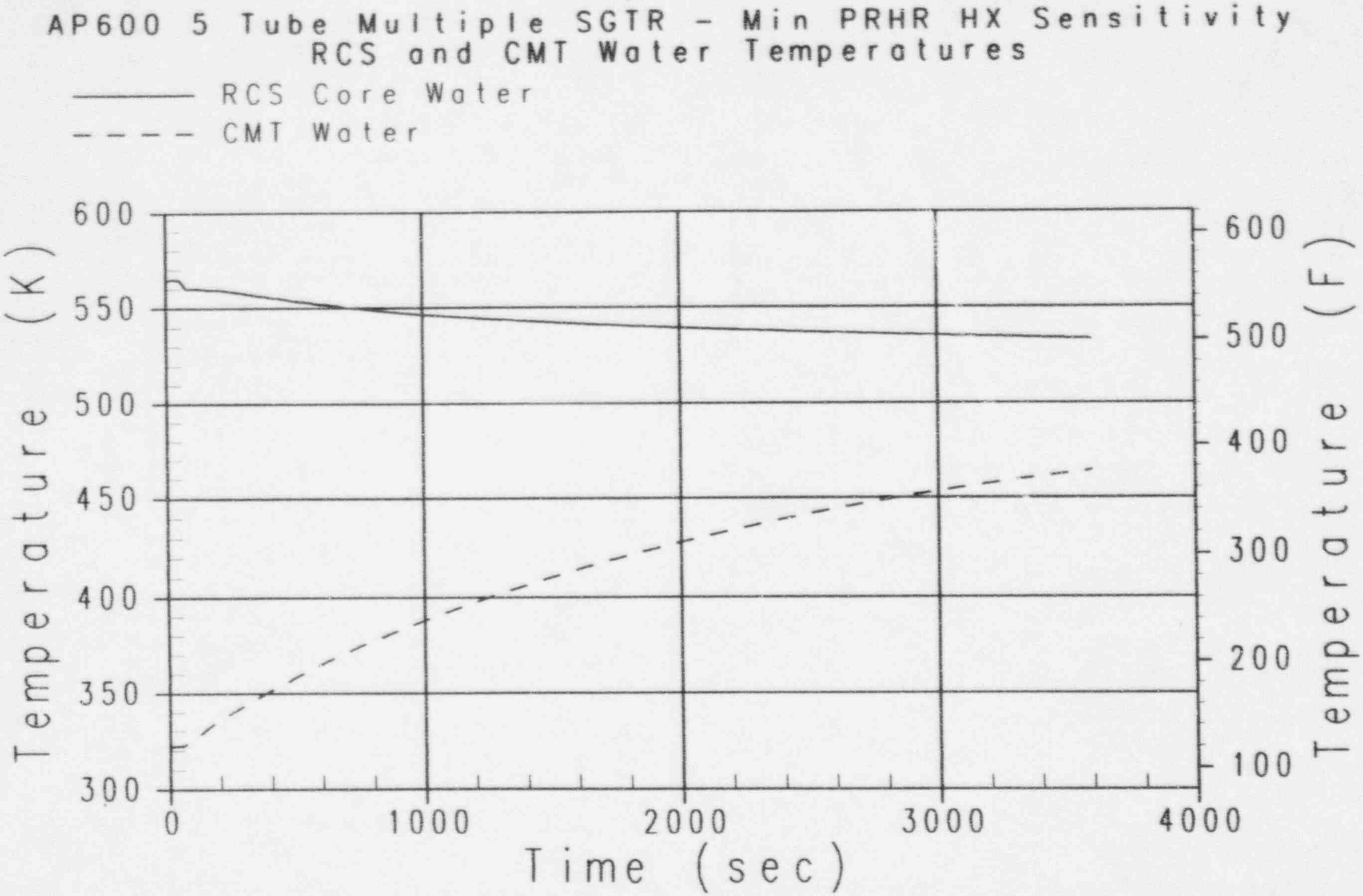
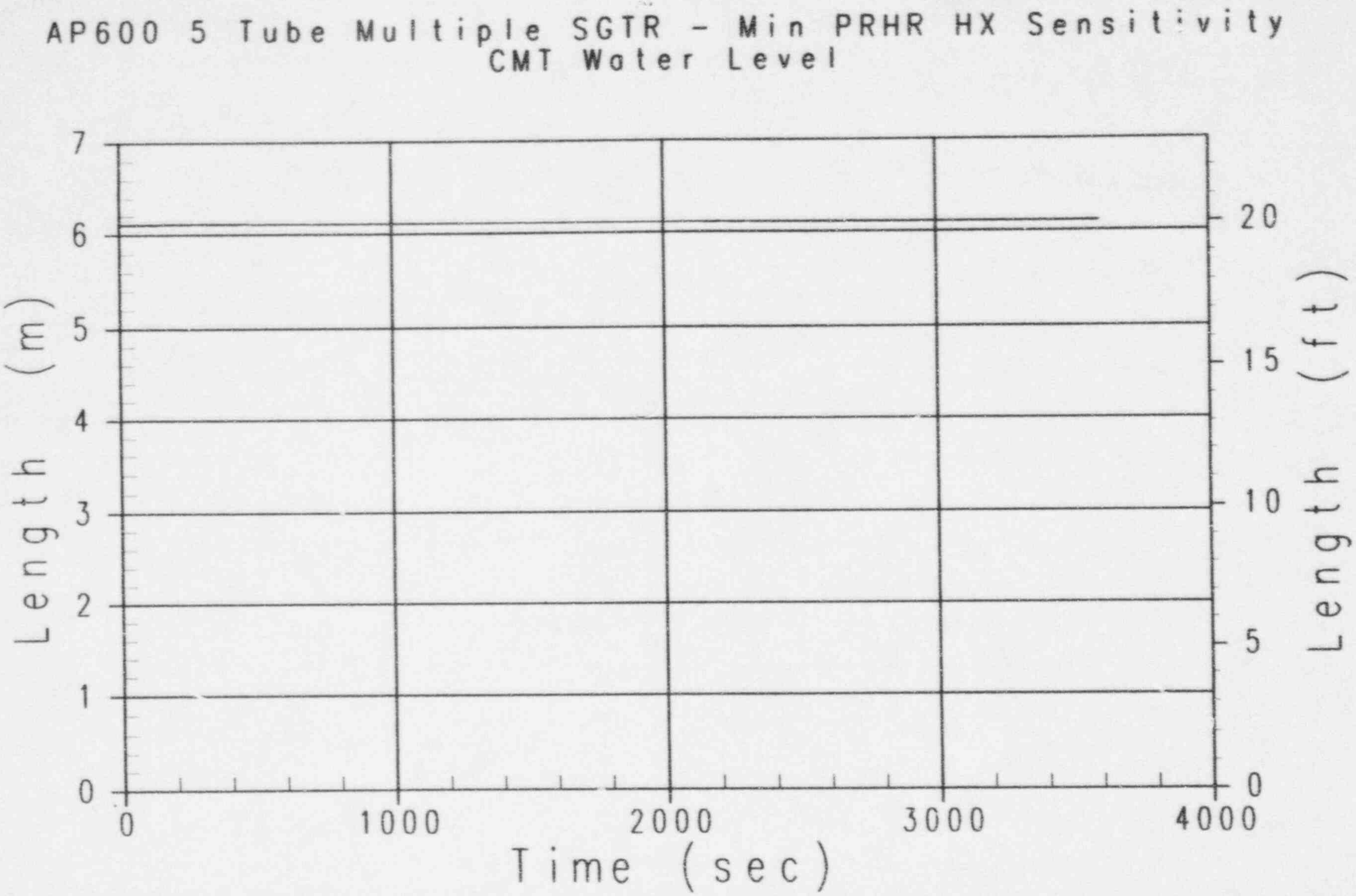
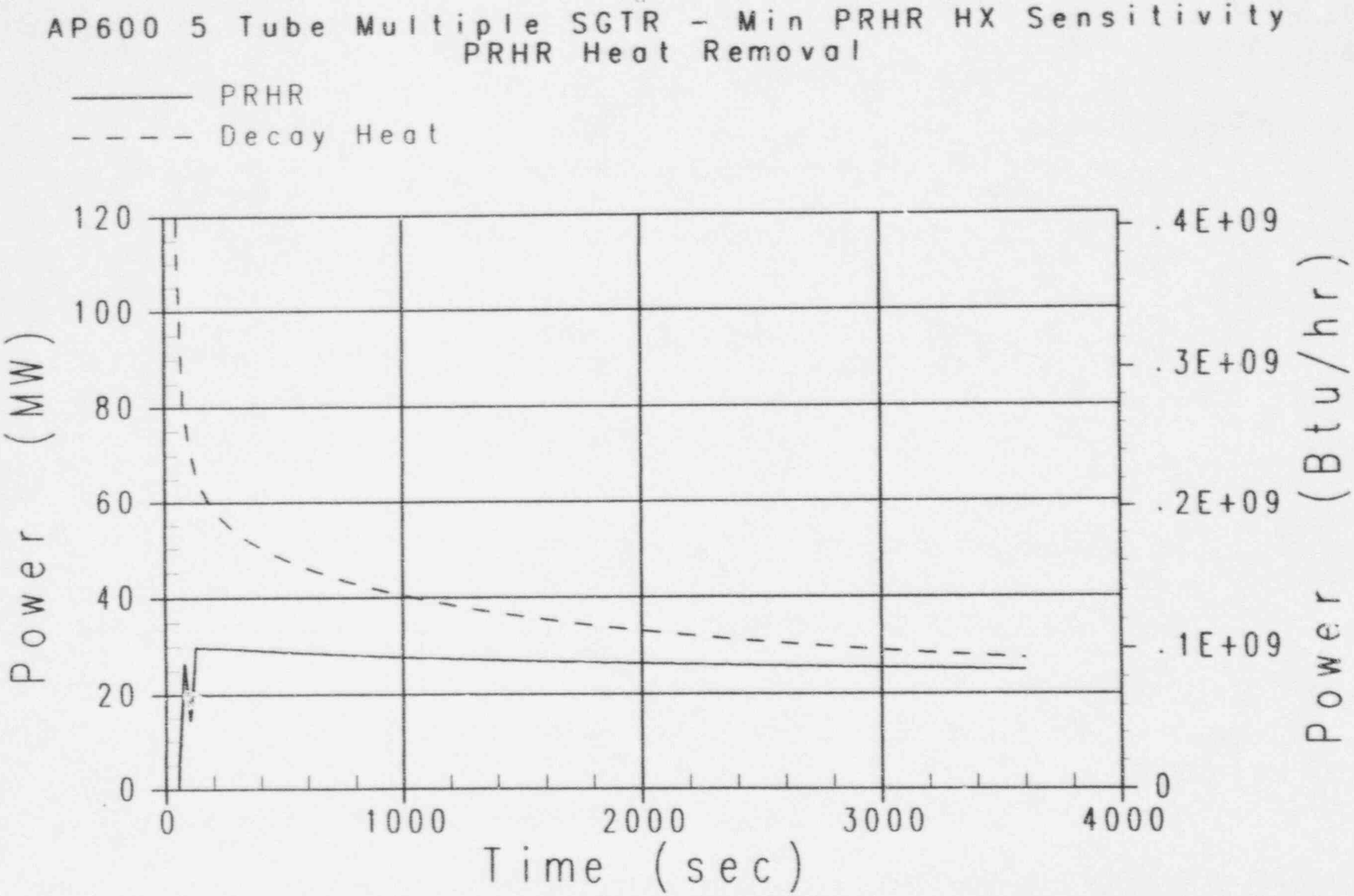

AP600 5 Tube Multiple SGTR - Min PRHR HX Sensitivity
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
Temperature (K)
600
550
500
450
400
350
300
Temperature (F)
600
500
400
300
200
100
0
1000
2000
3000
4000
Time (sec)

Figure 70



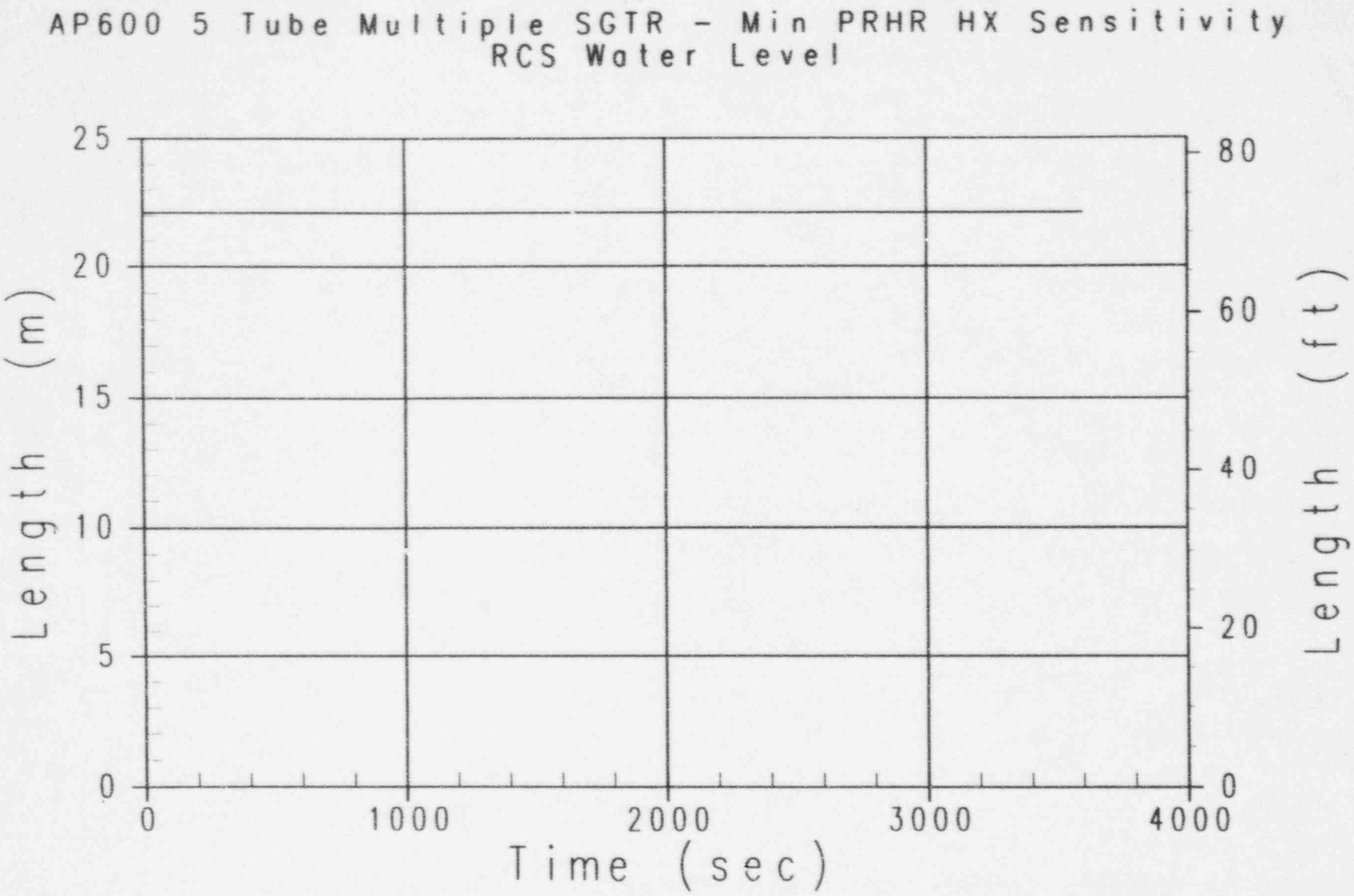
AP600 5 Tube Multiple SGTR - Min PRHR HX Sensitivity
CMT Water Level
Length (m)
Length (ft)
Time (sec)
0
1
2
3
4
5
6
7
0
5
10
15
20
0
1000
2000
3000
4000

Figure 71



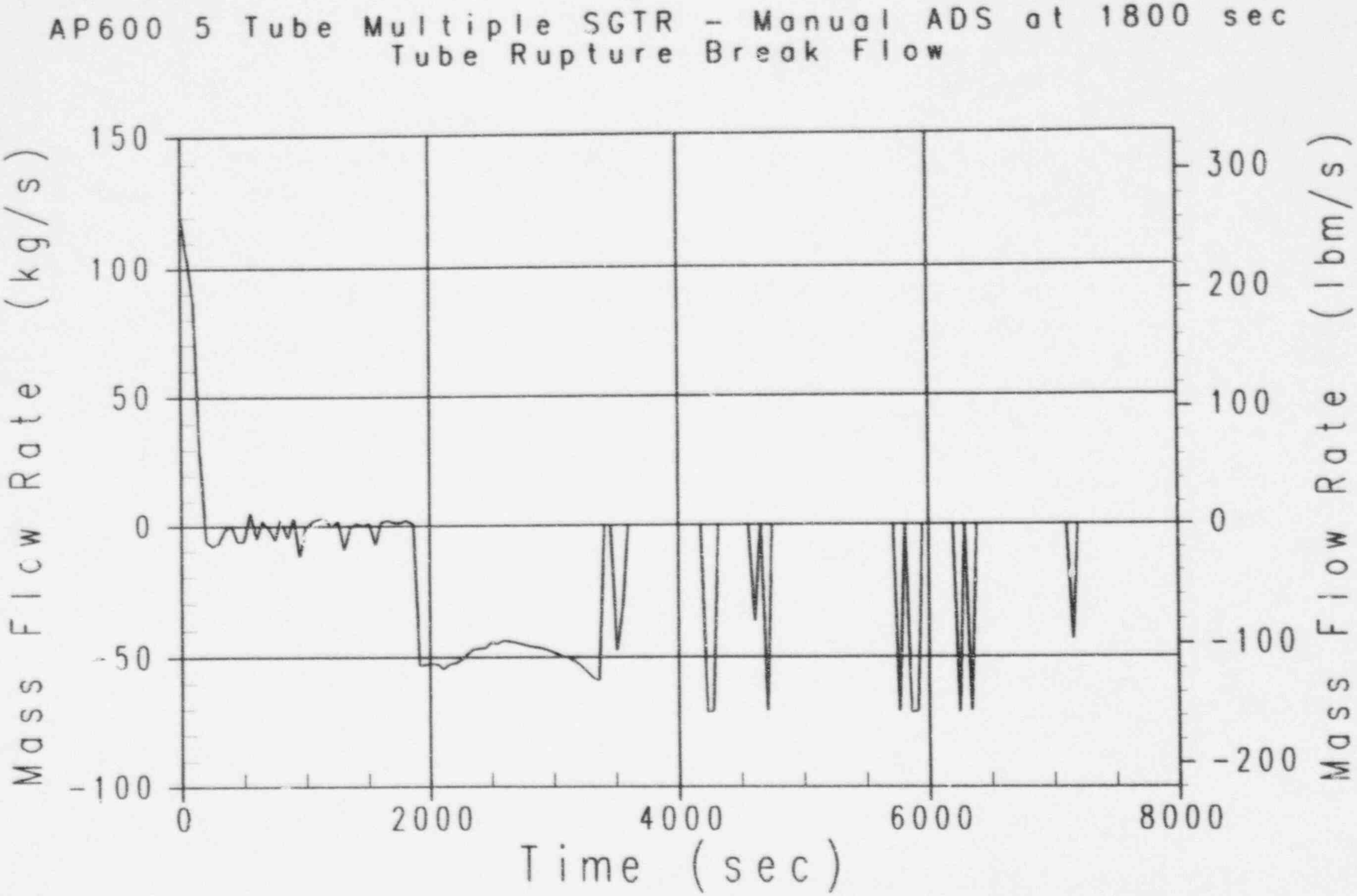
AP600 5 Tube Multiple SGTR - Min PRHR HX Sensitivity
PRHR Heat Removal
PRHR
Decay Heat
Power (MW)
Power (Btu/hr)
Time (sec)
0
20
40
60
80
100
120
0
1000
2000
3000
4000
.1E+09
.2E+09
.3E+09
.4E+09

Figure 72



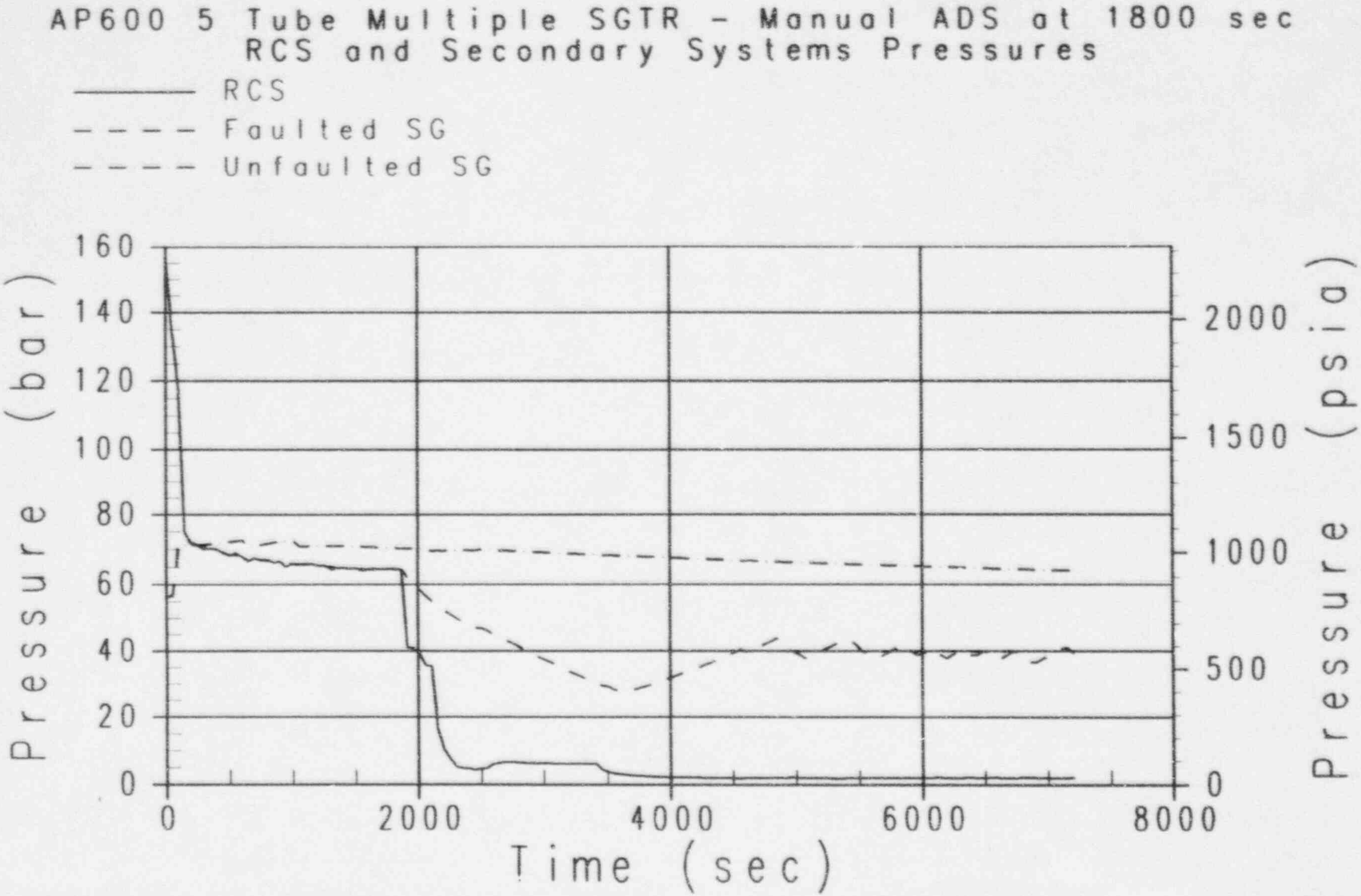
AP600 5 Tube Multiple SGTR - Min PRHR HX Sensitivity
RCS Water Level
Length (m)
Length (ft)
Time (sec)
0
5
10
15
20
25
0
20
40
60
80
0
1000
2000
3000
4000

Figure 73



AP600 5 Tube Multiple SGTR - Manual ADS at 1800 sec
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
150
100
50
0
-50
-100
300
200
100
0
-100
-200
0
2000
4000
6000
8000

Figure 74



AP600 5 Tube Multiple SGTR - Manual ADS at 1800 sec
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
Pressure (psia)
Time (sec)
0
20
40
60
80
100
120
140
160
500
1000
1500
2000
2000
4000
6000
8000

Figure 75

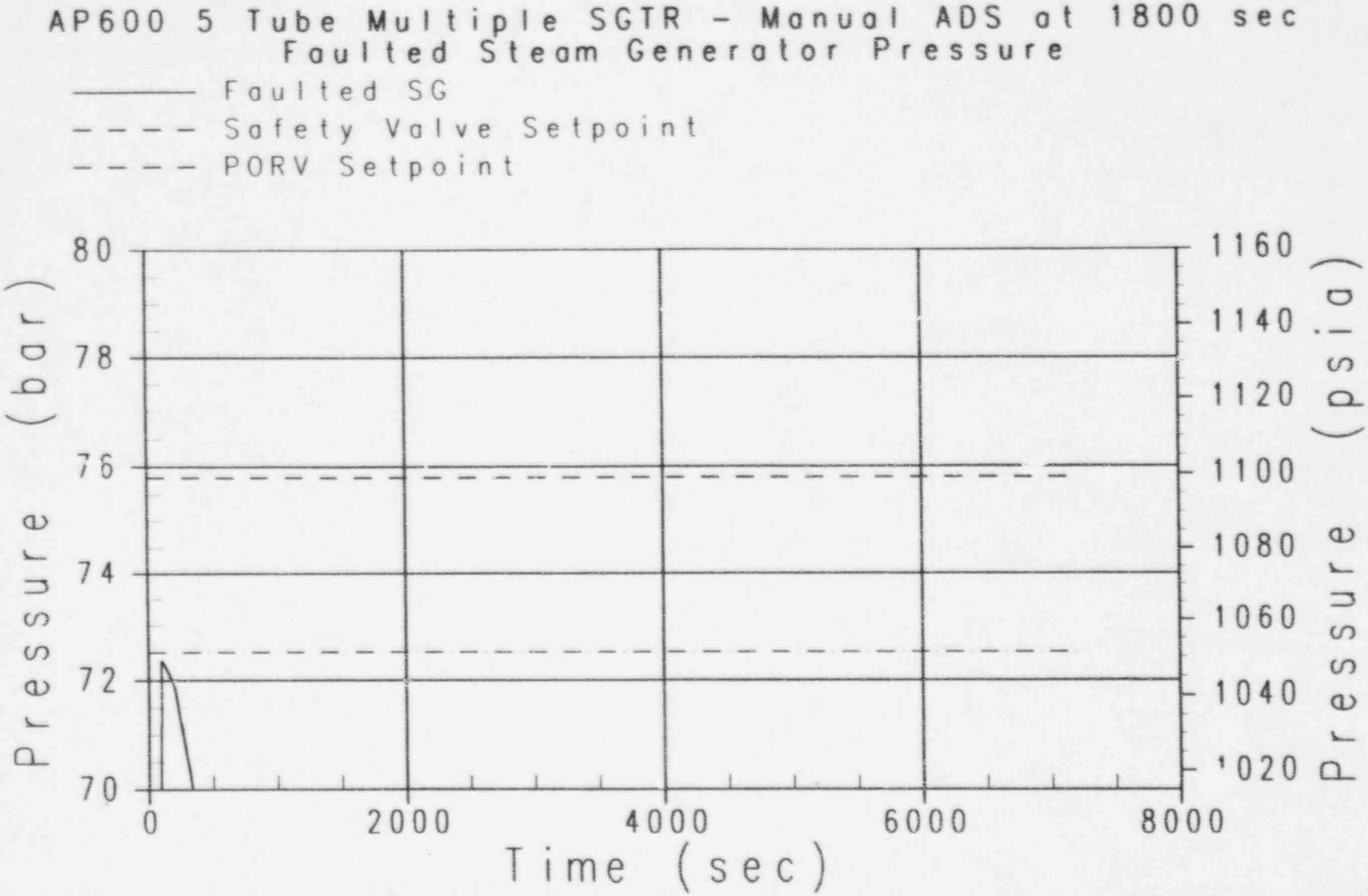

AP600 5 Tube Multiple SGTR - Manual ADS at 1800 sec
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
PORV Setpoint
80
78
76
74
72
70
Pressure (bar)
1160
1140
1120
1100
1080
1060
1040
1020
Pressure (psia)
0
2000
4000
6000
8000
Time (sec)

Figure 76

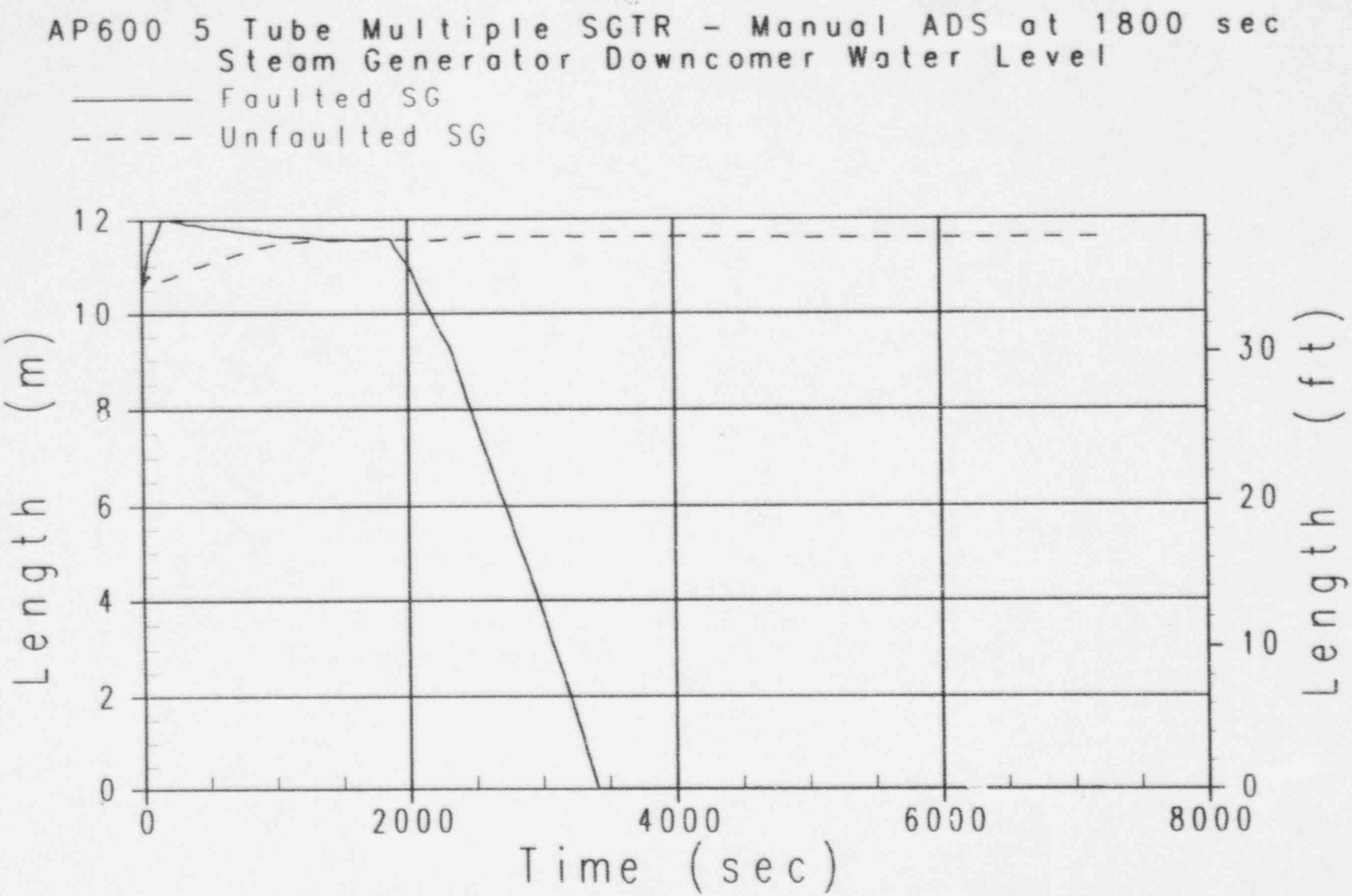

AP600 5 Tube Multiple SGTR - Manual ADS at 1800 sec
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
Length (m)
Length (ft)
Time (sec)
0
2
4
6
8
10
12
0
10
20
30
0
2000
4000
6000
8000

Figure 77

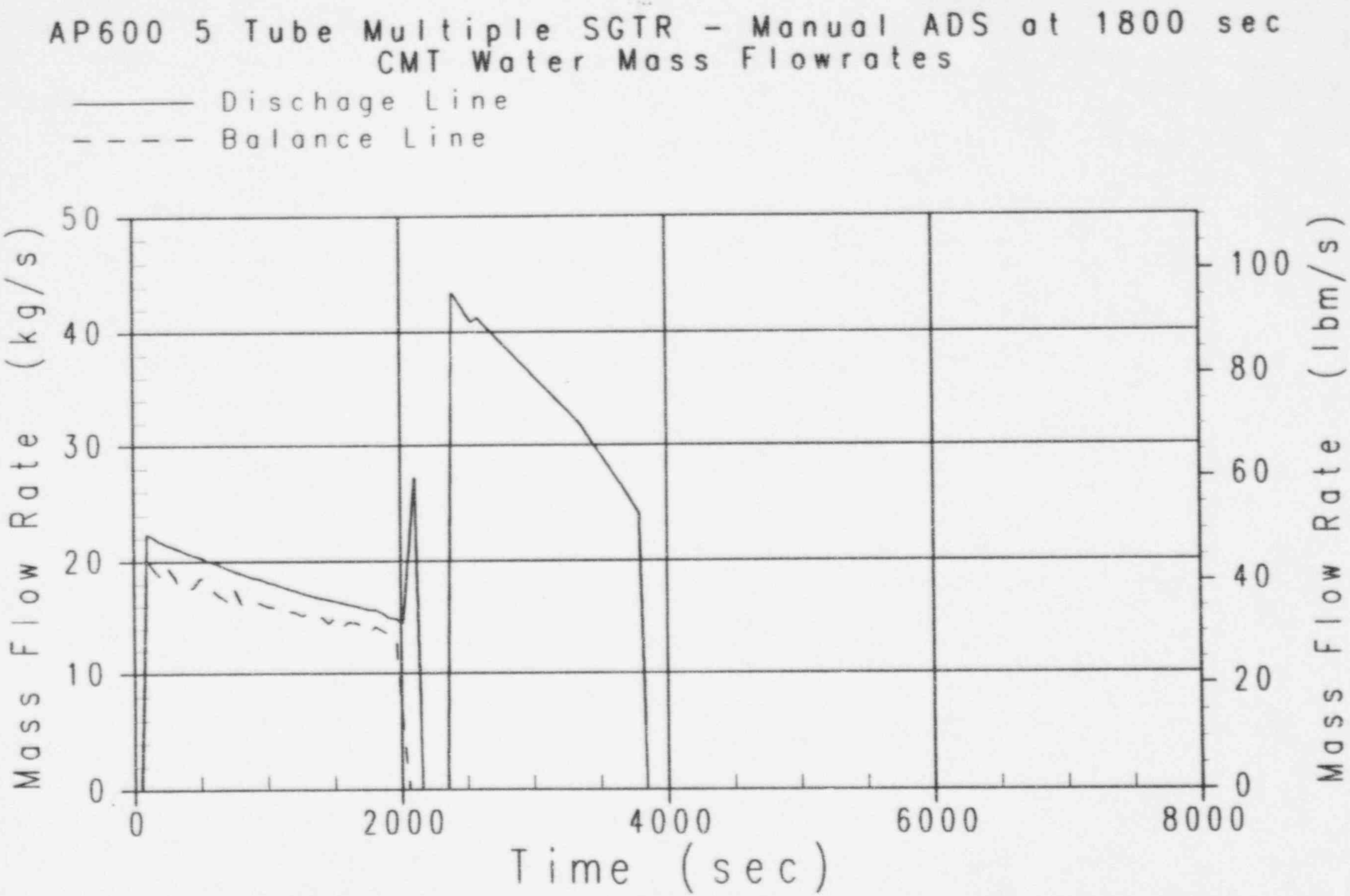

AP600 5 Tube Multiple SGTR - Manual ADS at 1800 sec
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
10
20
30
40
50
0
20
40
60
80
100
0
2000
4000
6000
8000

Figure 78

AP600 5 Tube Multiple SGTR - Manual ADS at 1800 sec
Total Accumulator Injection Mass Flowrate

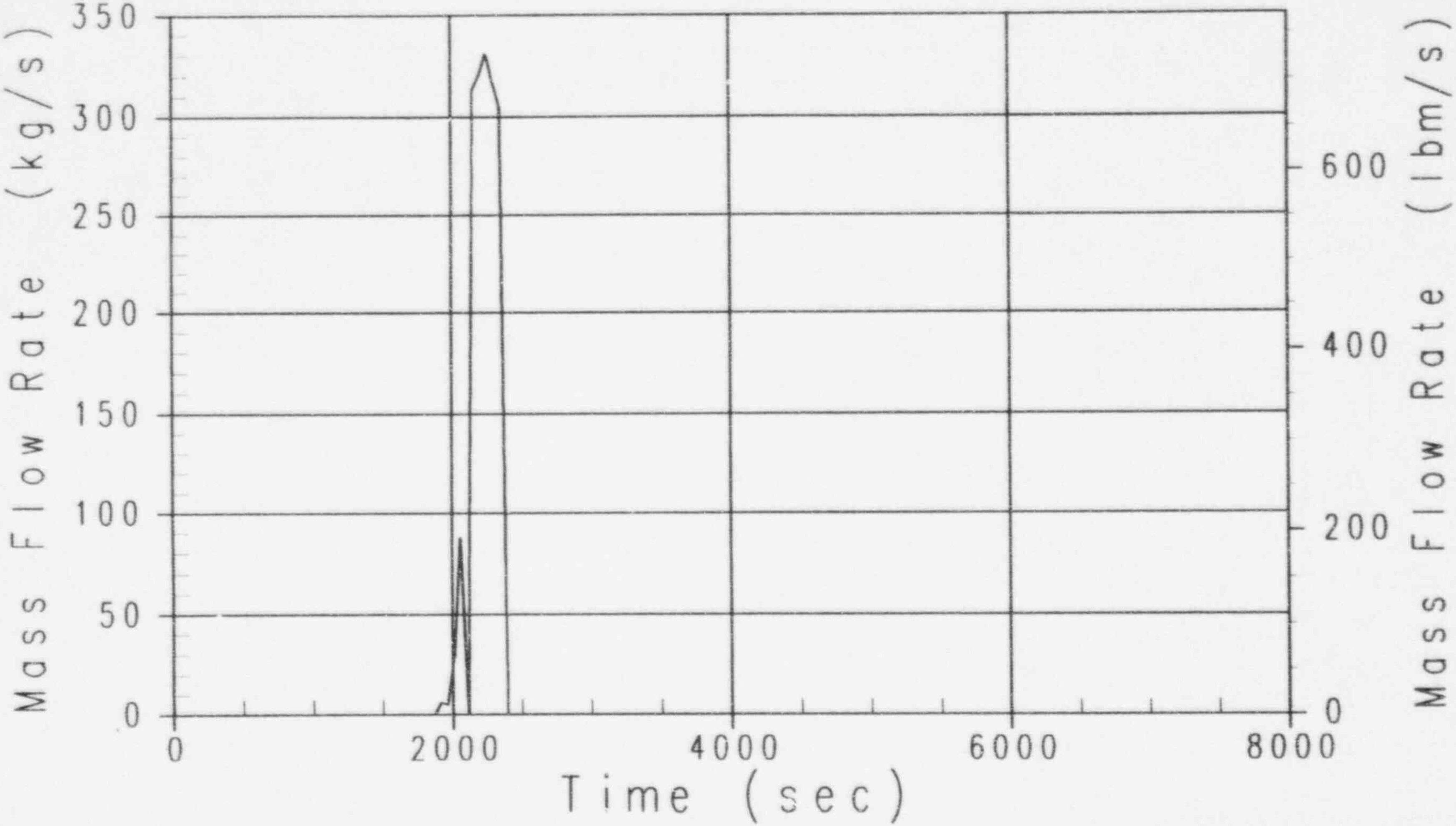


Figure 79

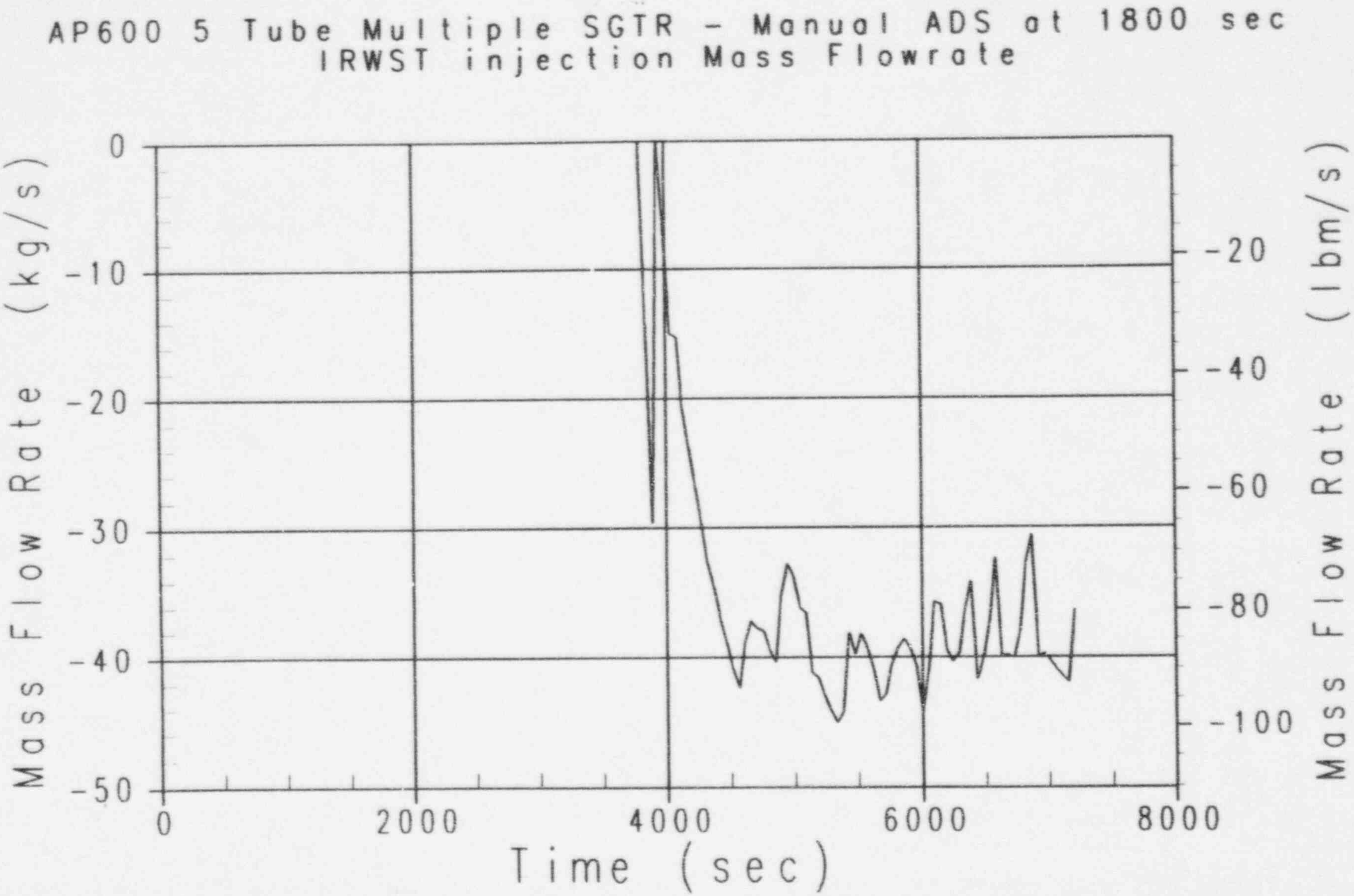

AP600 5 Tube Multiple SGTR - Manual ADS at 1800 sec
IRWST injection Mass Flowrate
0
-10
-20
-30
-40
-50
Mass Flow Rate (kg/s)
-20
-40
-60
-80
-100
Mass Flow Rate (lbm/s)
0
2000
4000
6000
8000
Time (sec)

Figure 80

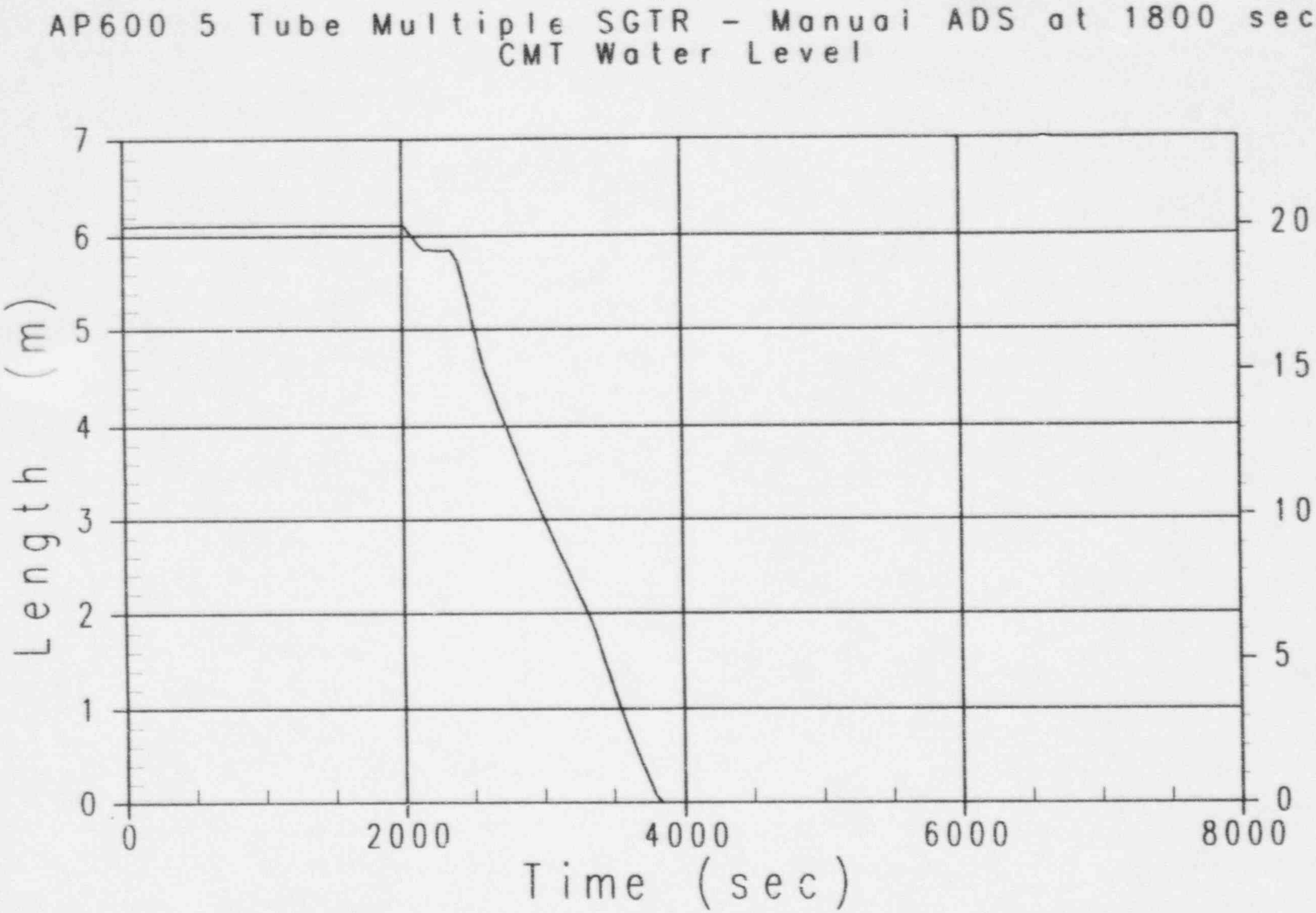

AP600 5 Tube Multiple SGTR - Manual ADS at 1800 sec
CMT Water Level
Length (m)
Length (ft)
Time (sec)
0
1
2
3
4
5
6
7
0
5
10
15
20
0
2000
4000
6000
8000

Figure 81

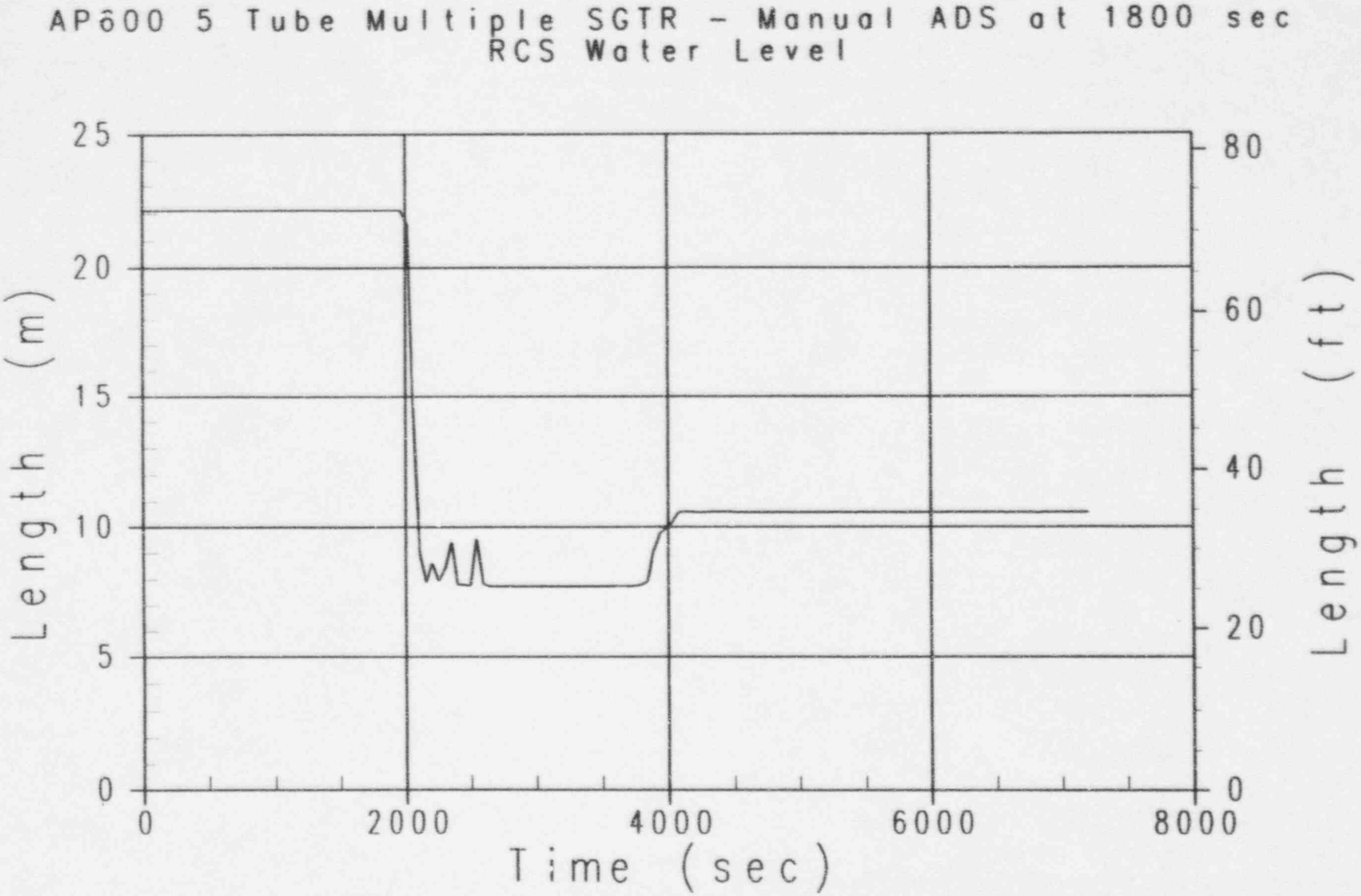

AP600 5 Tube Multiple SGTR - Manual ADS at 1800 sec
RCS Water Level
Length (m)
Length (ft)
Time (sec)
0
5
10
15
20
25
0
20
40
60
80
0
2000
4000
6000
8000

Figure 82

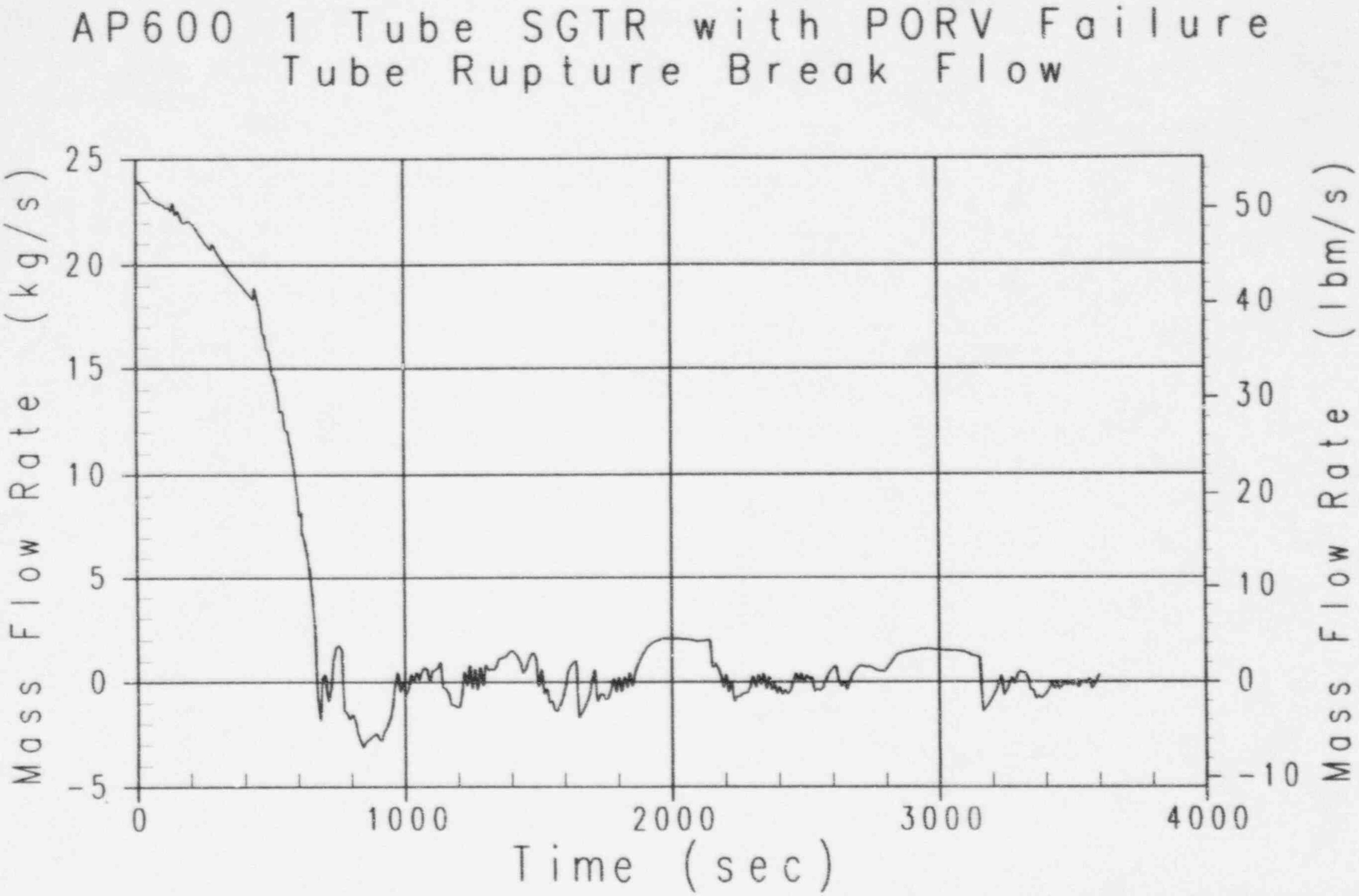

AP600 1 Tube SGTR with PORV Failure
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
25
20
15
10
5
0
-5
50
40
30
20
10
0
-10
0
1000
2000
3000
4000

Figure 83

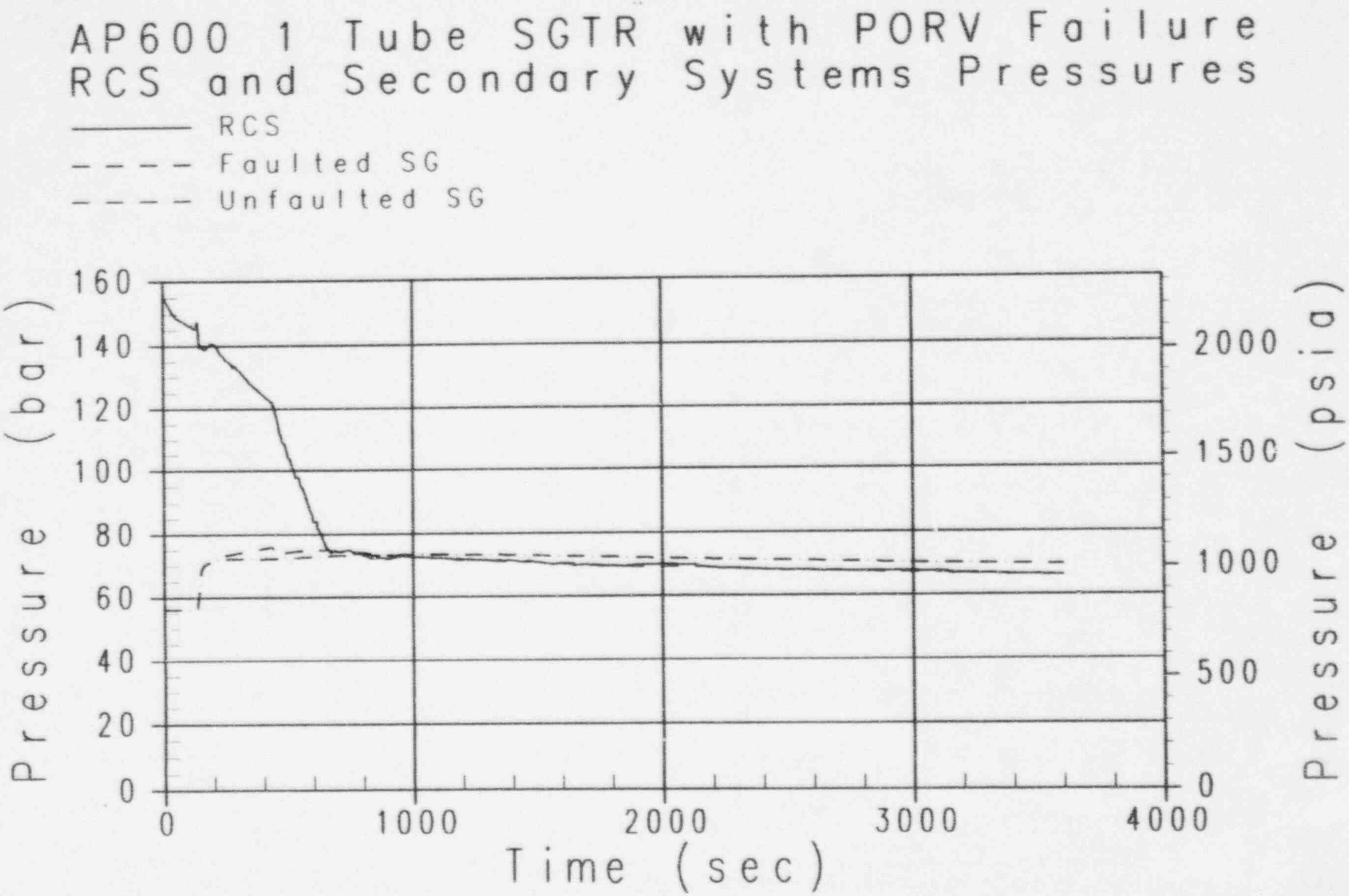

AP600 1 Tube SGTR with PORV Failure
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
Pressure (psia)
Time (sec)
0
20
40
60
80
100
120
140
160
500
1000
1500
2000
1000
2000
3000
4000

Figure 84

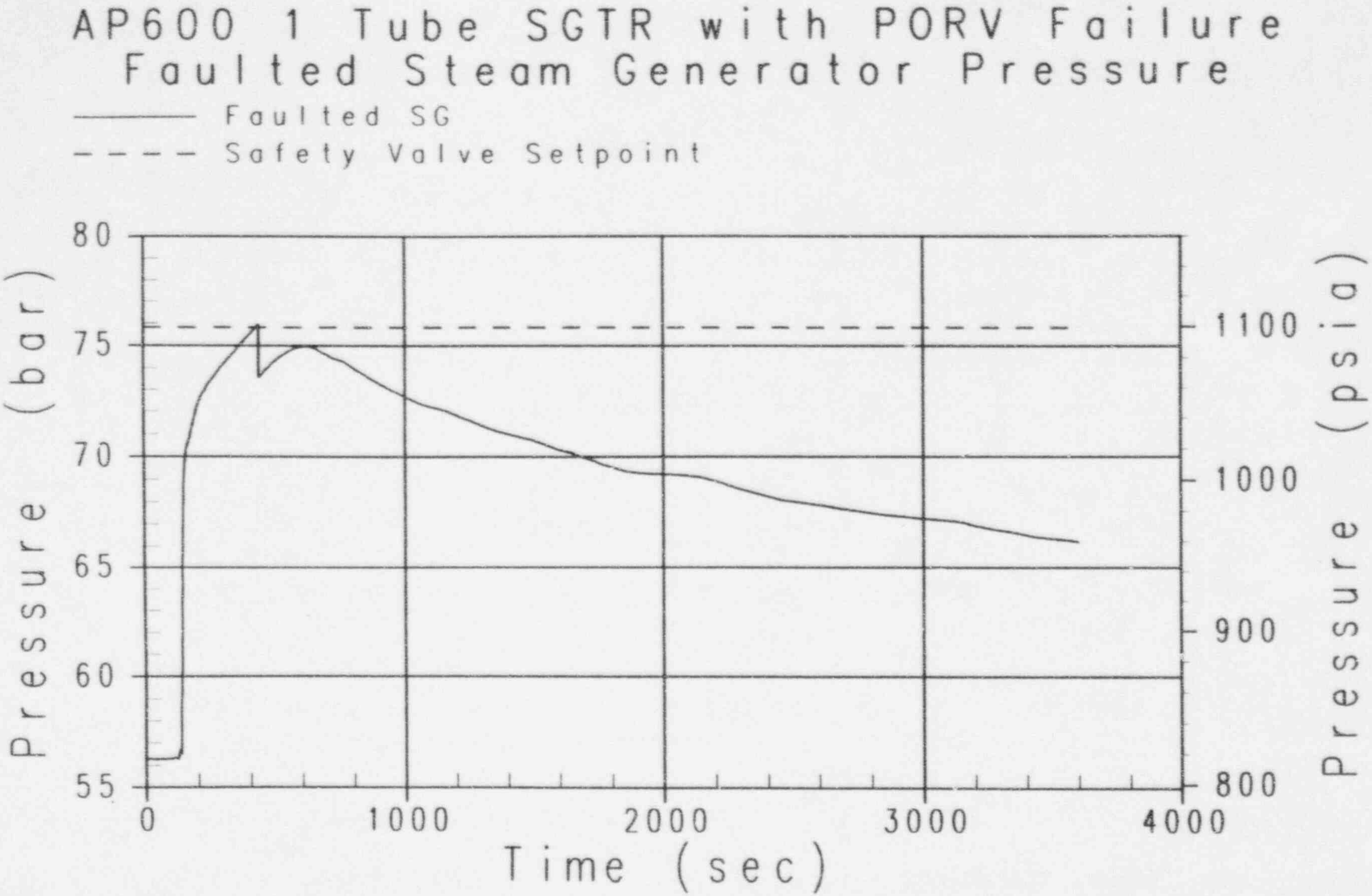

AP600 1 Tube SGTR with PORV Failure
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
Pressure (bar)
80
75
70
65
60
55
Pressure (psia)
1100
1000
900
800
0
1000
2000
3000
4000
Time (sec)

Figure 85

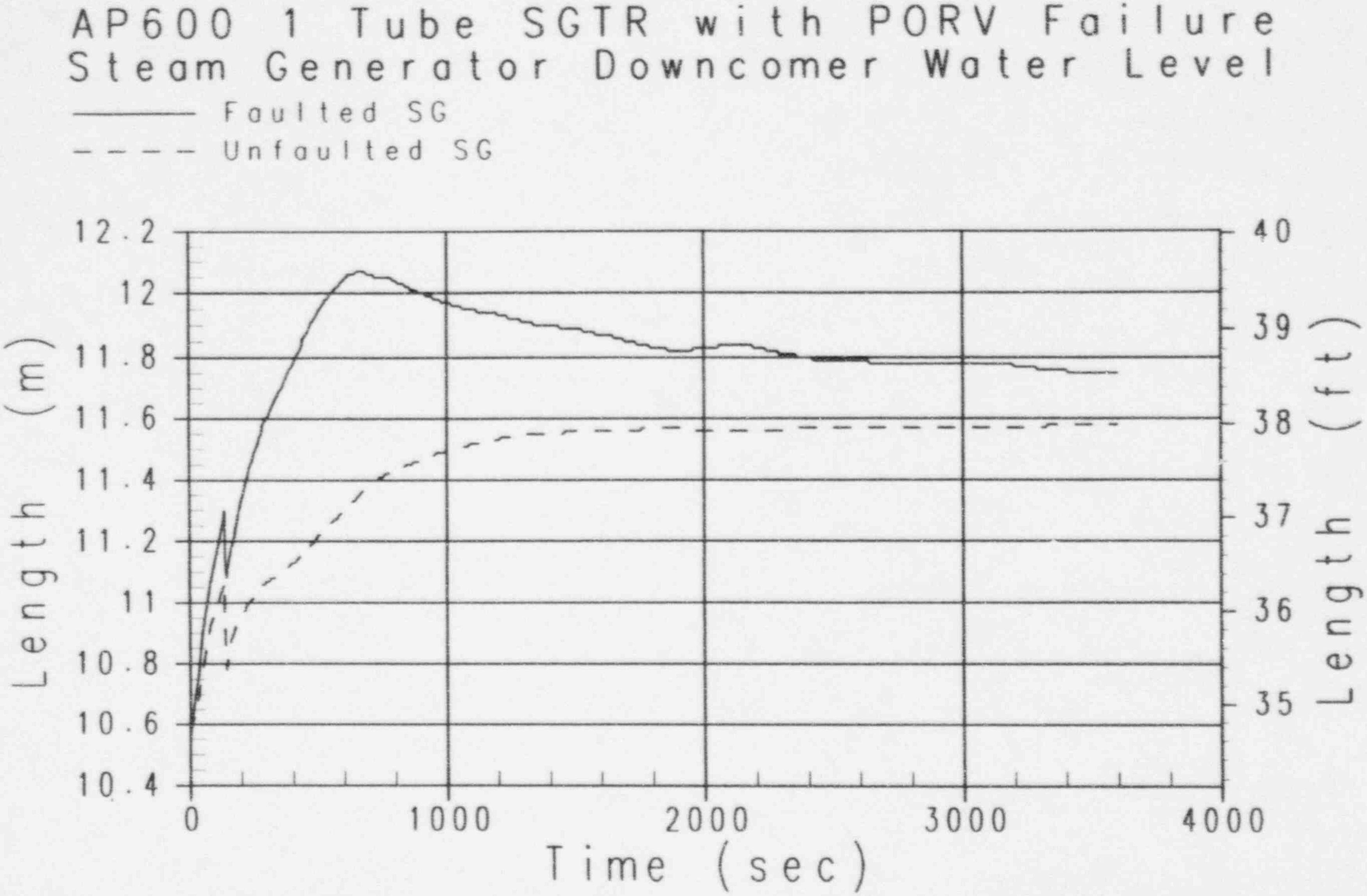

AP600 1 Tube SGTR with PORV Failure
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
Length (m)
Length (ft)
Time (sec)
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
40
39
38
37
36
35
0
1000
2000
3000
4000

Figure 86

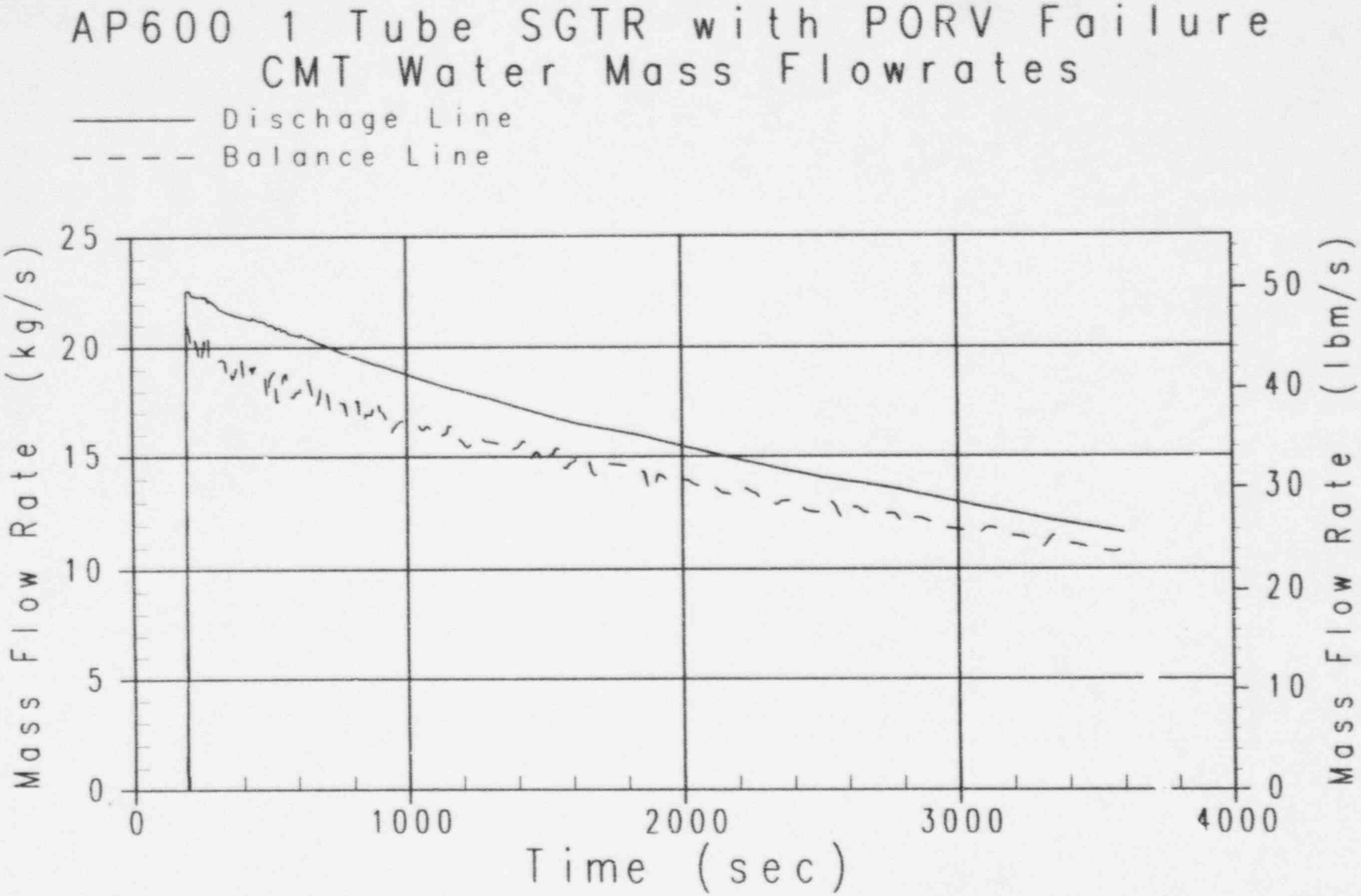

AP600 1 Tube SGTR with PORV Failure
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
25
20
15
10
5
0
50
40
30
20
10
0
0
1000
2000
3000
4000

Figure 87

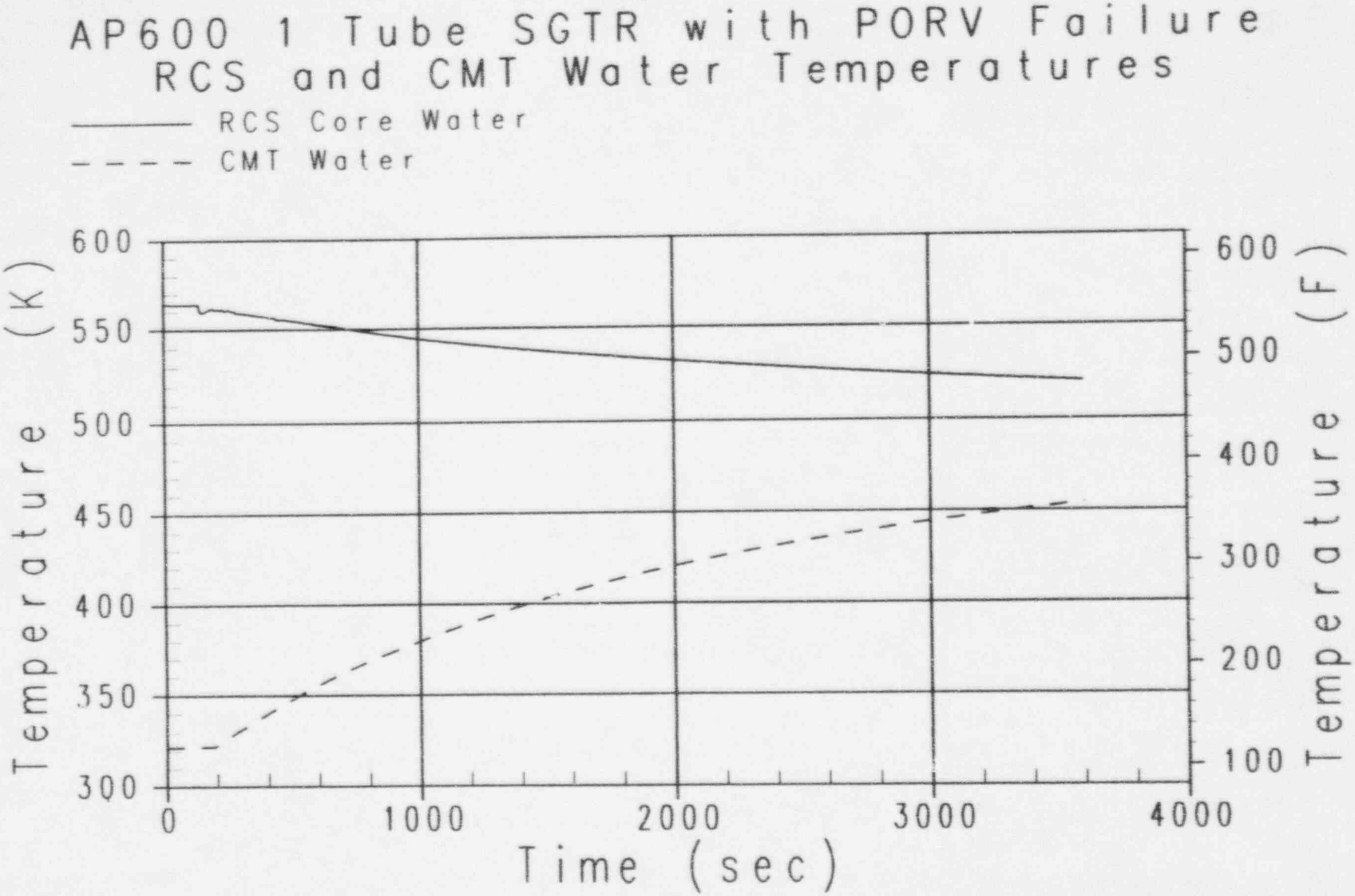

AP600 1 Tube SGTR with PORV Failure
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
Temperature (K)
600
550
500
450
400
350
300
Temperature (F)
600
500
400
300
200
100
0
1000
2000
3000
4000
Time (sec)

Figure 88

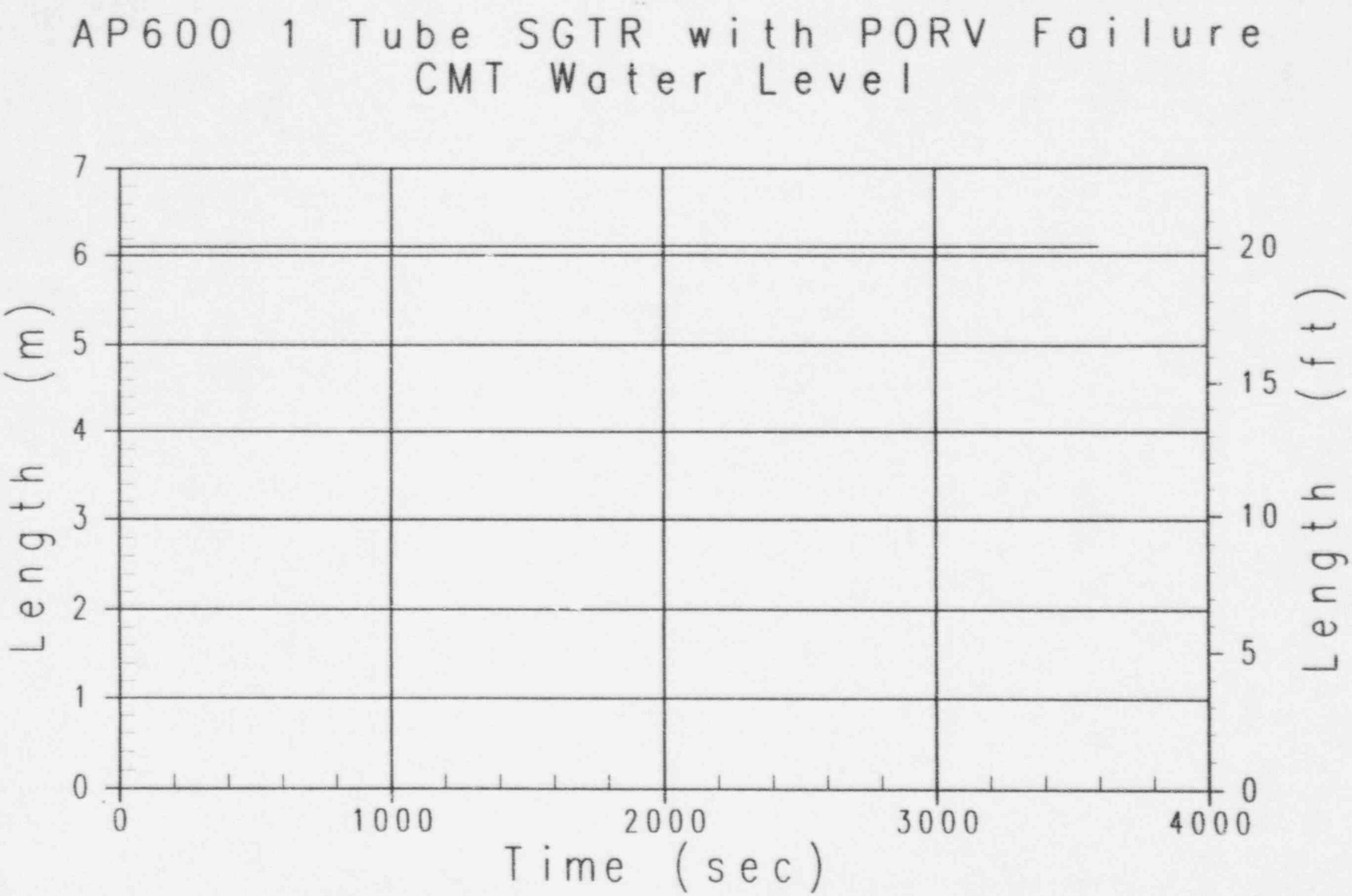
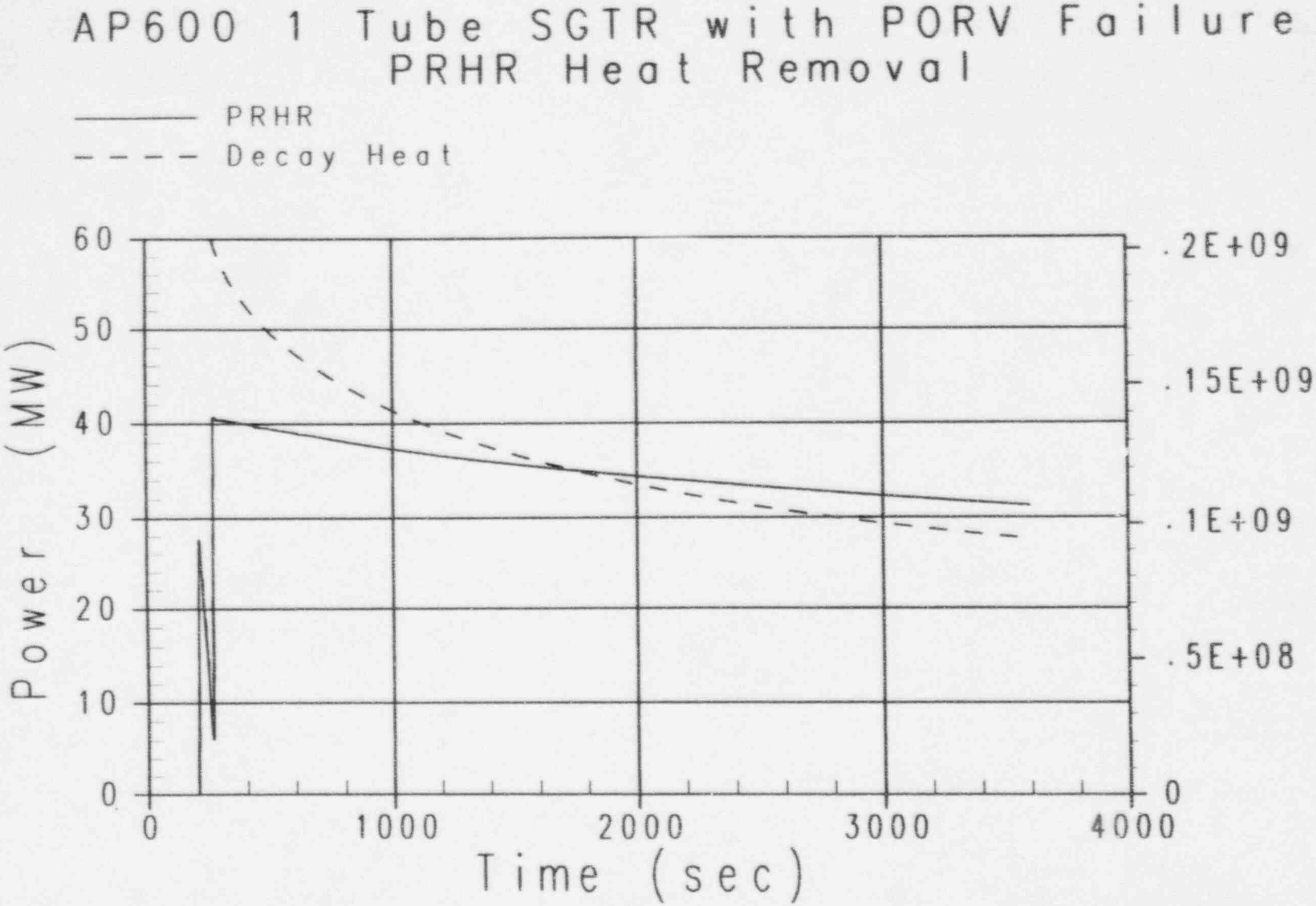
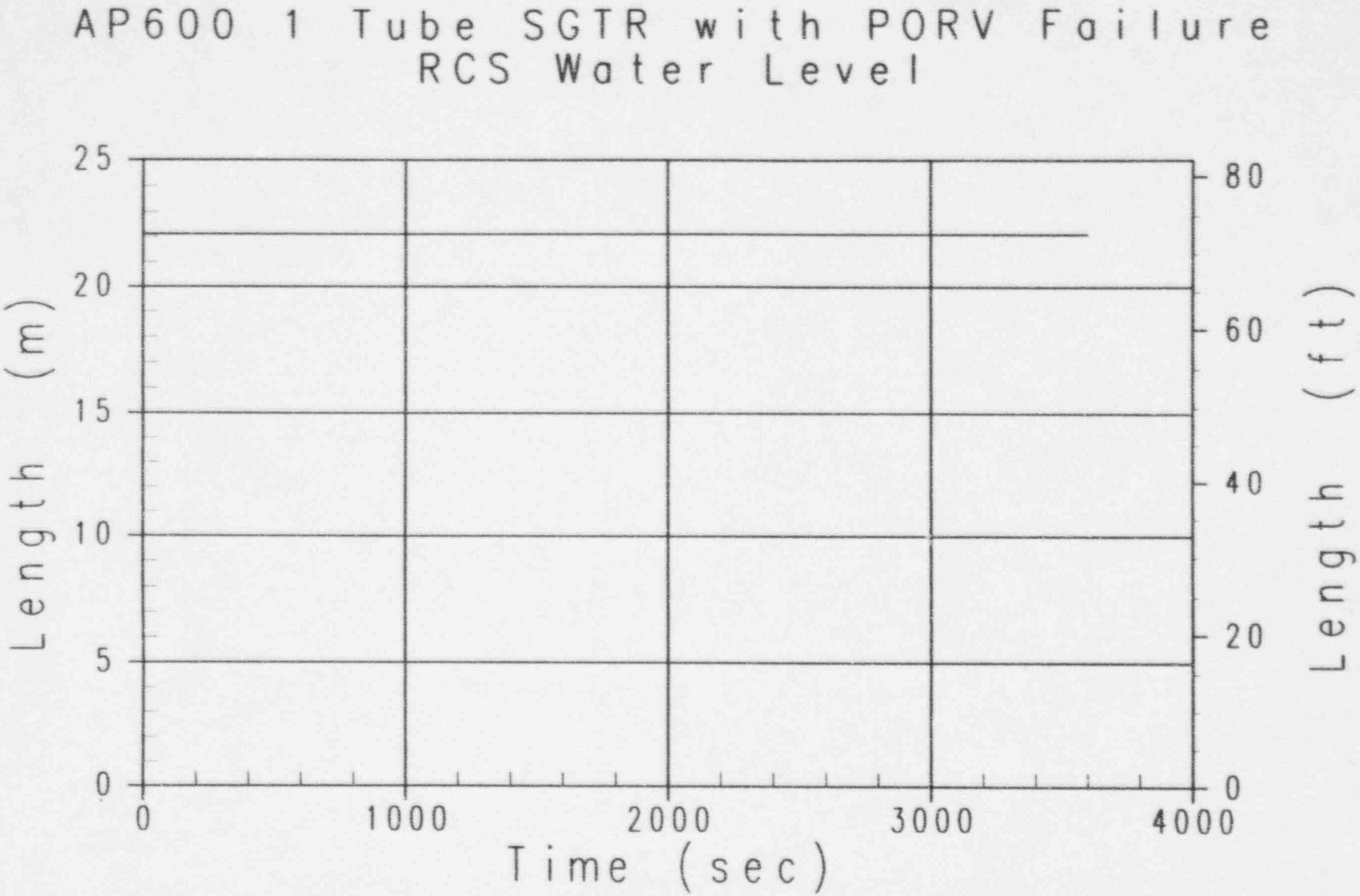

AP600 1 Tube SGTR with PORV Failure
CMT Water Level
Length (m)
7
6
5
4
3
2
1
0
Length (ft)
20
15
10
5
0
0
1000
2000
3000
4000
Time (sec)

Figure 89



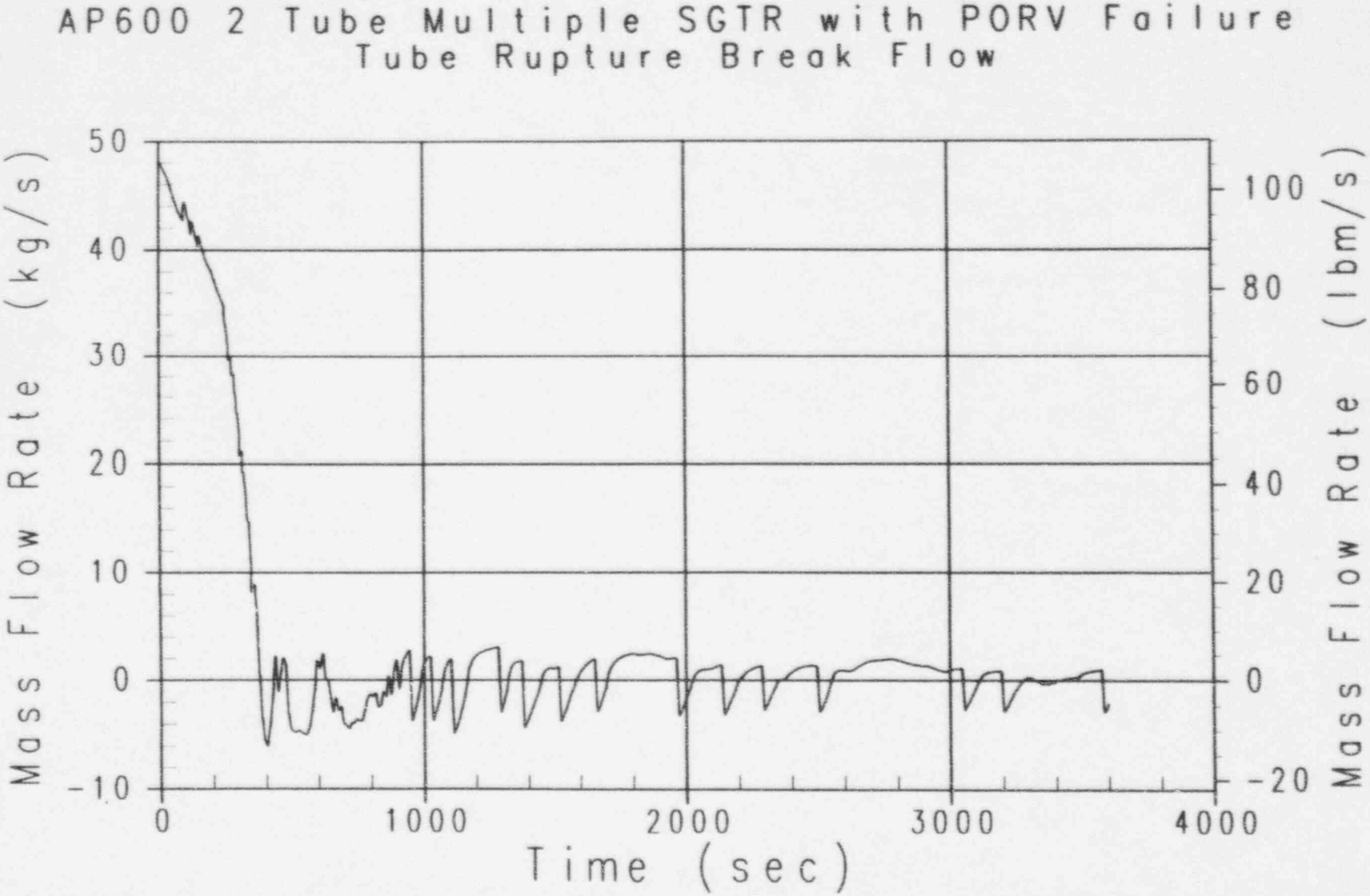
AP600 1 Tube SGTR with PORV Failure
PRHR Heat Removal
PRHR
Decay Heat
60
50
40
30
20
10
0
Power (MW)
.2E+09
.15E+09
.1E+09
.5E+08
0
Power (Btu/hr)
0
1000
2000
3000
4000
Time (sec)

Figure 90



AP600 1 Tube SGTR with PORV Failure
RCS Water Level
Length (m)
25
20
15
10
5
0
Length (ft)
80
60
40
20
0
0
1000
2000
3000
4000
Time (sec)

Figure 91



AP600 2 Tube Multiple SGTR with PORV Failure
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
50
40
30
20
10
0
-10
100
80
60
40
20
0
-20
0
1000
2000
3000
4000

Figure 92

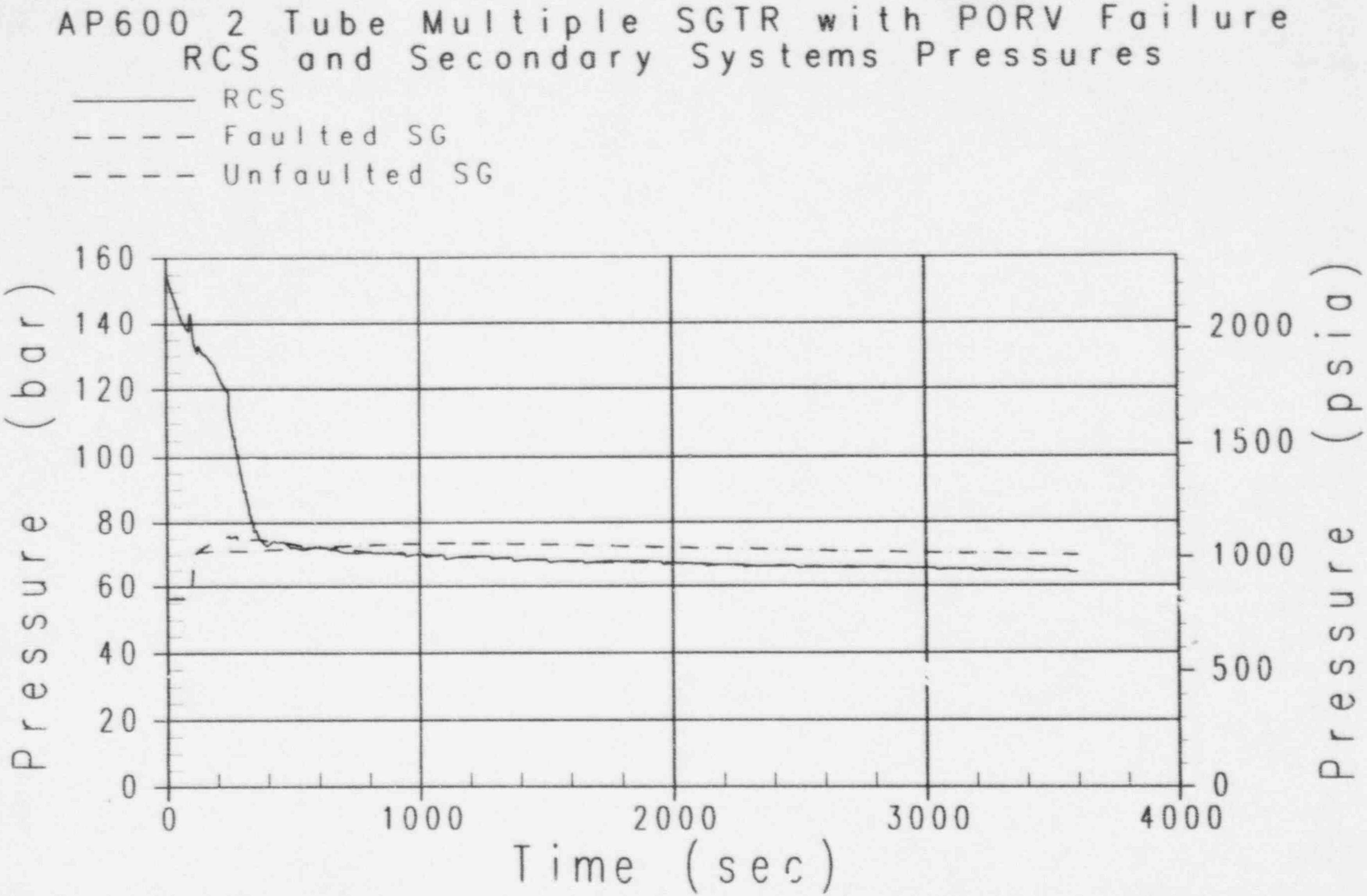
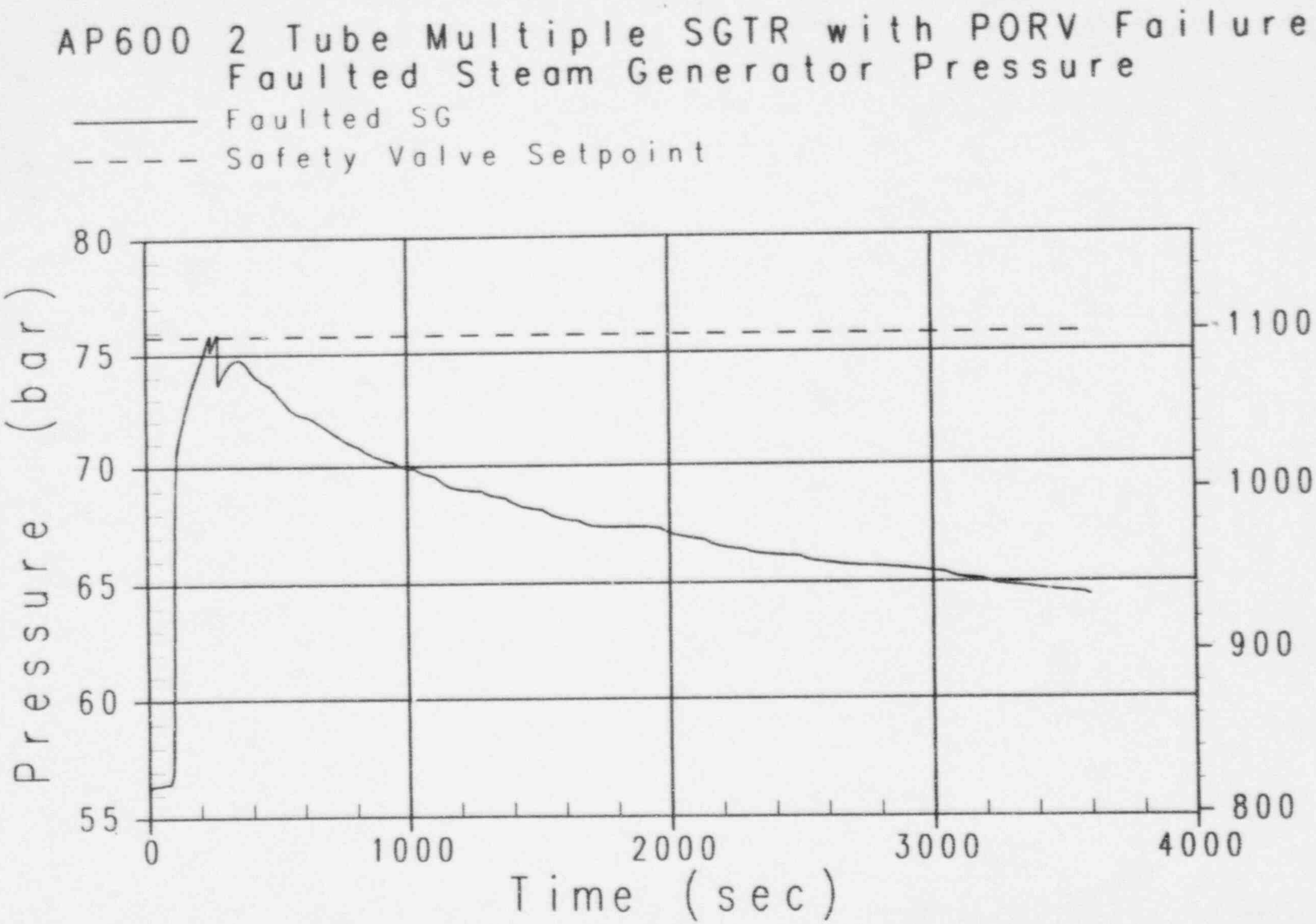

AP600 2 Tube Multiple SGTR with PORV Failure
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
Pressure (psia)
Time (sec)
160
140
120
100
80
60
40
20
0
2000
1500
1000
500
0
1000
2000
3000
4000

Figure 93



AP600 2 Tube Multiple SGTR with PORV Failure
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
Pressure (bar)
80
75
70
65
60
55
Pressure (psia)
1100
1000
900
800
0
1000
2000
3000
4000
Time (sec)

Figure 94

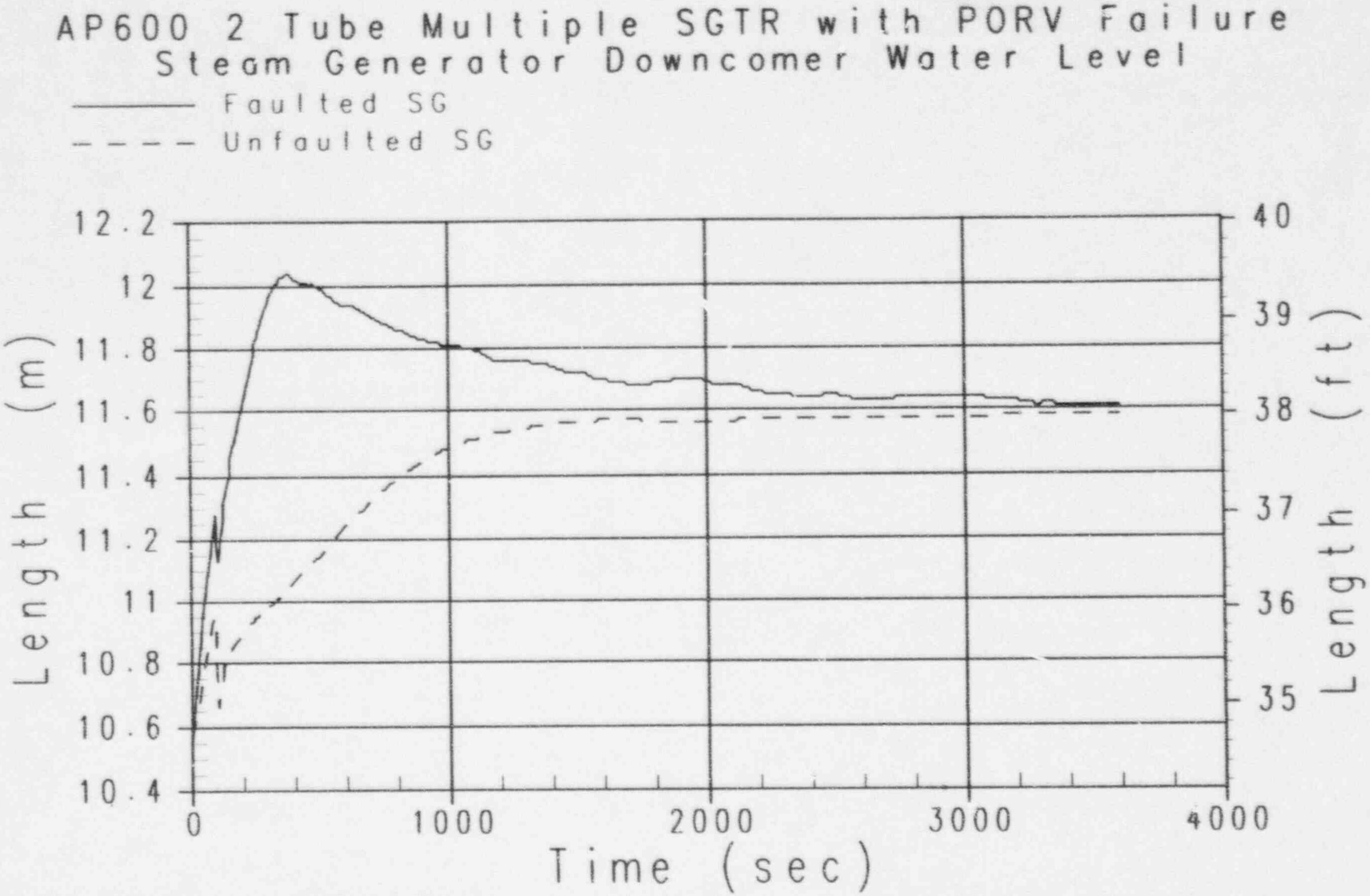

AP600 2 Tube Multiple SGTR with PORV Failure
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
Length (m)
Length (ft)
Time (sec)
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
40
39
38
37
36
35
0
1000
2000
3000
4000

Figure 95

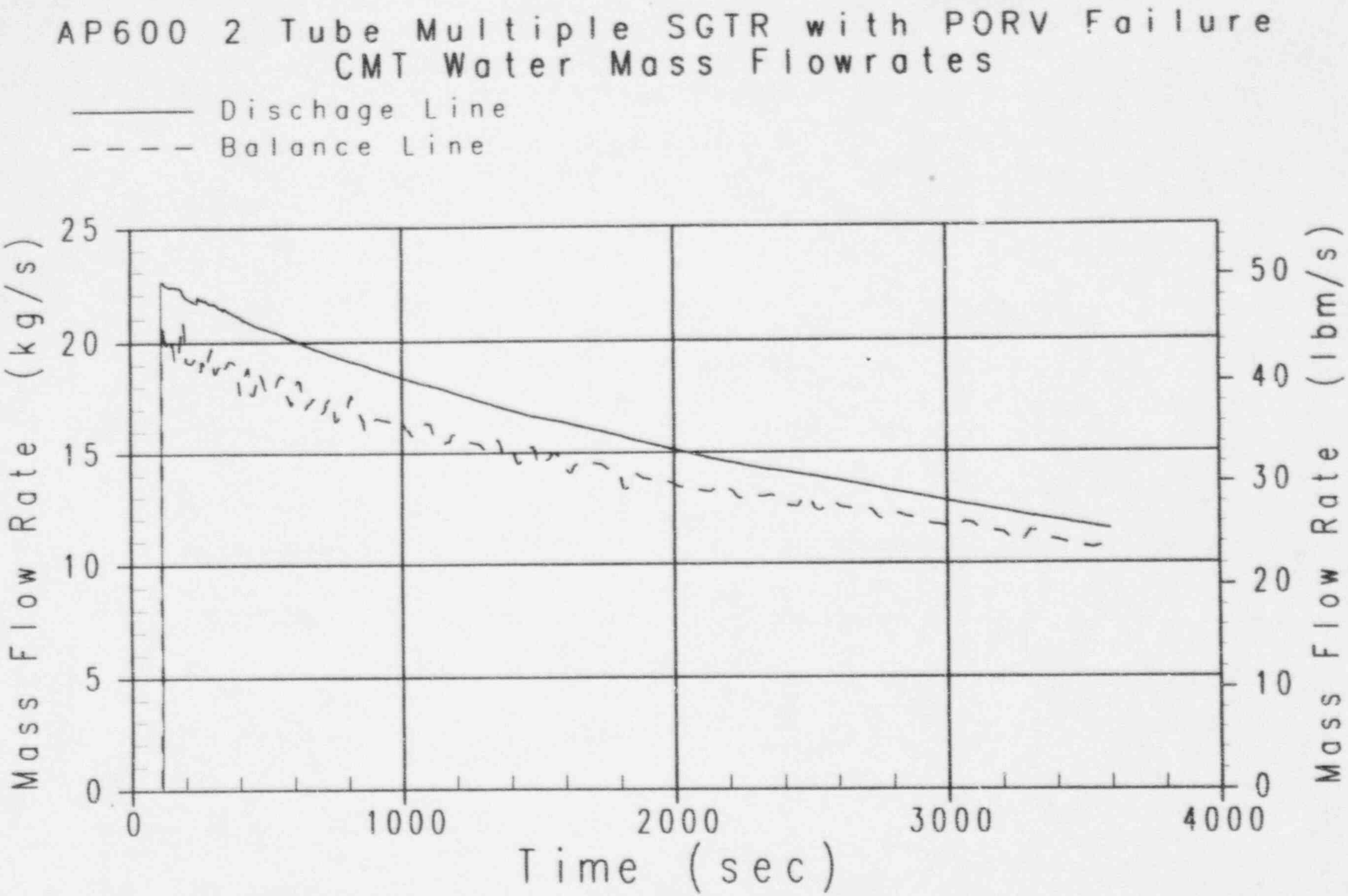

AP600 2 Tube Multiple SGTR with PORV Failure
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
5
10
15
20
25
0
10
20
30
40
50
0
1000
2000
3000
4000

Figure 96

AP600 2 Tube Multiple SGTR with PORV Failure
RCS and CMT Water Temperatures

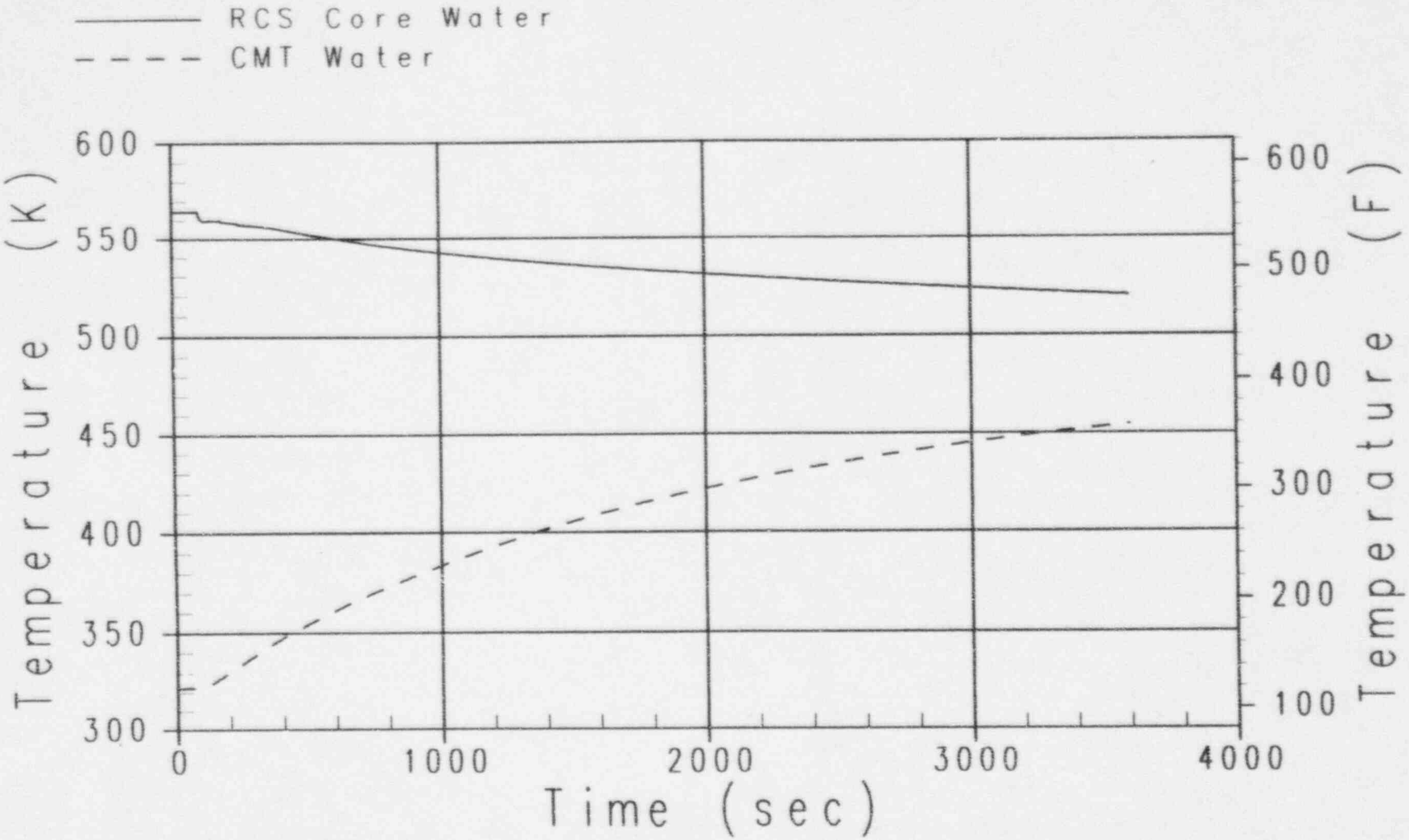


Figure 97

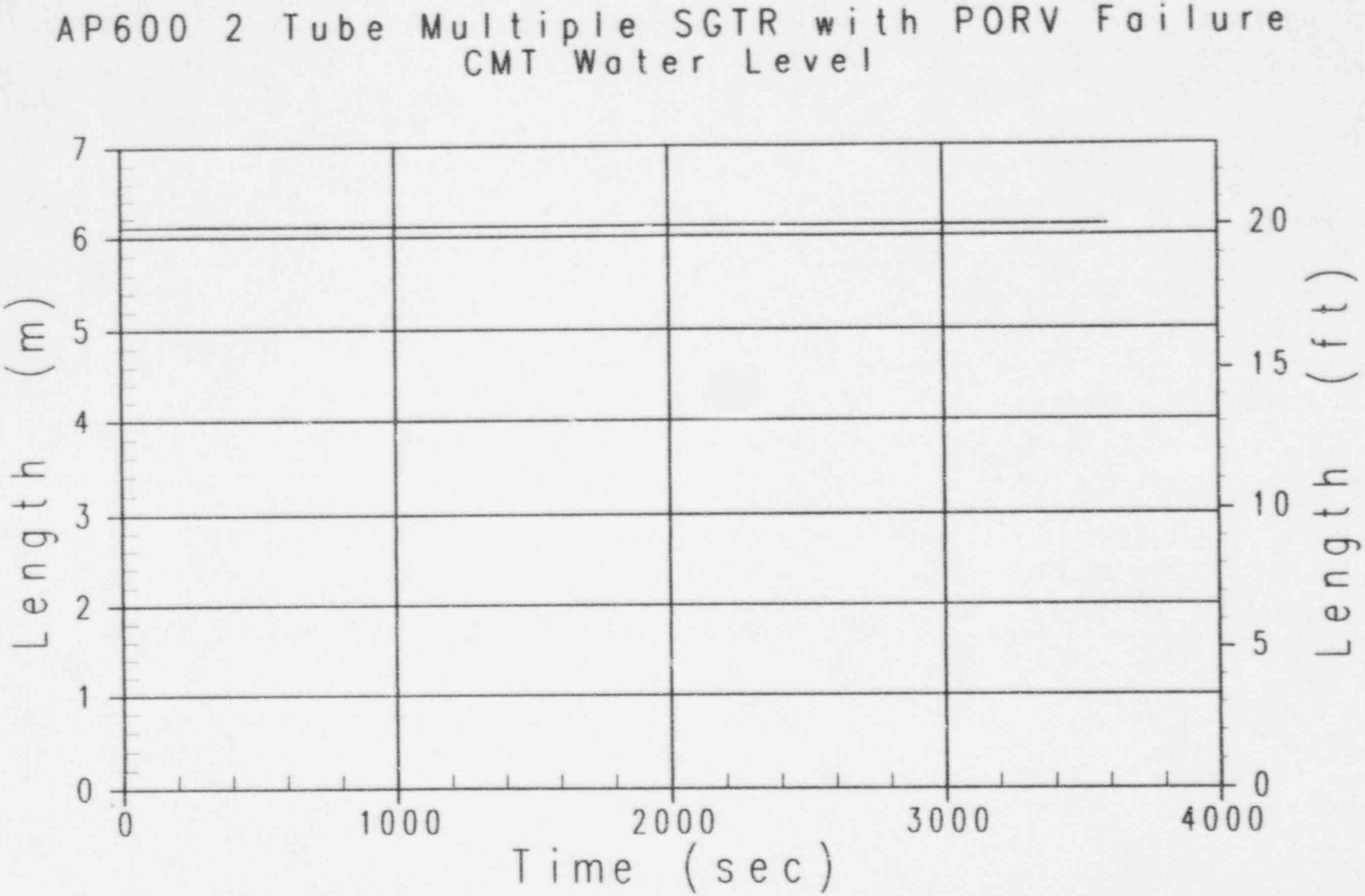

AP600 2 Tube Multiple SGTR with PORV Failure
CMT Water Level
Length (m)
Length (ft)
Time (sec)
0
1
2
3
4
5
6
7
0
5
10
15
20
0
1000
2000
3000
4000

Figure 98

AP600 2 Tube Multiple SGTR with PORV Failure
PRHR Heat Removal

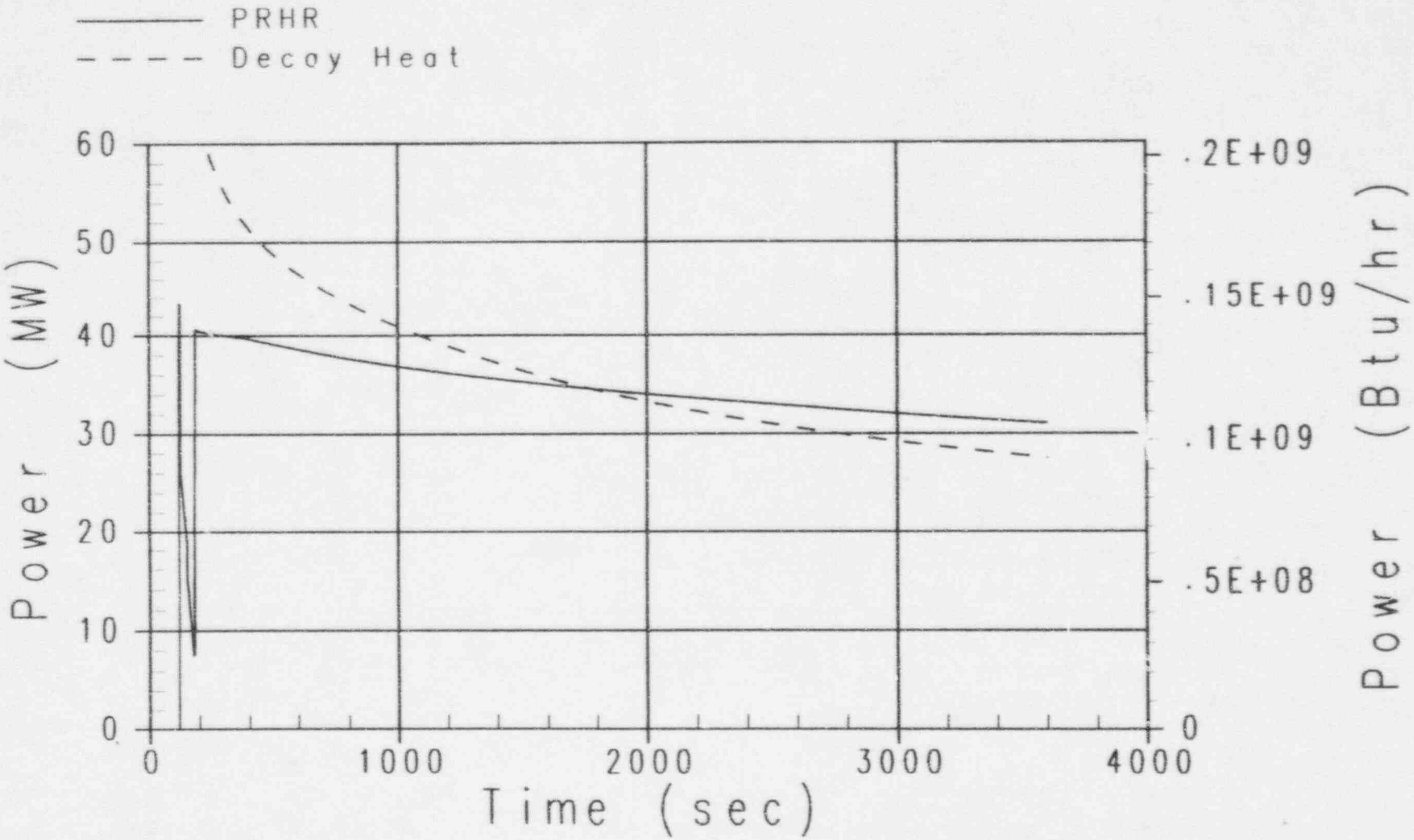


Figure 99

AP600 2 Tube Multiple SGTR with PORV Failure
RCS Water Level

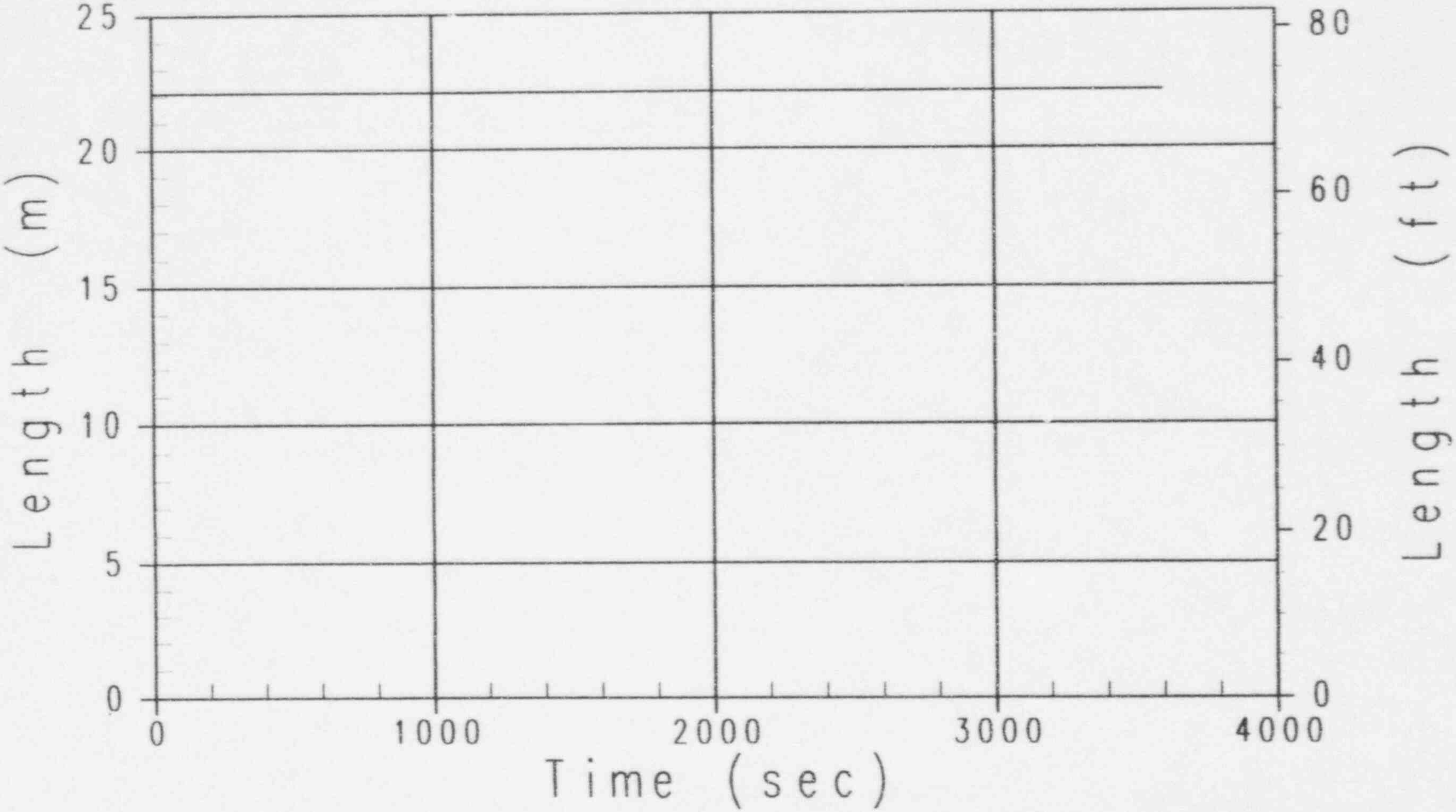


Figure 100

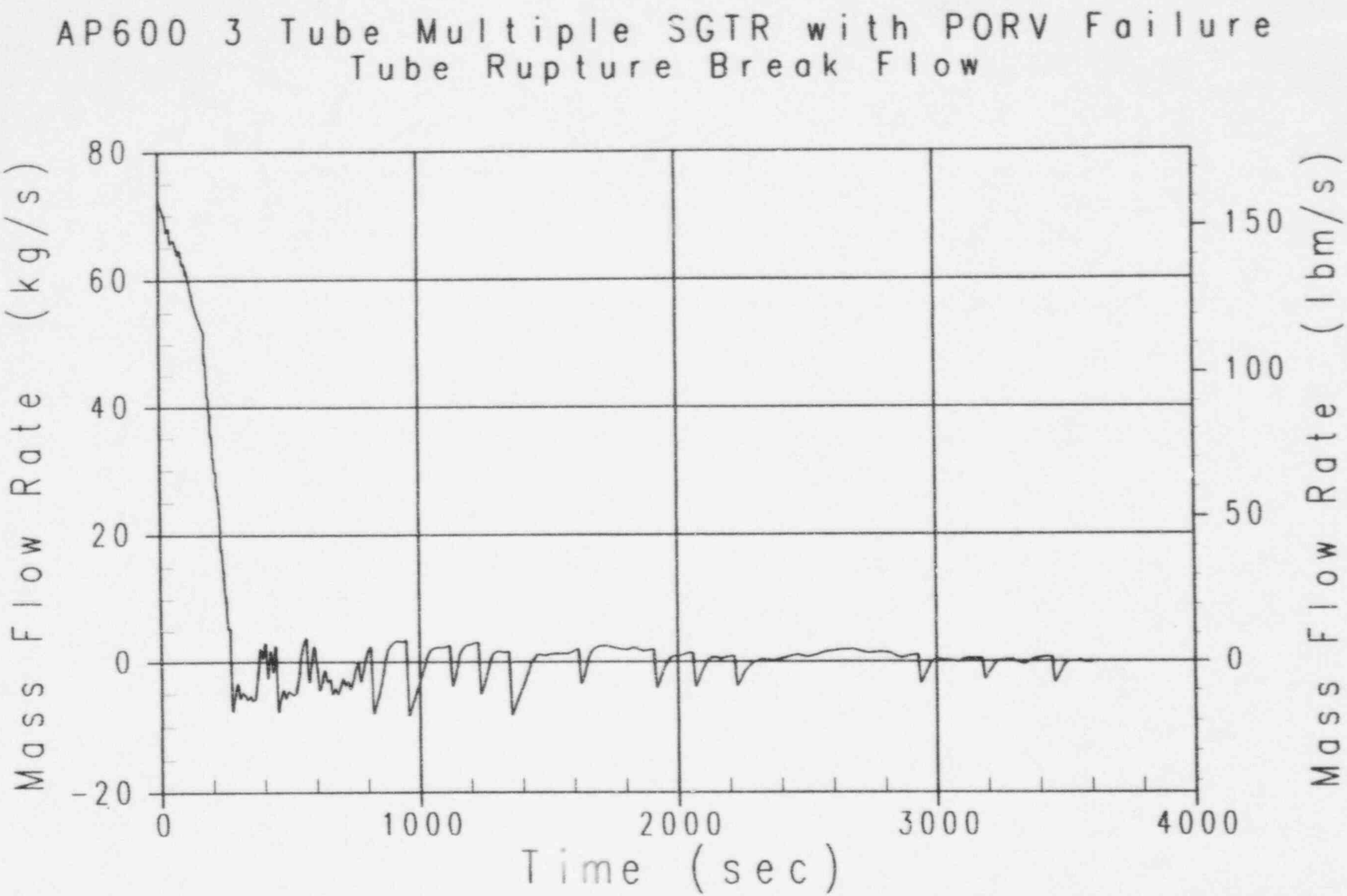

AP600 3 Tube Multiple SGTR with PORV Failure
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
80
60
40
20
0
-20
150
100
50
0
0
1000
2000
3000
4000

Figure 101

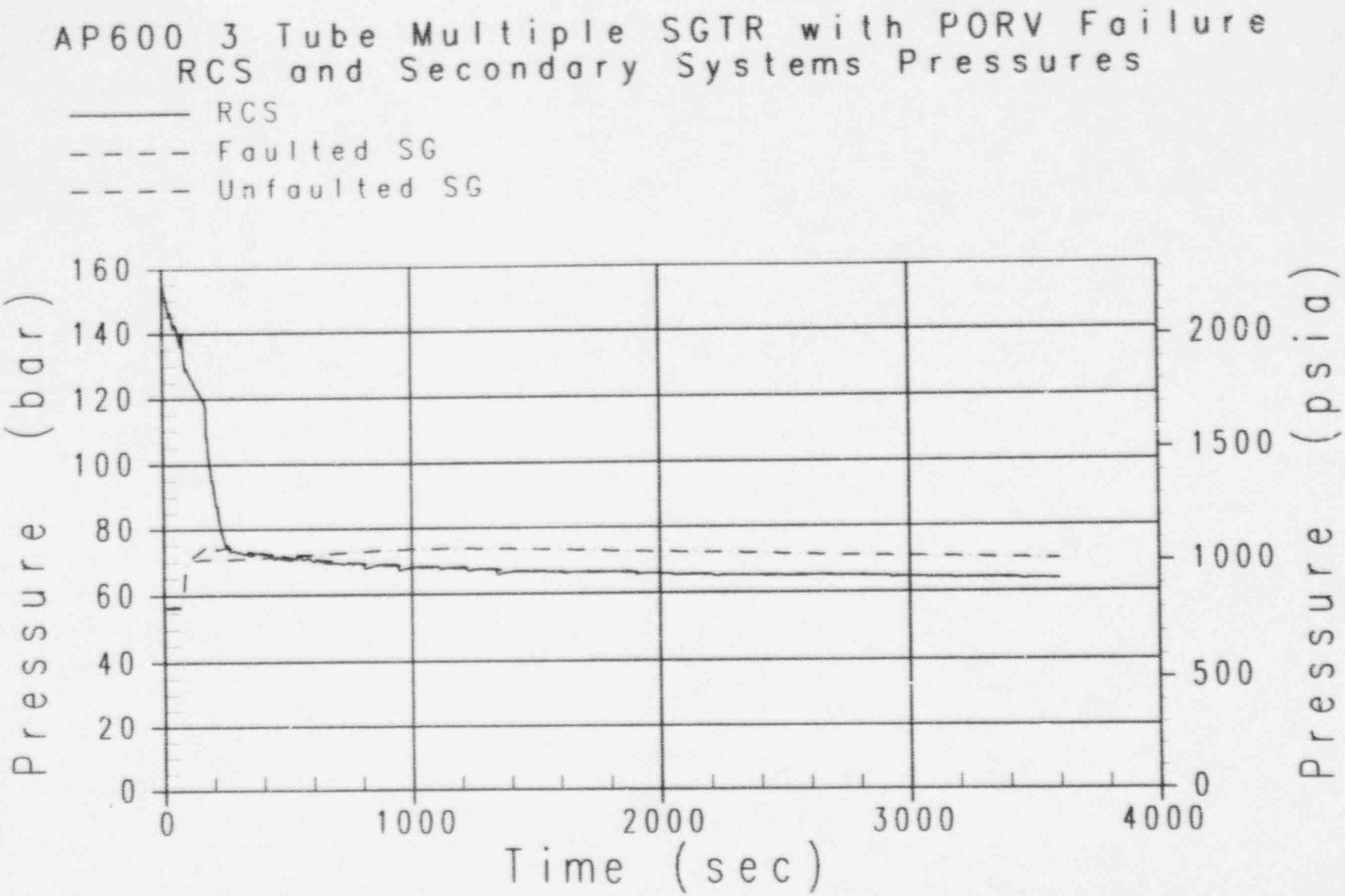

AP600 3 Tube Multiple SGTR with PORV Failure
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
160
140
120
100
80
60
40
20
0
Pressure (psia)
2000
1500
1000
500
0
0
1000
2000
3000
4000
Time (sec)

Figure 102

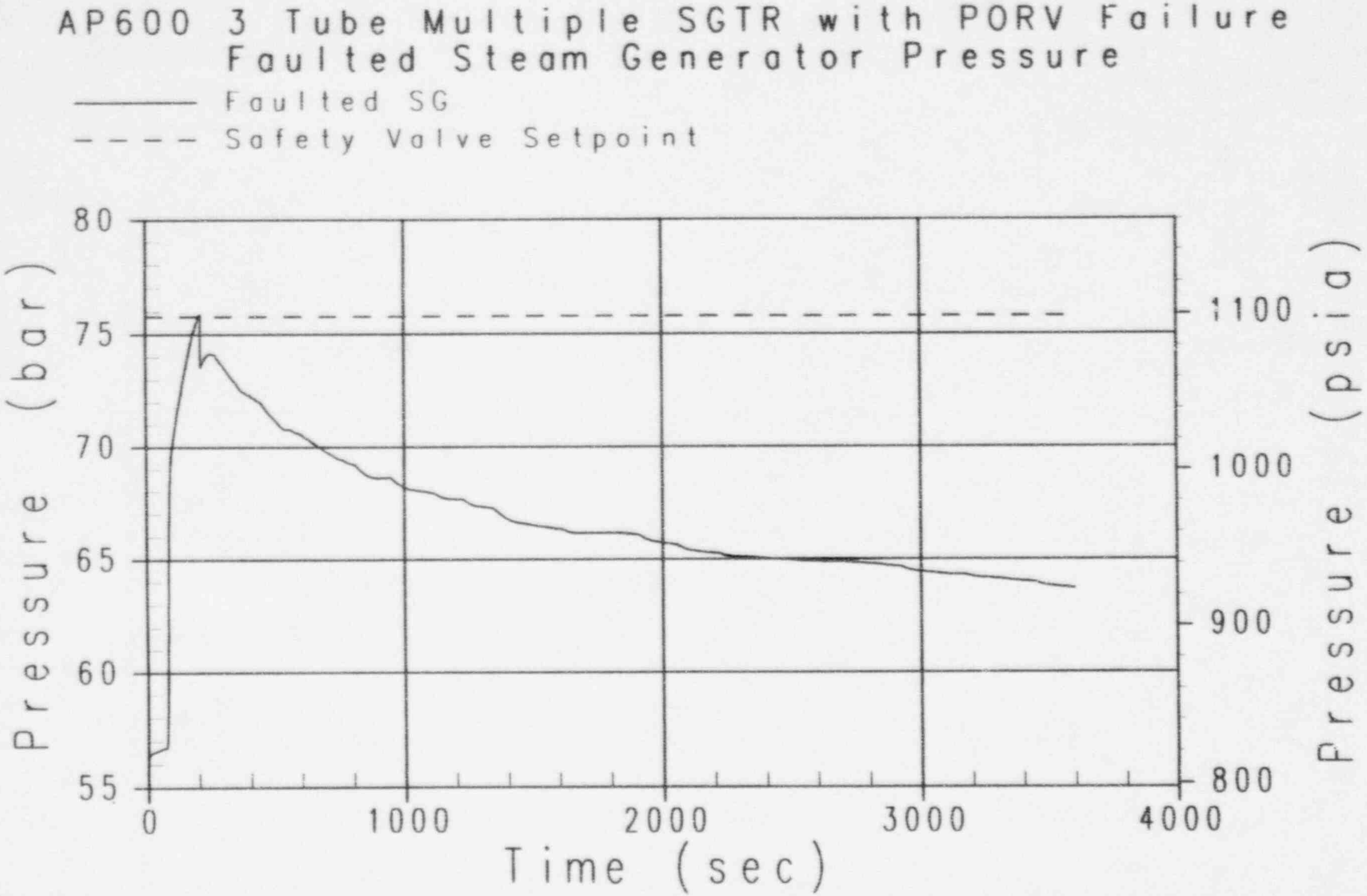
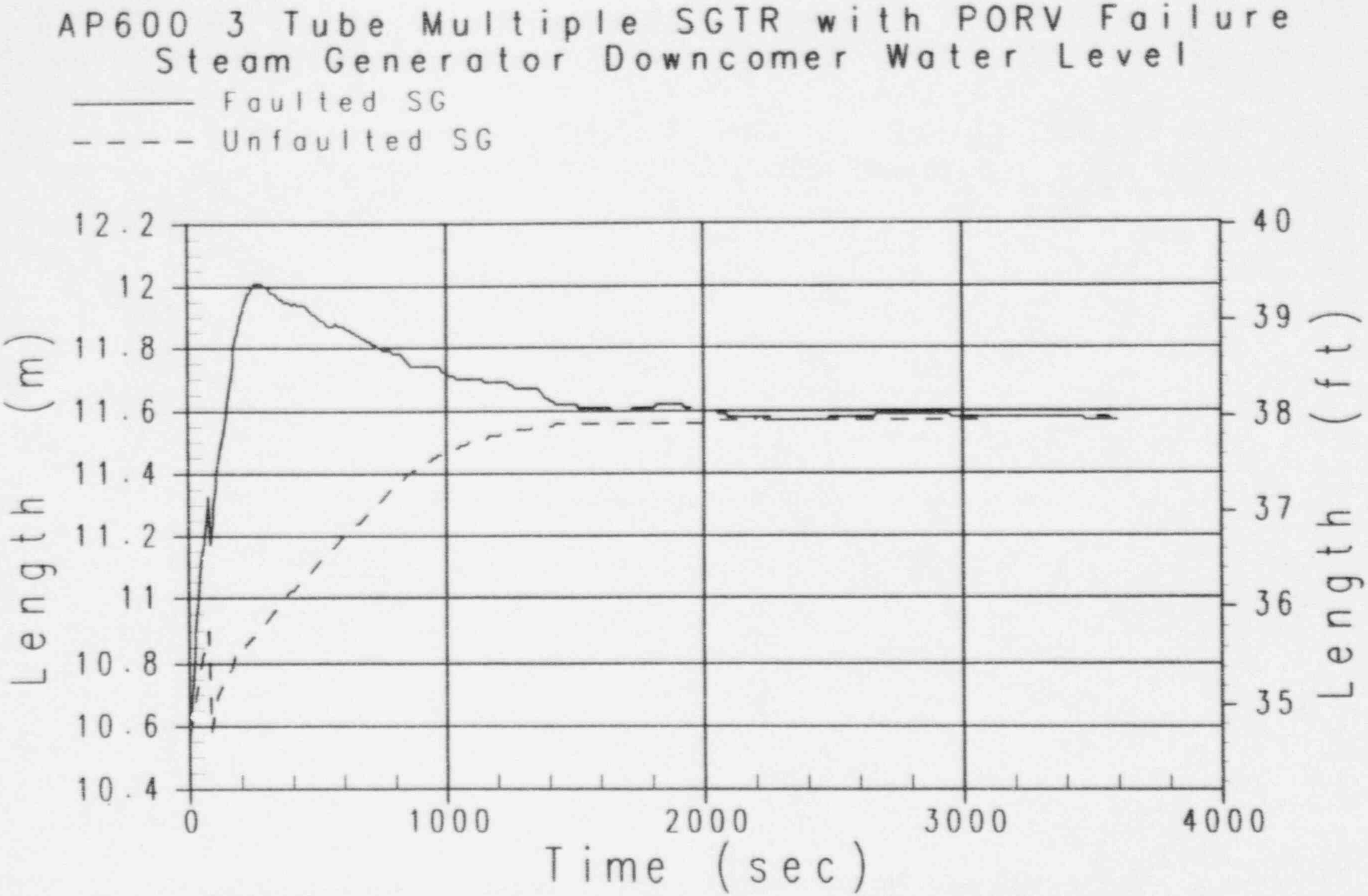

AP600 3 Tube Multiple SGTR with PORV Failure
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
Pressure (bar)
Pressure (psia)
Time (sec)
80
75
70
65
60
55
1100
1000
900
800
0
1000
2000
3000
4000

Figure 103



AP600 3 Tube Multiple SGTR with PORV Failure
Steam Generator Downcomer Water Level
Faulted SG
Unfaulted SG
Length (m)
Length (ft)
Time (sec)
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
40
39
38
37
36
35
0
1000
2000
3000
4000

Figure 104

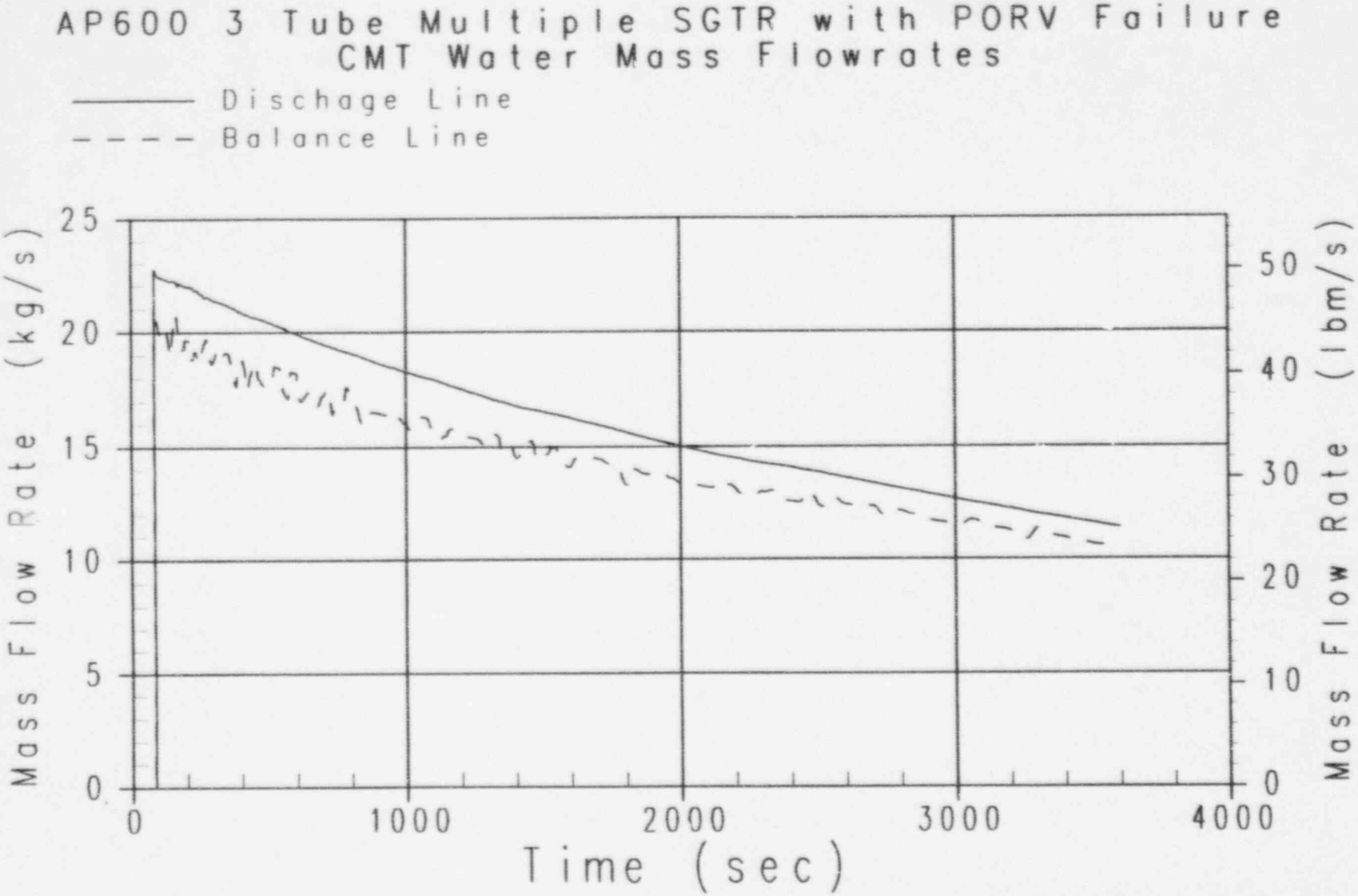

AP600 3 Tube Multiple SGTR with PORV Failure
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
5
10
15
20
25
0
10
20
30
40
50
0
1000
2000
3000
4000

Figure 105

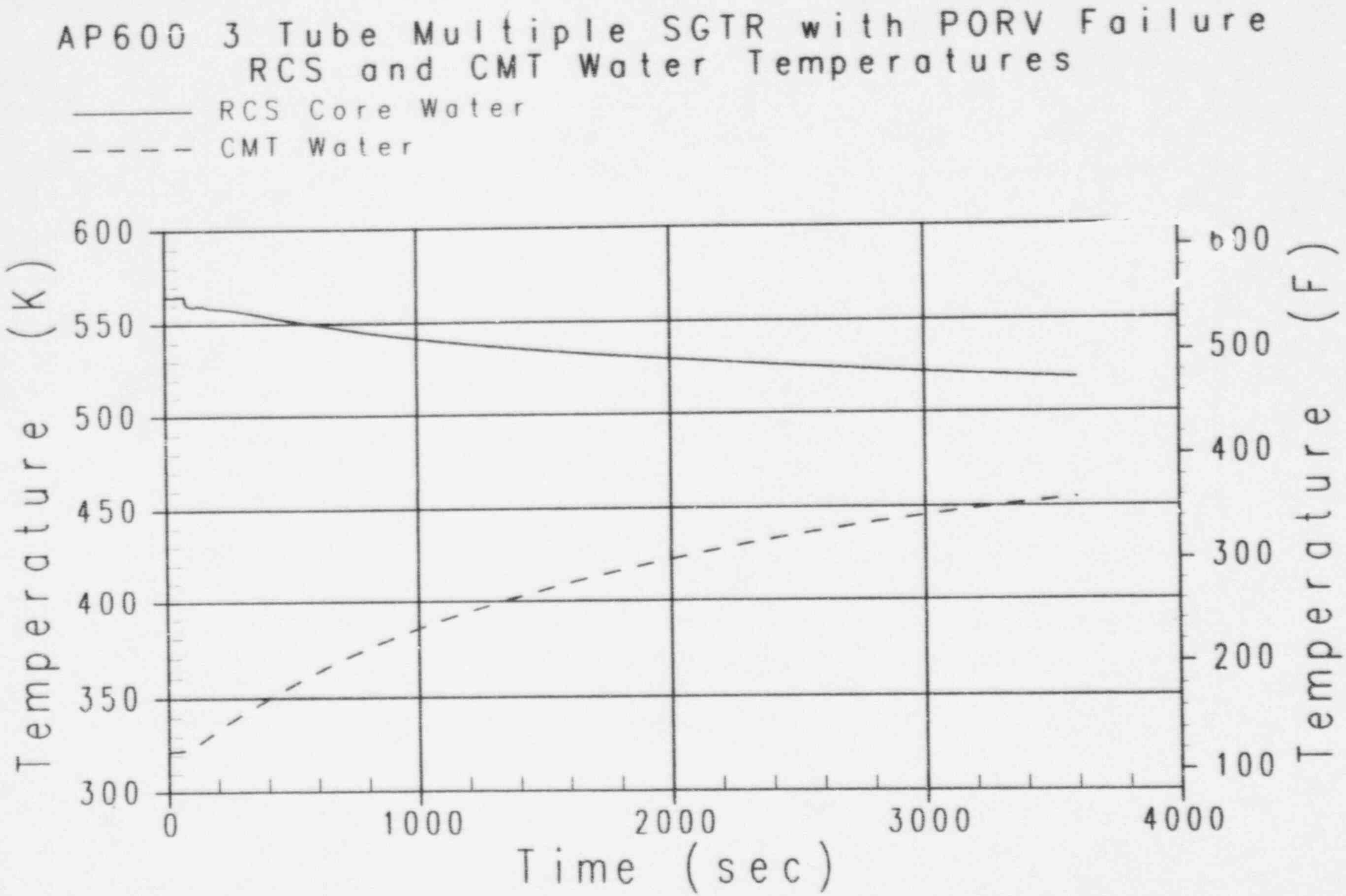

AP600 3 Tube Multiple SGTR with PORV Failure
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
Temperature (K)
Temperature (F)
Time (sec)
600
550
500
450
400
350
300
600
500
400
300
200
100
0
1000
2000
3000
4000

Figure 106

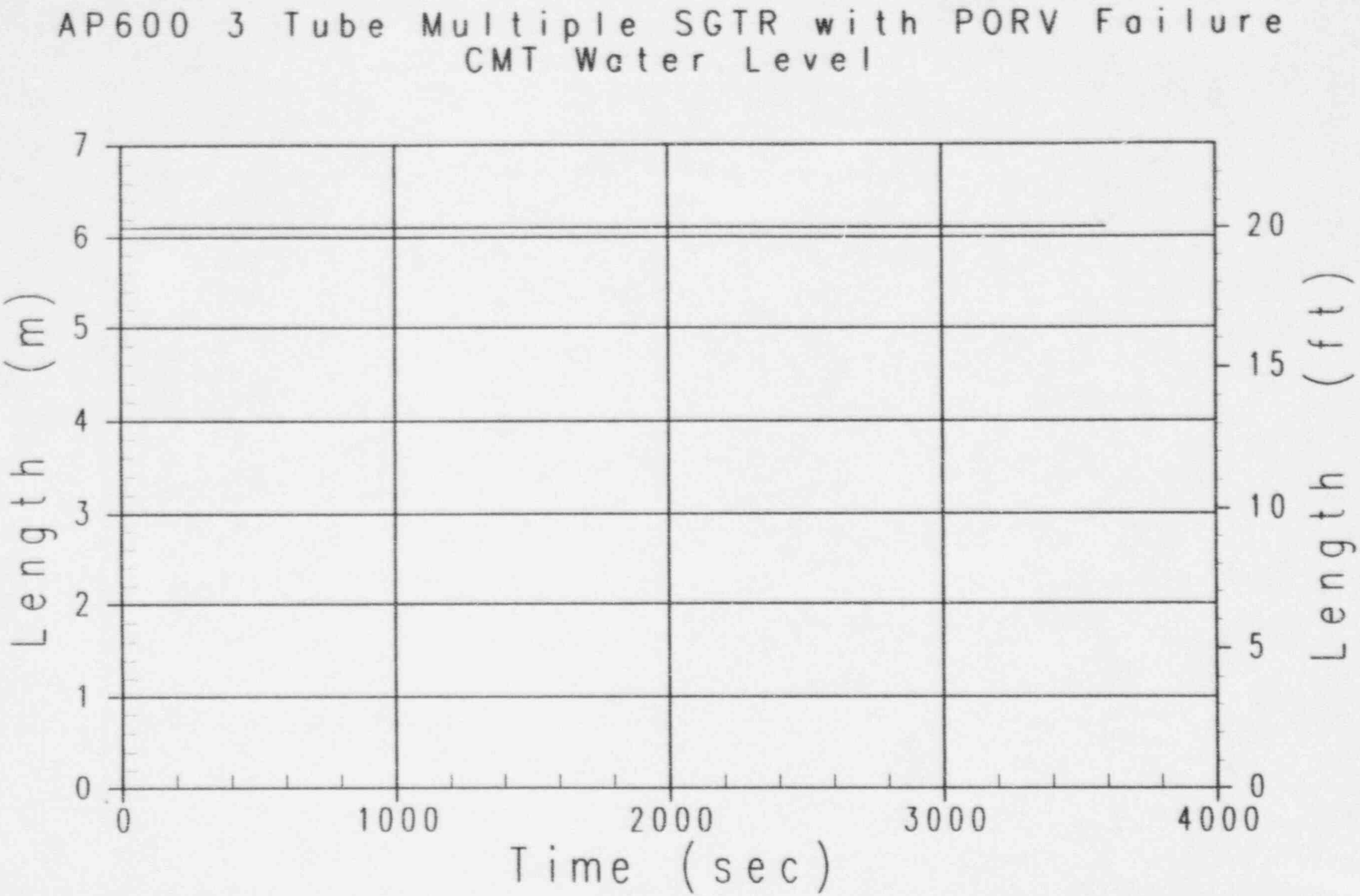
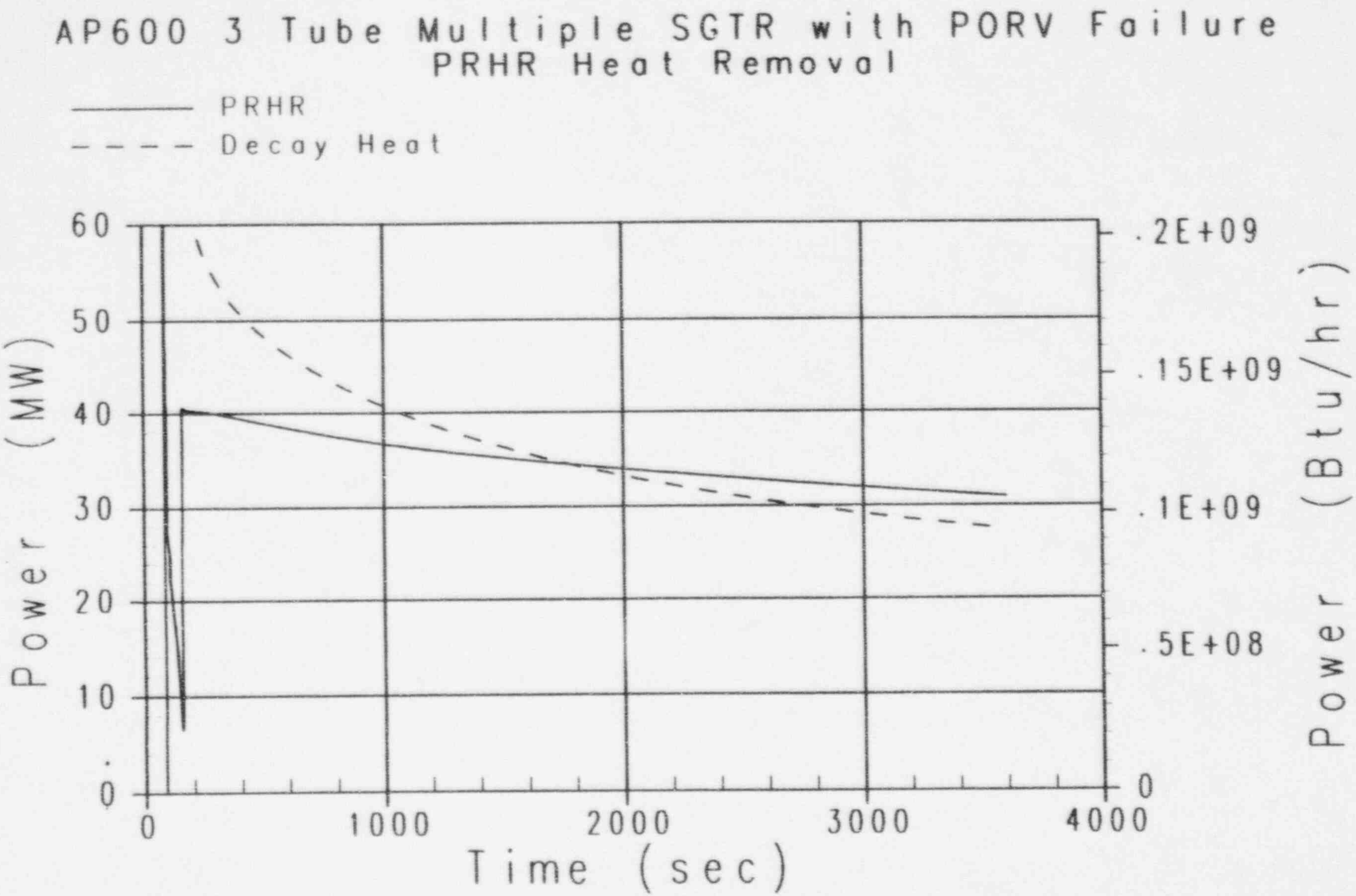
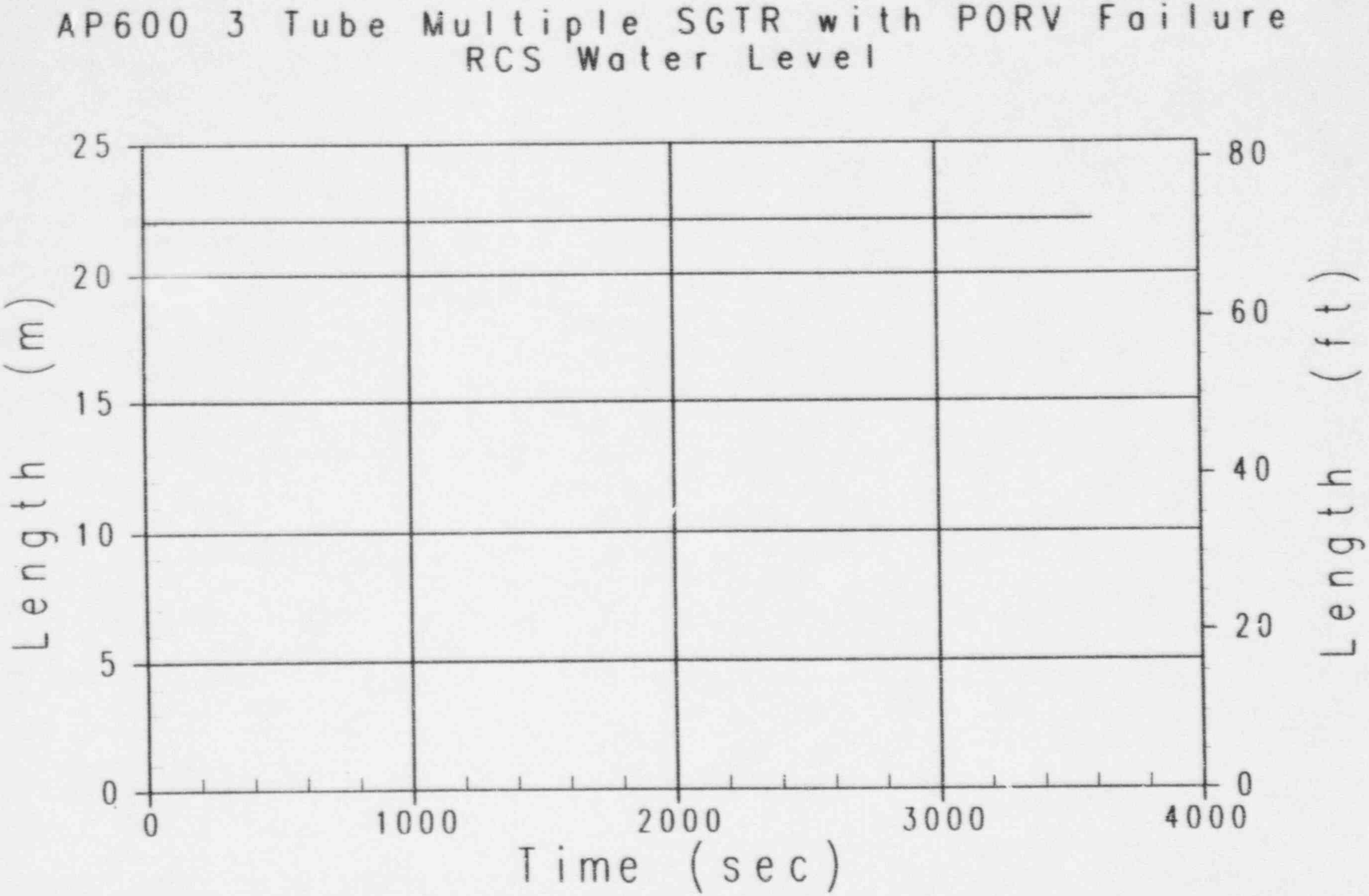

AP600 3 Tube Multiple SGTR with PORV Failure
CMT Water Level
Length (m)
Length (ft)
Time (sec)
0
1
2
3
4
5
6
7
0
5
10
15
20
0
1000
2000
3000
4000

Figure 107



AP600 3 Tube Multiple SGTR with PORV Failure
PRHR Heat Removal
PRHR
Decay Heat
Power (MW)
Power (Btu/hr)
Time (sec)
0
10
20
30
40
50
60
0
1000
2000
3000
4000
.2E+09
.15E+09
.1E+09
.5E+08

Figure 108



AP600 3 Tube Multiple SGTR with PORV Failure
RCS Water Level
Length (m)
25
20
15
10
5
0
0
1000
2000
3000
4000
Time (sec)
80
60
40
20
0
Length (ft)

Figure 109

AP600 4 Tube Multiple SGTR with PORV Failure
Tube Rupture Break Flow

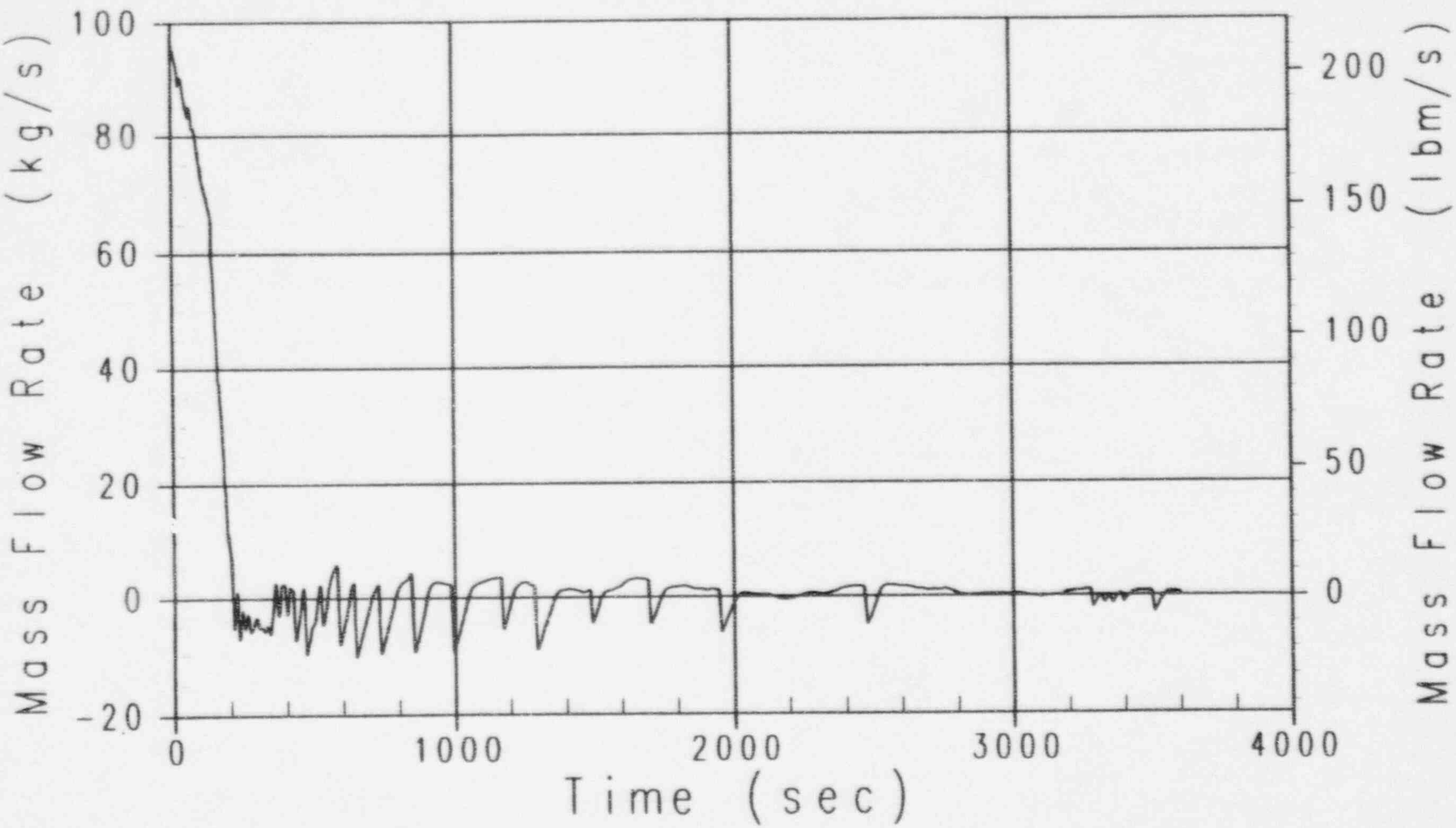


Figure 110

AP600 4 Tube Multiple SGTR with PORV Failure
RCS and Secondary Systems Pressures

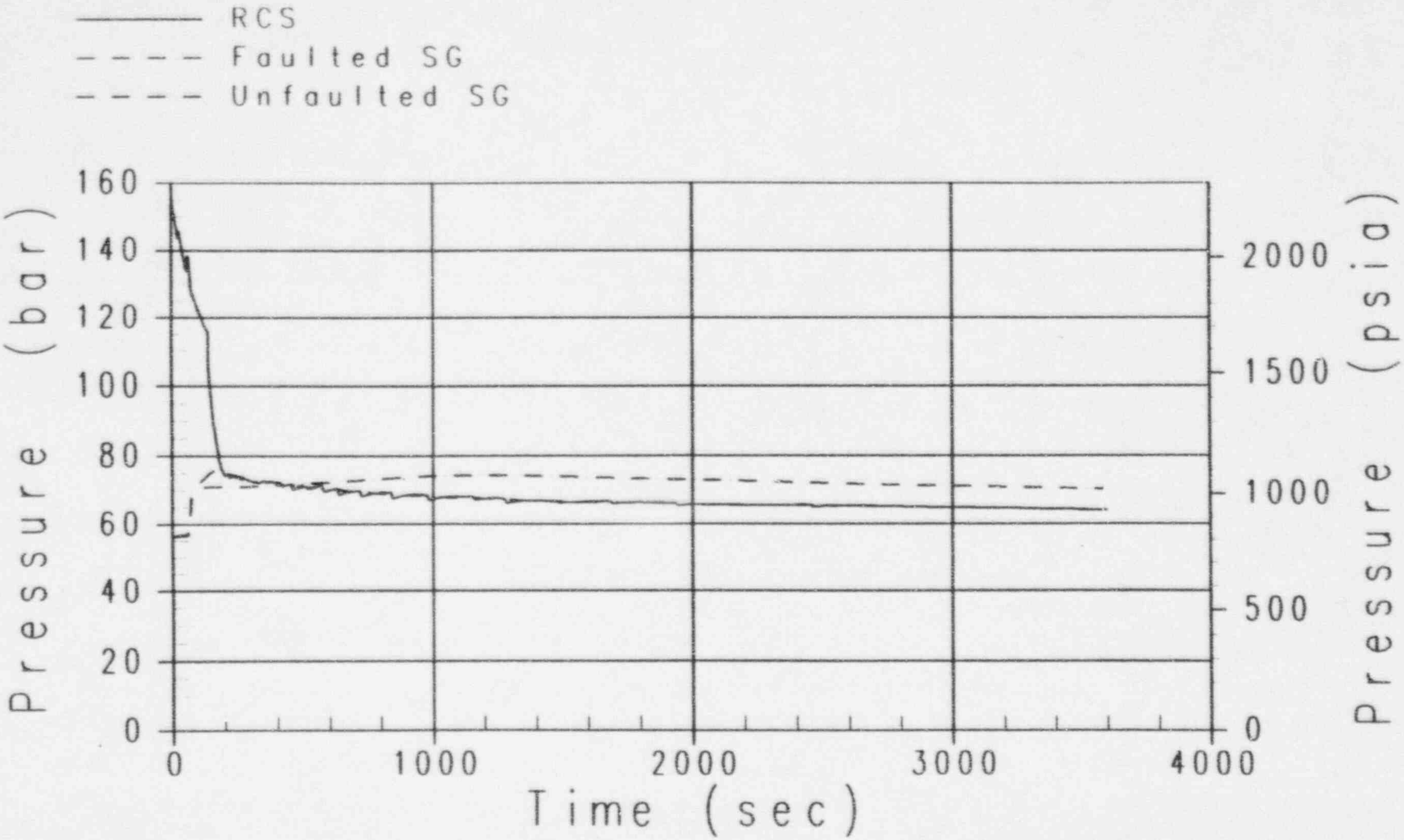


Figure 111

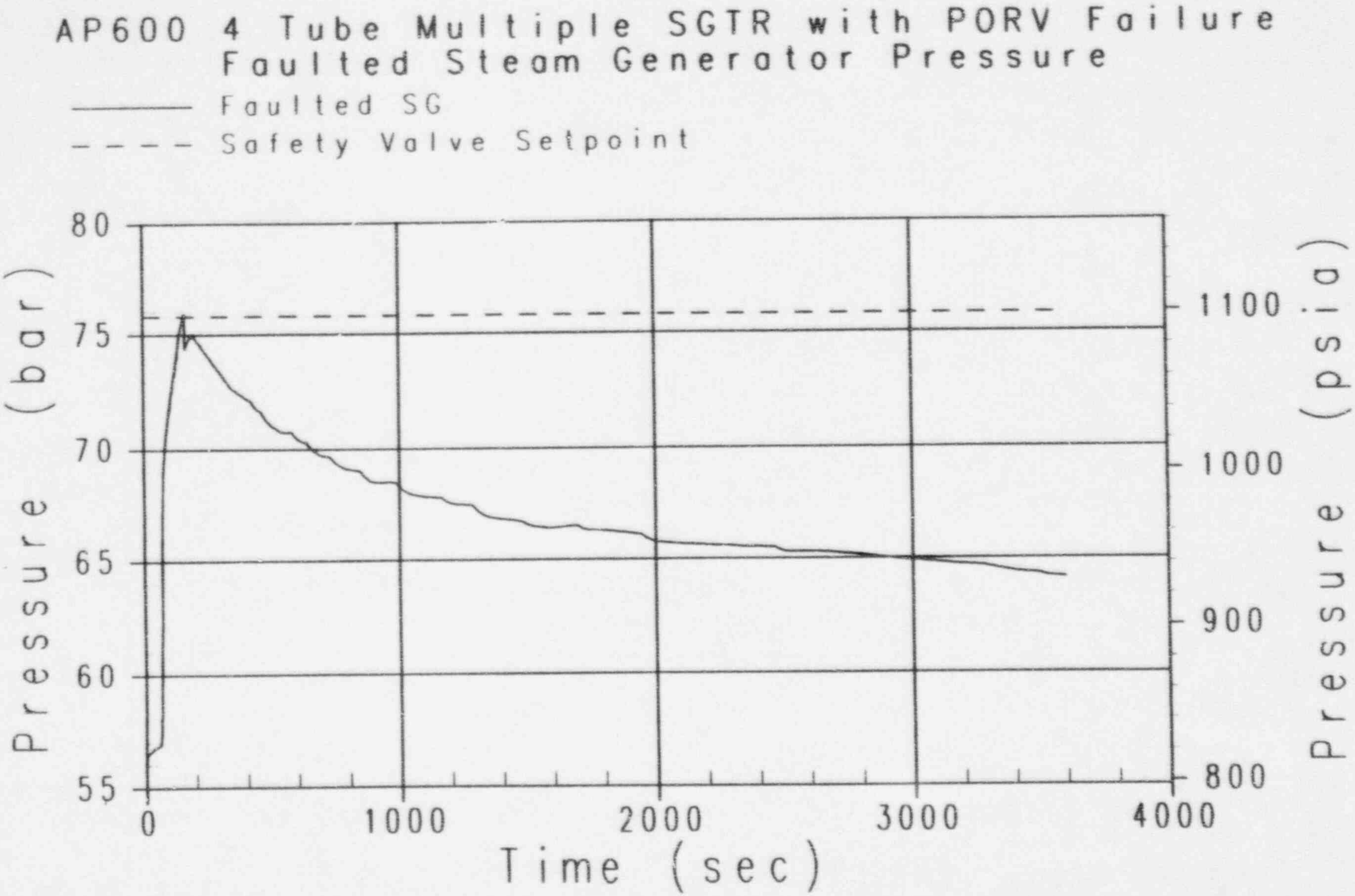

AP600 4 Tube Multiple SGTR with PORV Failure
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
Pressure (bar)
Pressure (psia)
Time (sec)
80
75
70
65
60
55
1100
1000
900
800
0
1000
2000
3000
4000

Figure 112

AP600 4 Tube Multiple SGTR with PORV Failure
Steam Generator Downcomer Water Level

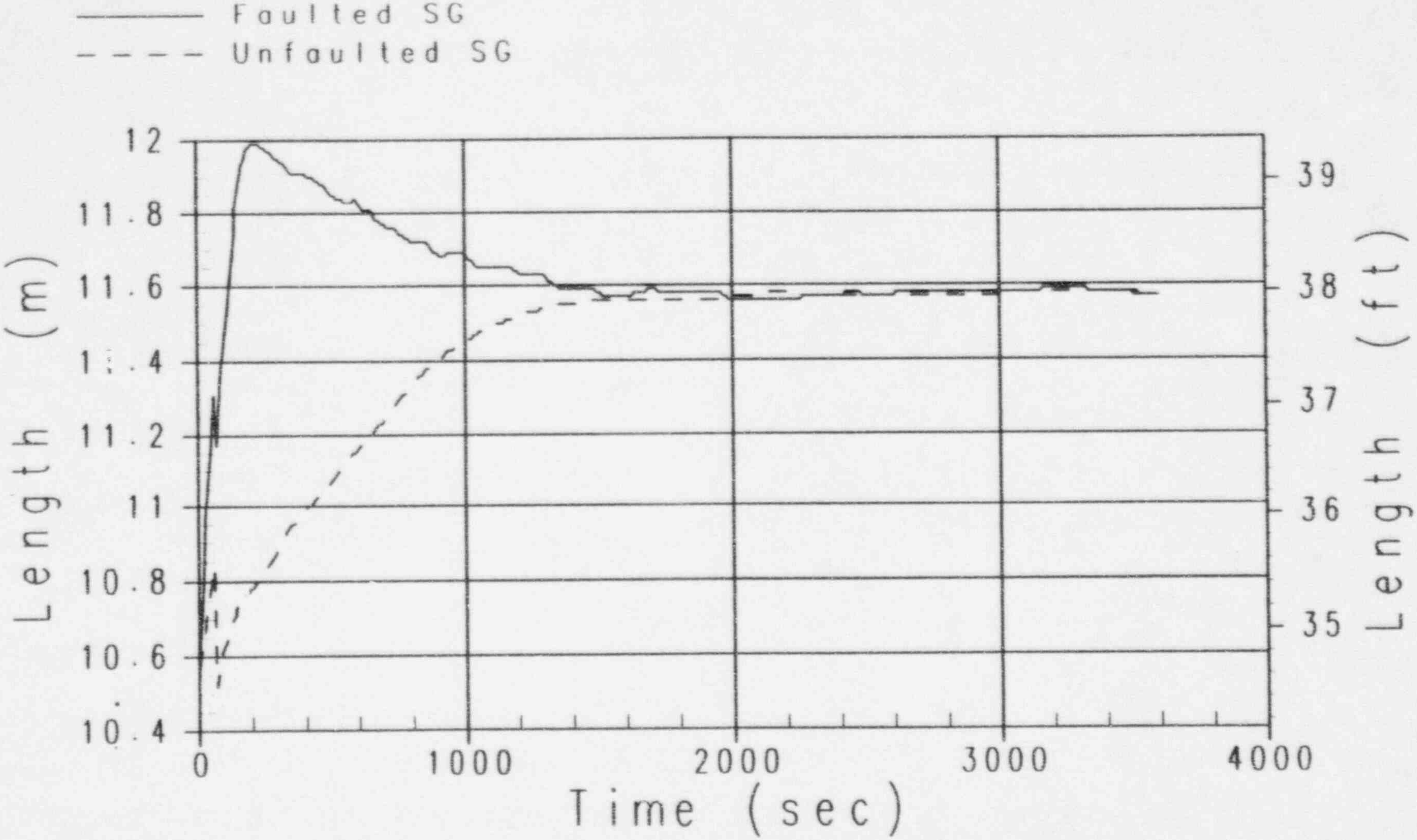


Figure 113

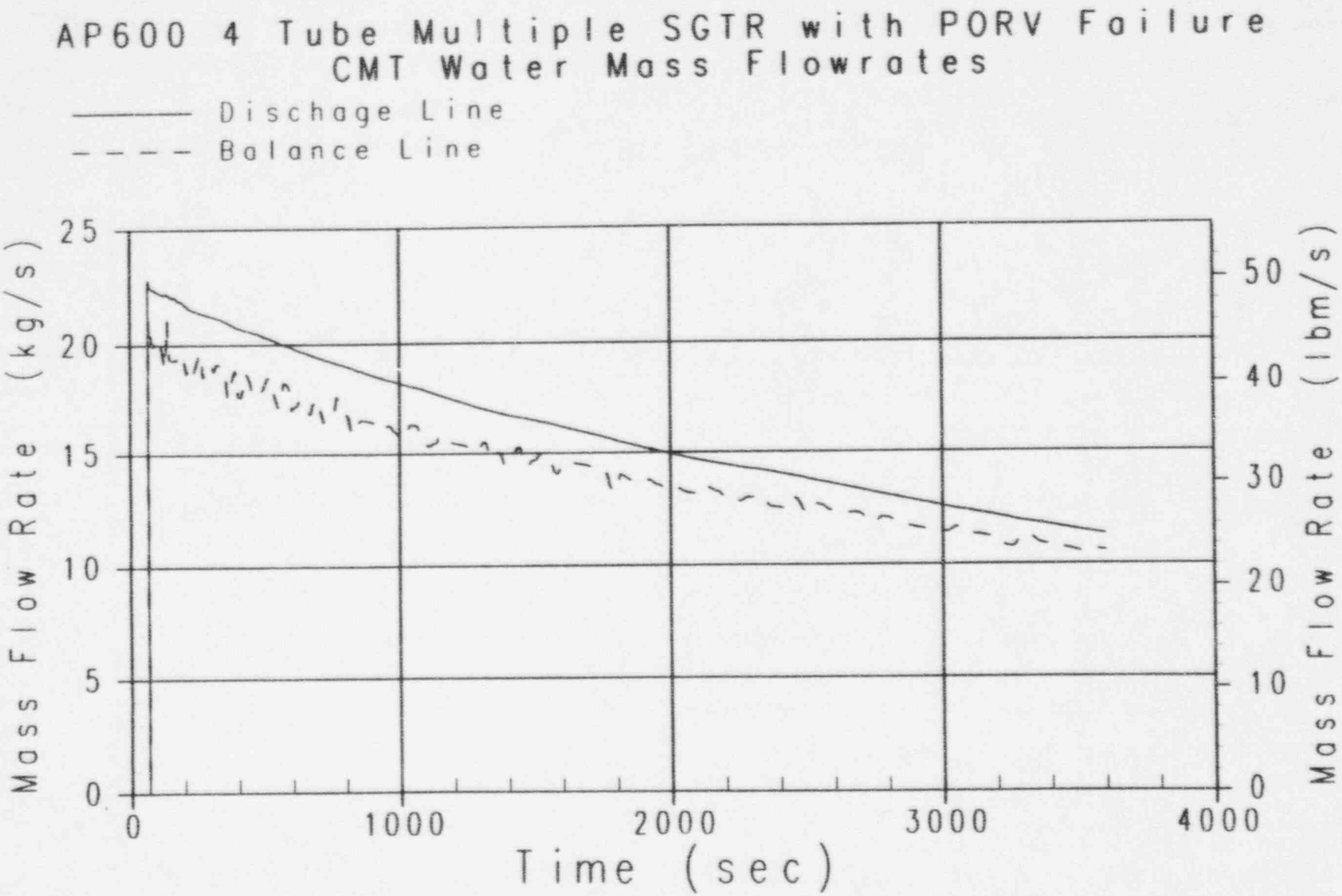

AP600 4 Tube Multiple SGTR with PORV Failure
CMT Water Mass Flowrates
Dischage Line
Balance Line
Mass Flow Rate (kg/s)
Mass Flow Rate (lbm/s)
Time (sec)
0
5
10
15
20
25
0
10
20
30
40
50
0
1000
2000
3000
4000

Figure 114

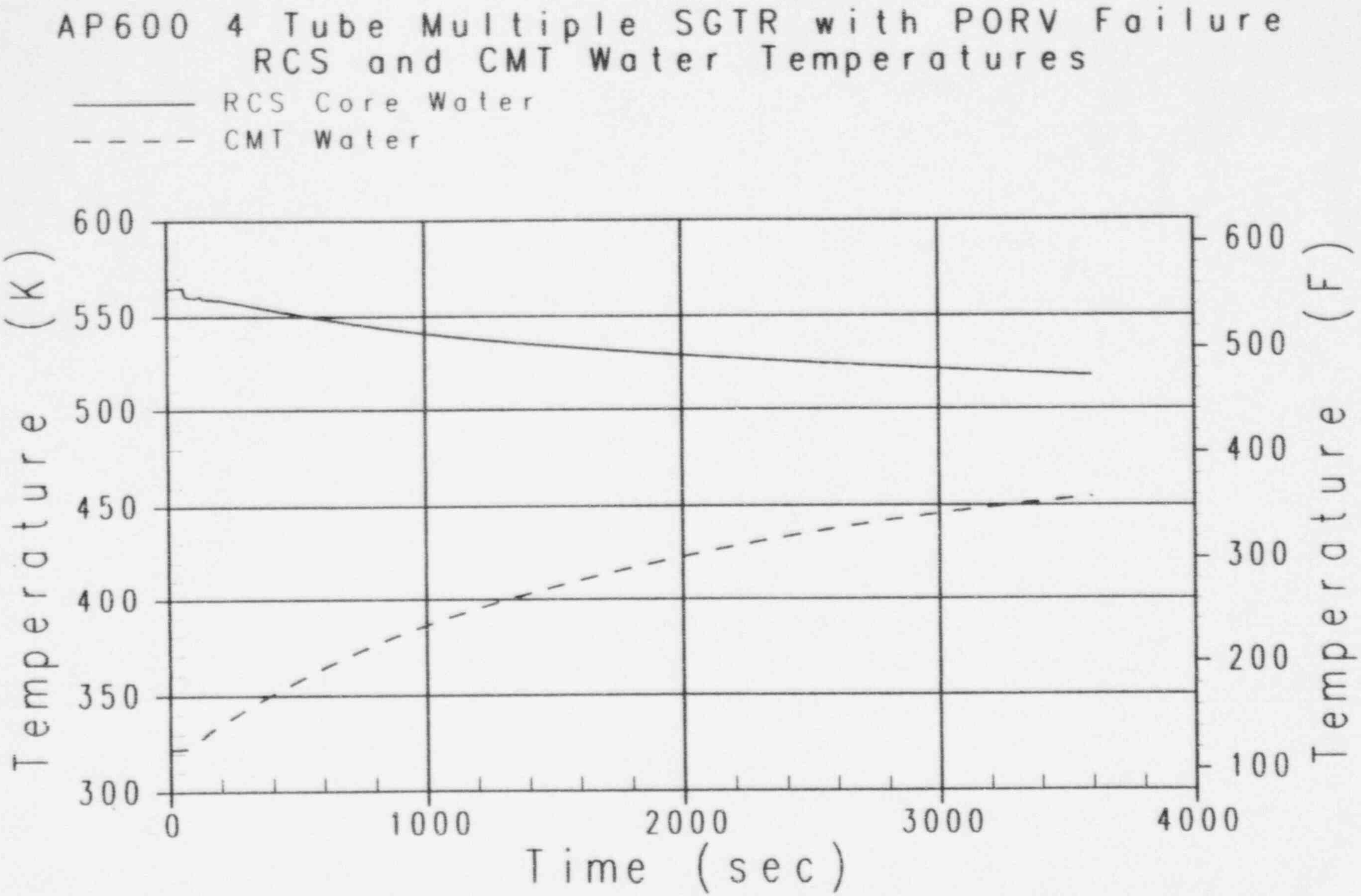

AP600 4 Tube Multiple SGTR with PORV Failure
RCS and CMT Water Temperatures
RCS Core Water
CMT Water
Temperature (K)
Temperature (F)
Time (sec)
600
550
500
450
400
350
300
600
500
400
300
200
100
0
1000
2000
3000
4000

Figure 115

AP600 4 Tube Multiple SGTR with PORV Failure
CMT Water Level

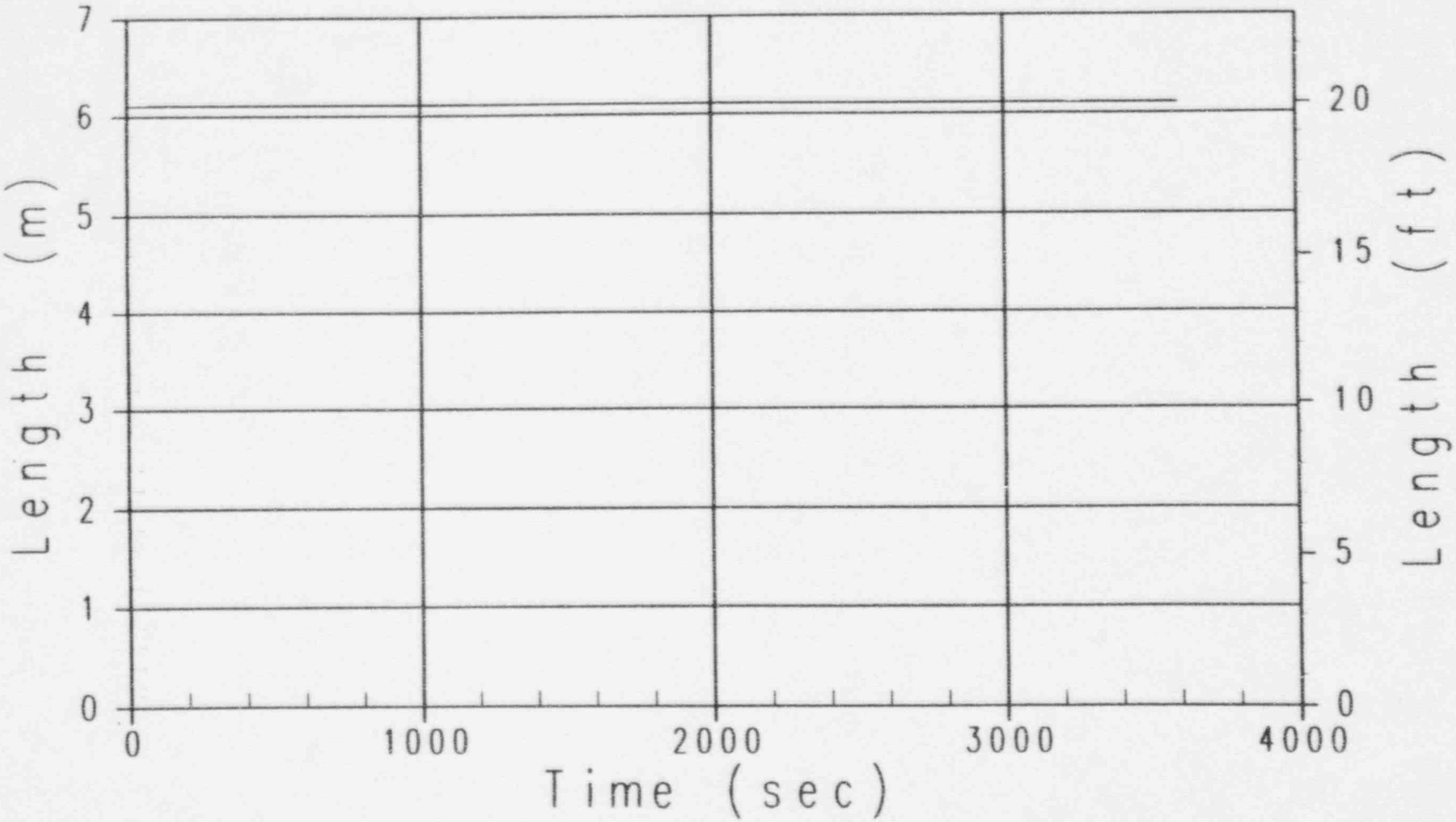
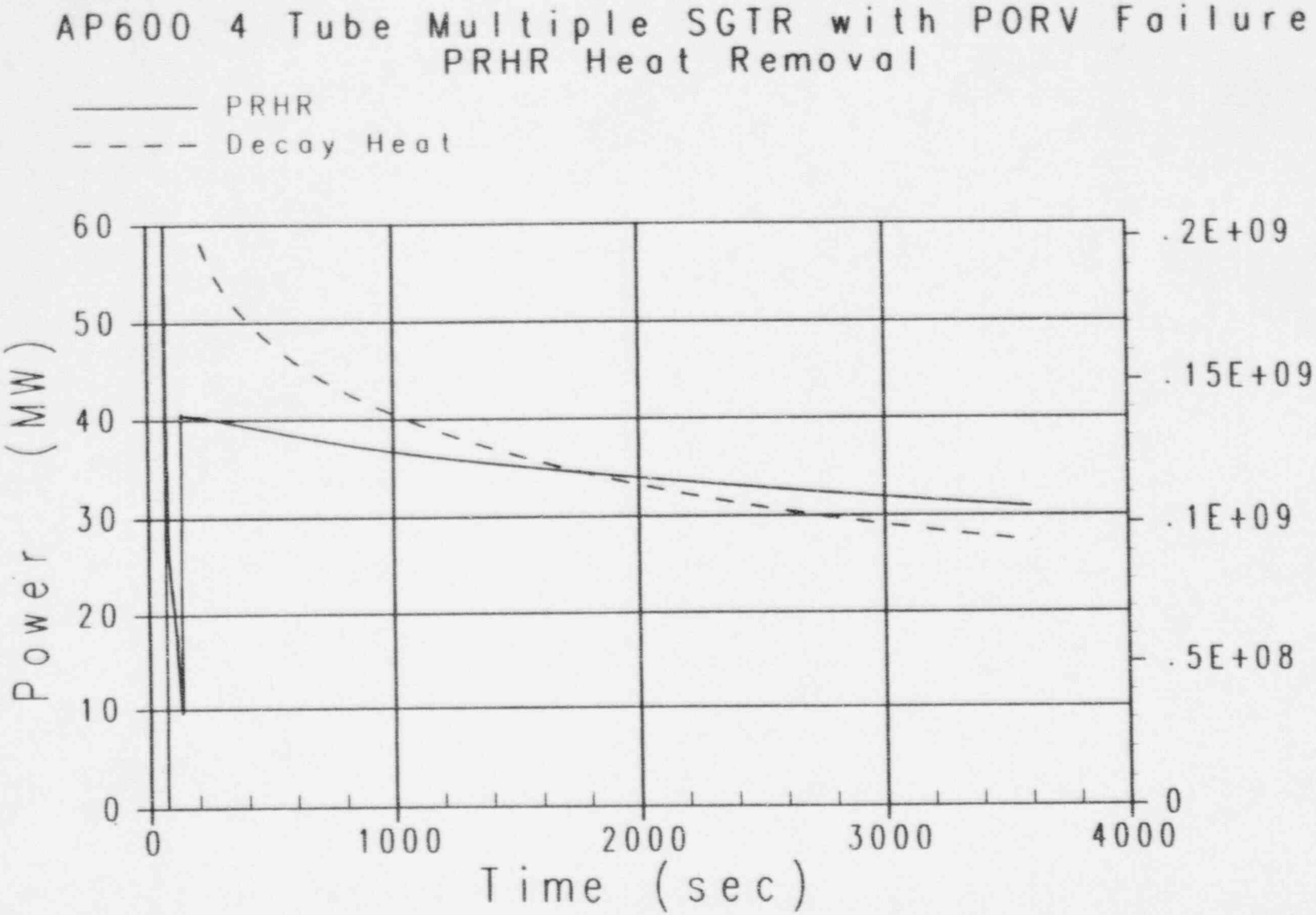


Figure 116



AP600 4 Tube Multiple SGTR with PORV Failure
PRHR Heat Removal
PRHR
Decay Heat
60
50
40
30
20
10
0
Power (MW)
0
1000
2000
3000
4000
Time (sec)
.2E+09
.15E+09
.1E+09
.5E+08
0
Power (Btu/hr)

Figure 117

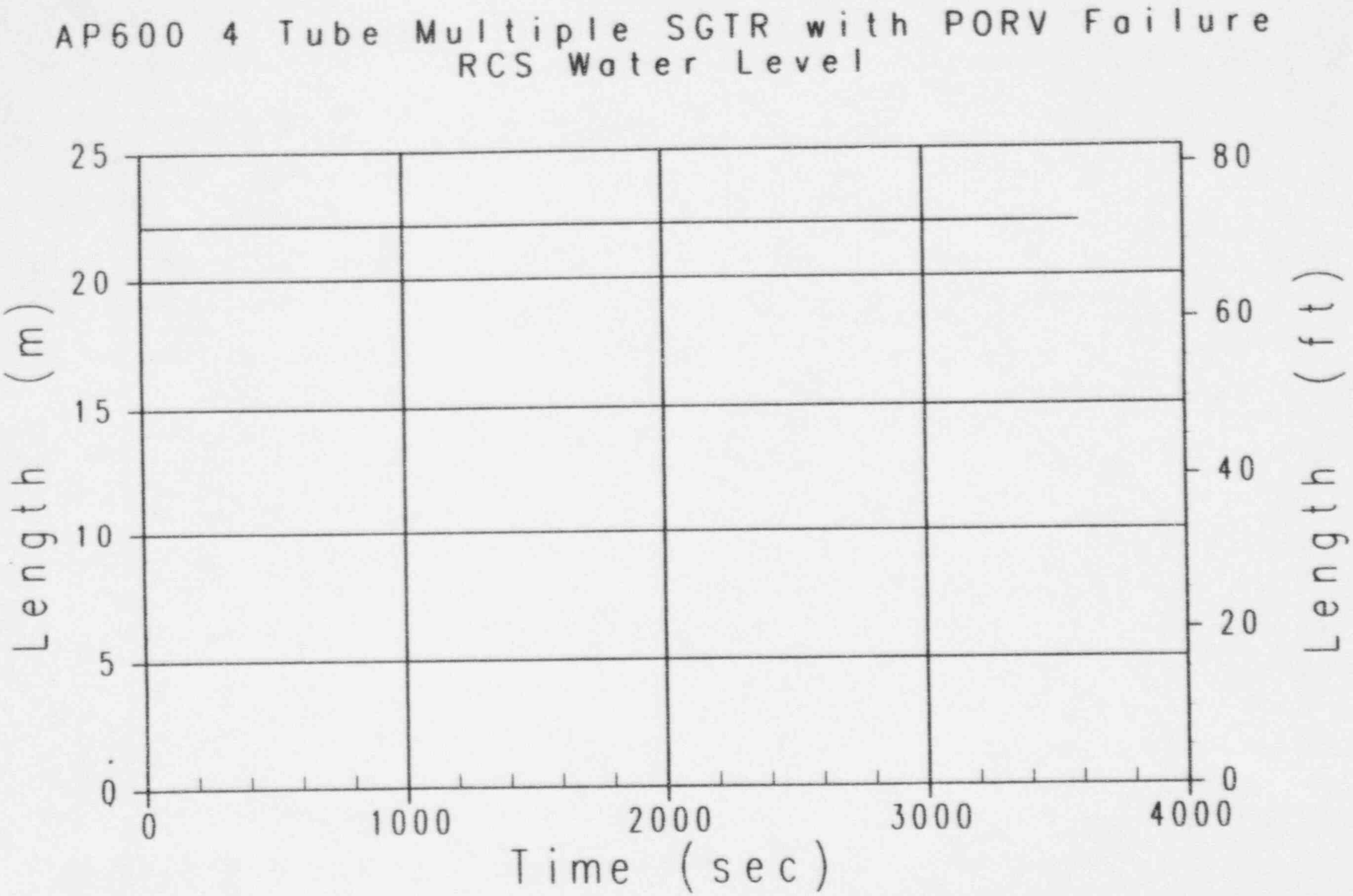

AP600 4 Tube Multiple SGTR with PORV Failure
RCS Water Level
Length (m)
Length (ft)
Time (sec)
0
5
10
15
20
25
0
20
40
60
80
0
1000
2000
3000
4000

Figure 118

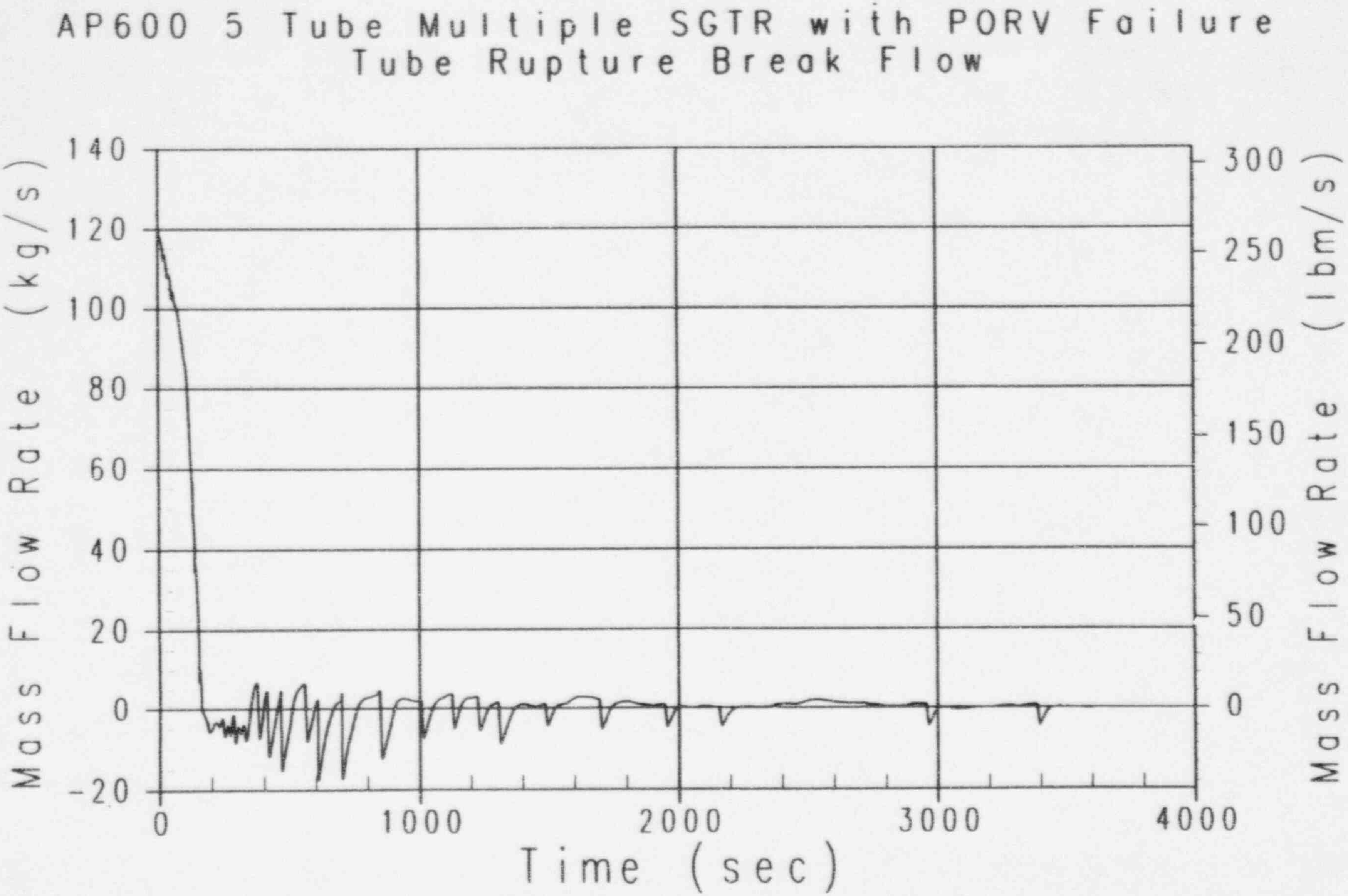

AP600 5 Tube Multiple SGTR with PORV Failure
Tube Rupture Break Flow
Mass Flow Rate (kg/s)
140
120
100
80
60
40
20
0
-20
Mass Flow Rate (lbm/s)
300
250
200
150
100
50
0
0
1000
2000
3000
4000
Time (sec)

Figure 119

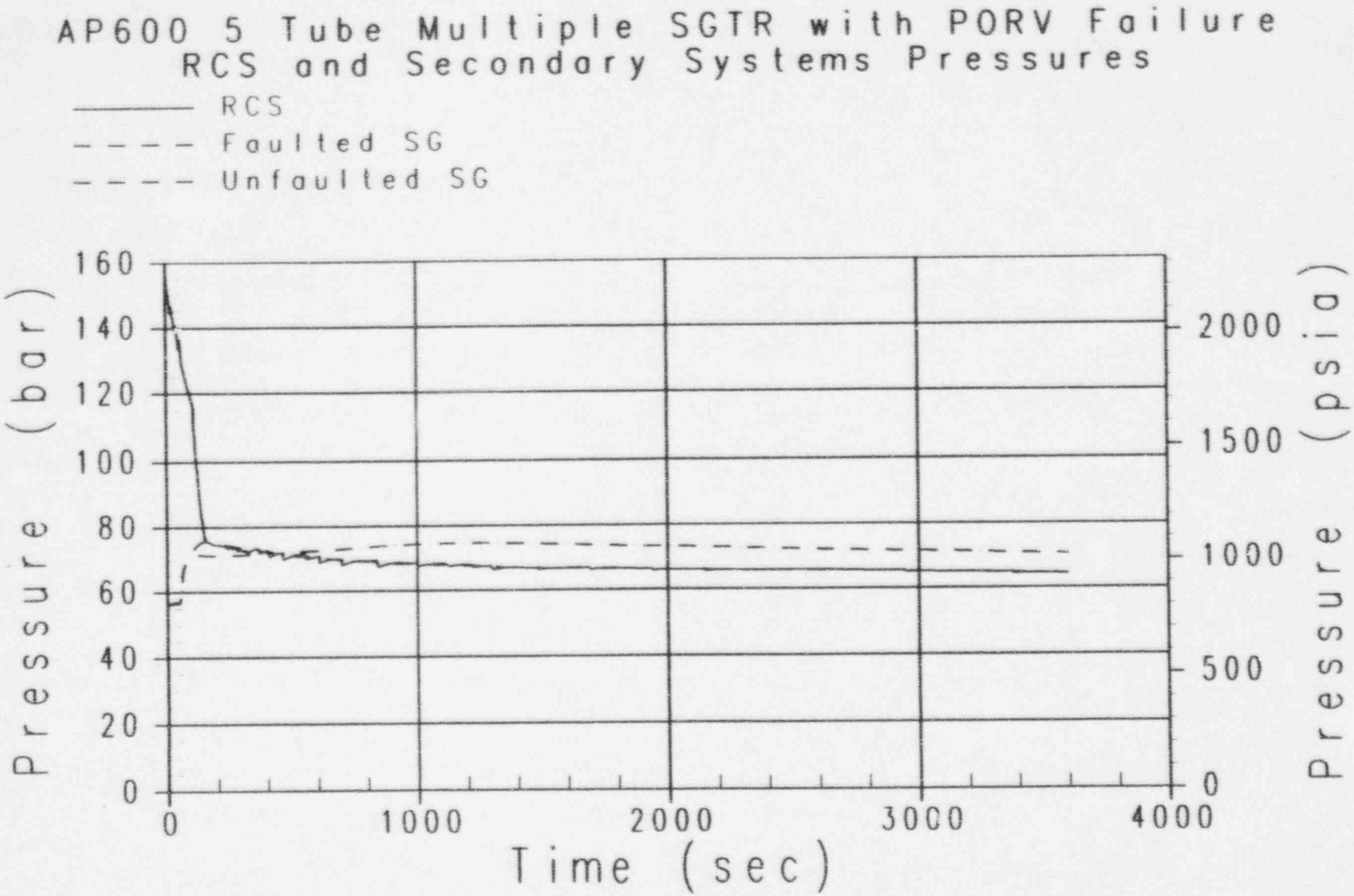

AP600 5 Tube Multiple SGTR with PORV Failure
RCS and Secondary Systems Pressures
RCS
Faulted SG
Unfaulted SG
Pressure (bar)
Pressure (psia)
Time (sec)
0
20
40
60
80
100
120
140
160
0
500
1000
1500
2000
1000
2000
3000
4000

Figure 120

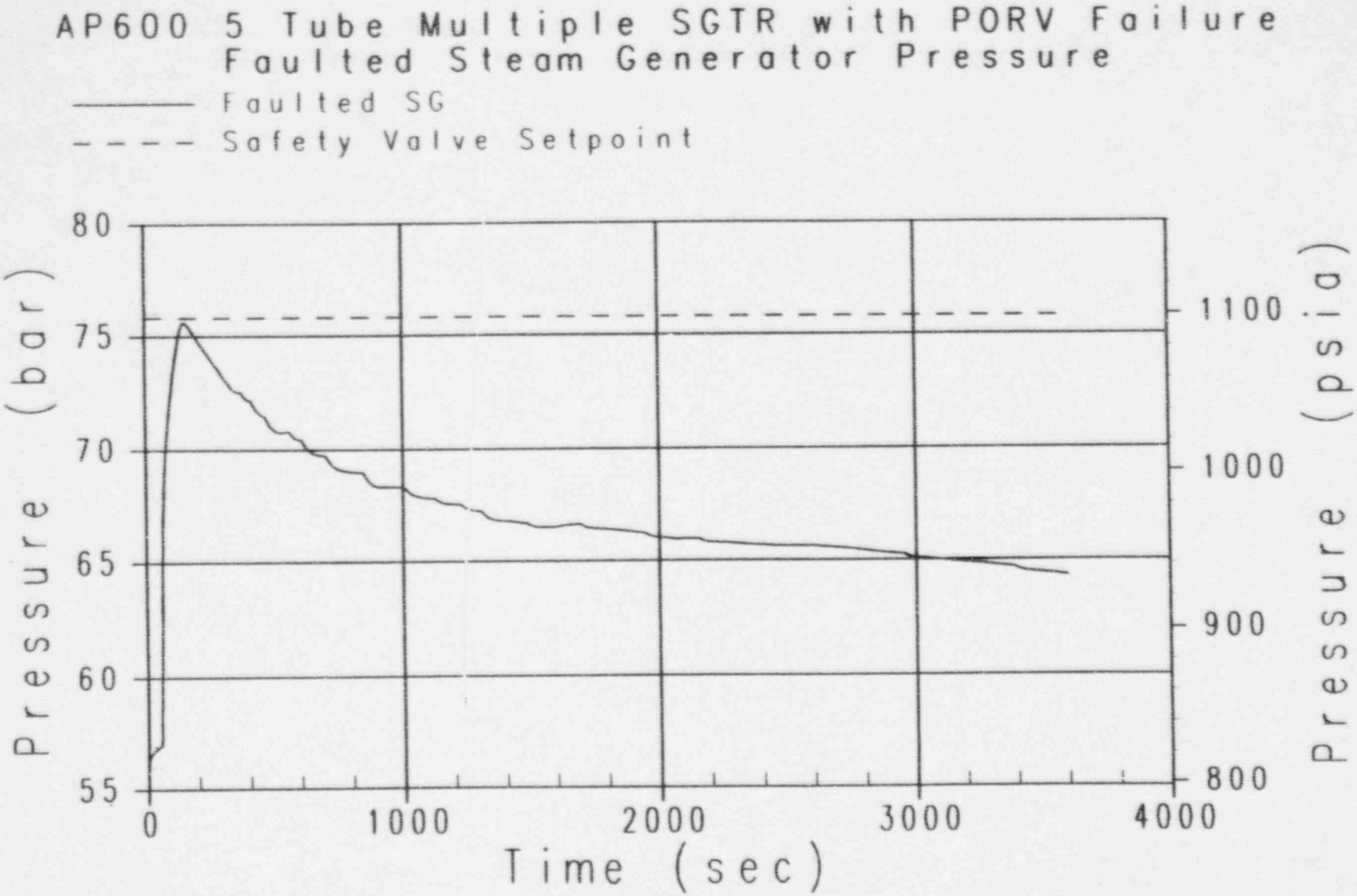

AP600 5 Tube Multiple SGTR with PORV Failure
Faulted Steam Generator Pressure
Faulted SG
Safety Valve Setpoint
Pressure (bar)
Pressure (psia)
Time (sec)
80
75
70
65
60
55
1100
1000
900
800
0
1000
2000
3000
4000

Figure 121

AP600 5 Tube Multiple SGTR with PORV Failure
Steam Generator Downcomer Water Level

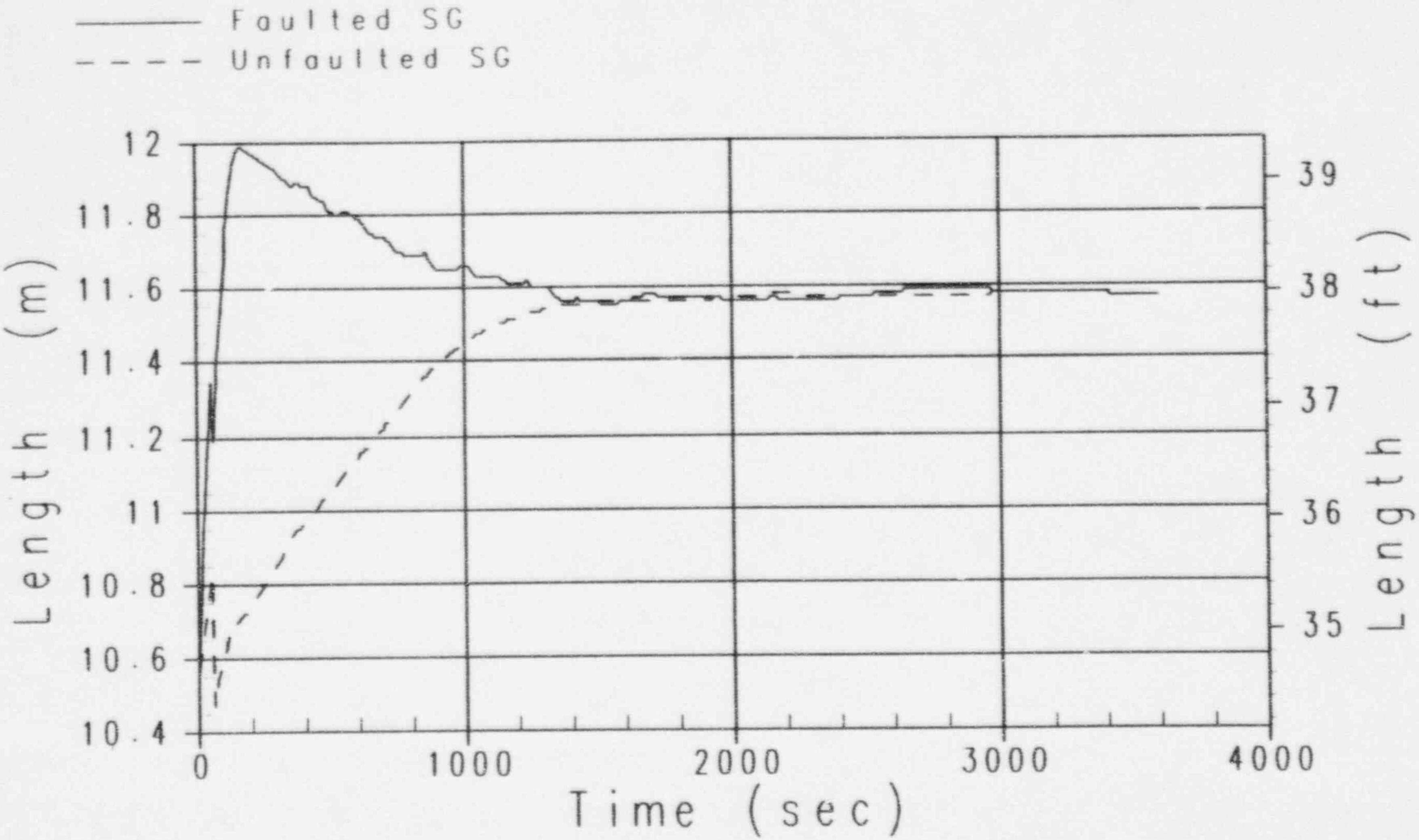
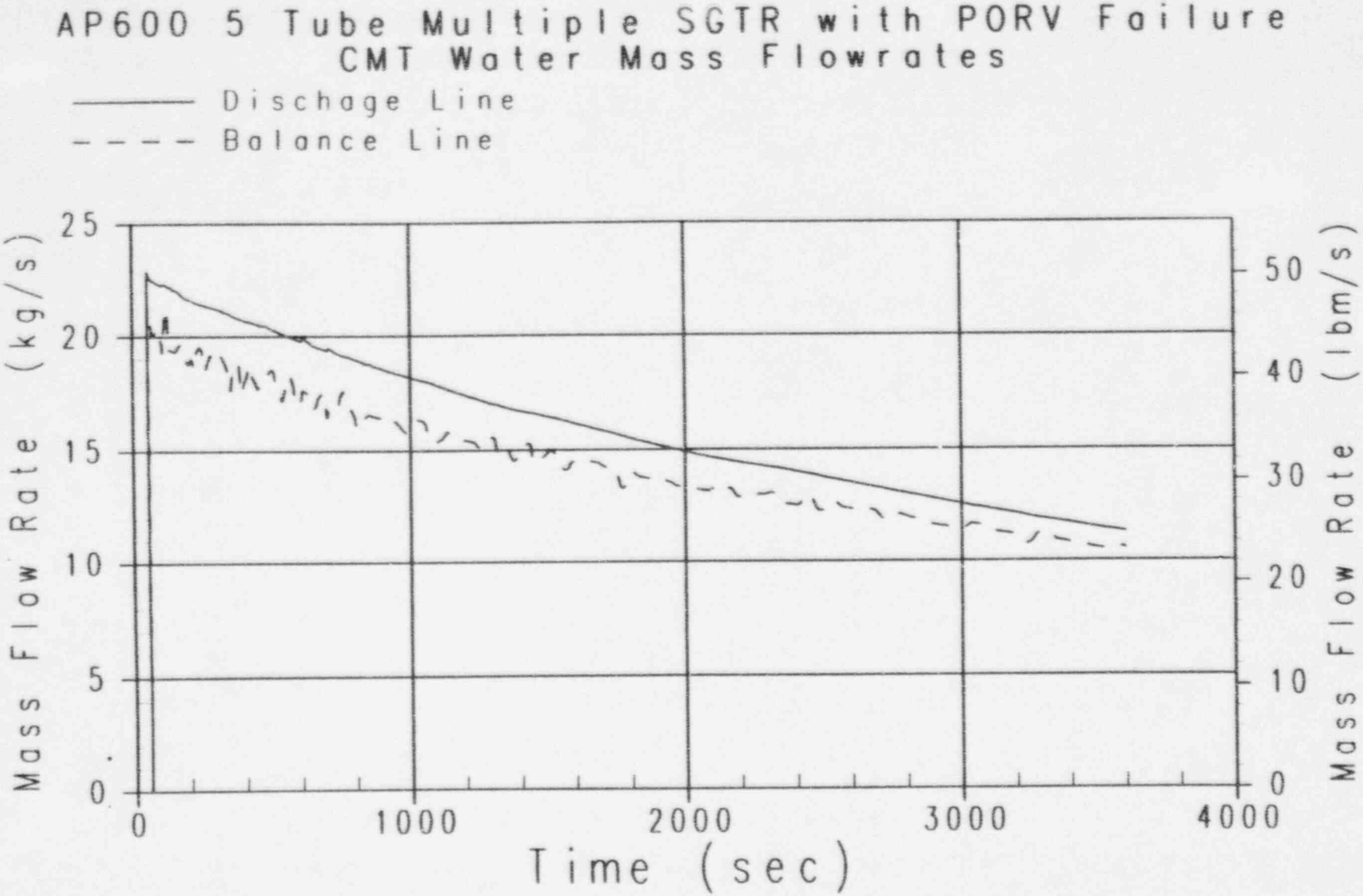


Figure 122



AP600 5 Tube Multiple SGTR with PORV Failure
CMT Water Mass Flowrates
Dischage Line
Balance Line
25
20
15
10
5
0
Mass Flow Rate (kg/s)
50
40
30
20
10
0
Mass Flow Rate (lbm/s)
0
1000
2000
3000
4000
Time (sec)

Figure 123

AP600 5 Tube Multiple SGTR with PORV Failure
RCS and CMT Water Temperatures

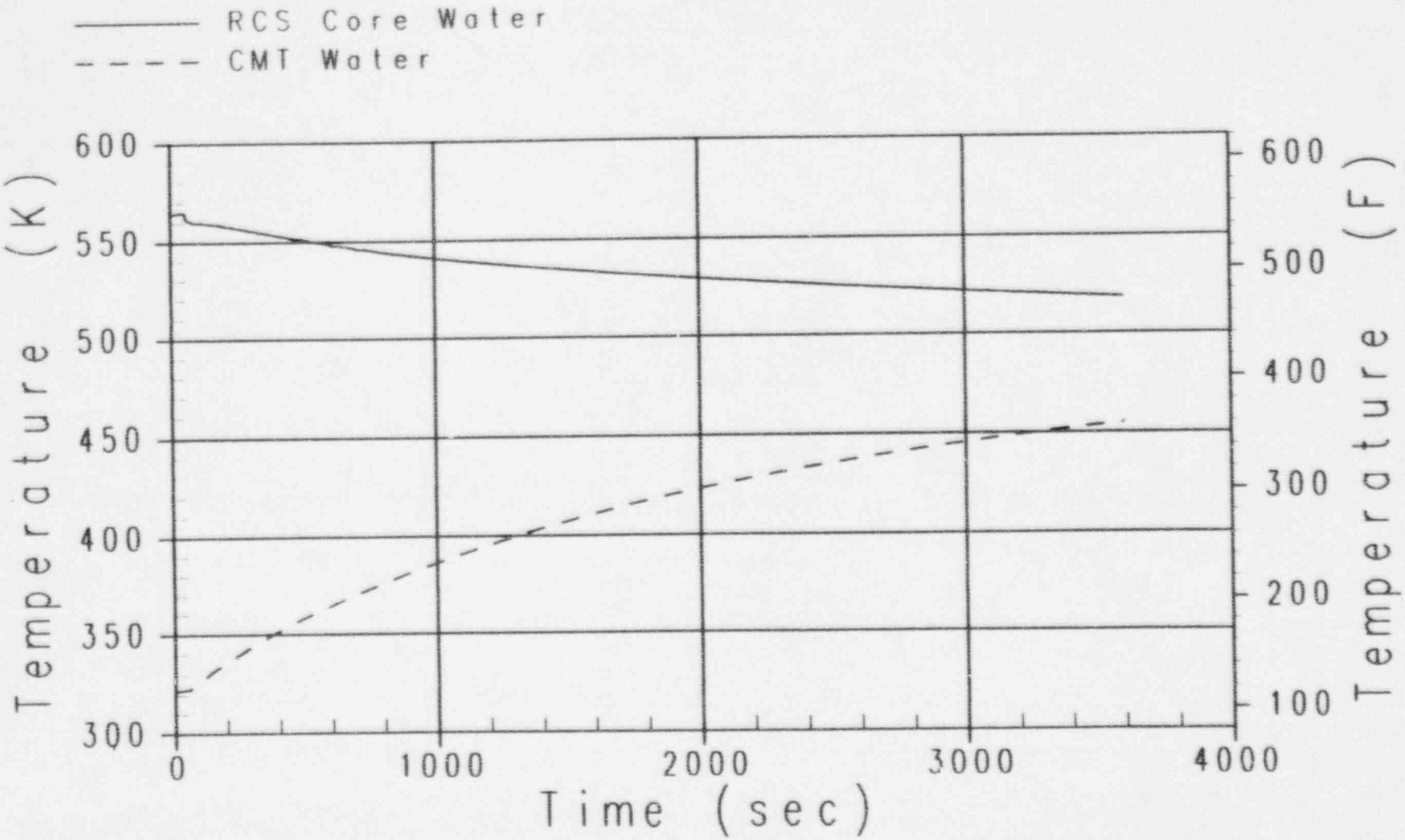


Figure 124

AP600 5 Tube Multiple SGTR with PORV Failure
CMT Water Level

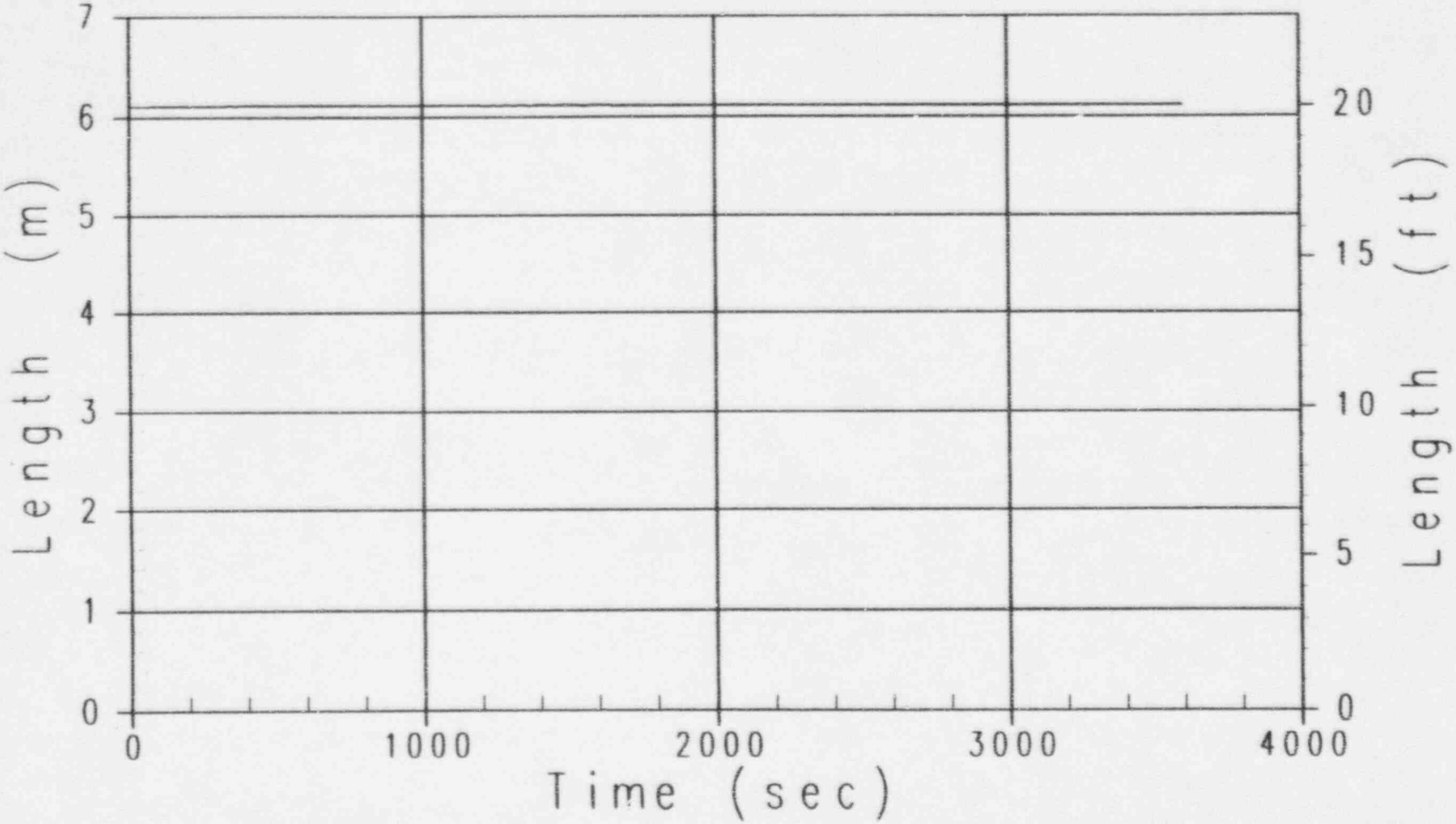


Figure 125

AP600 5 Tube Multiple SGTR with PORV Failure
PRHR Heat Removal

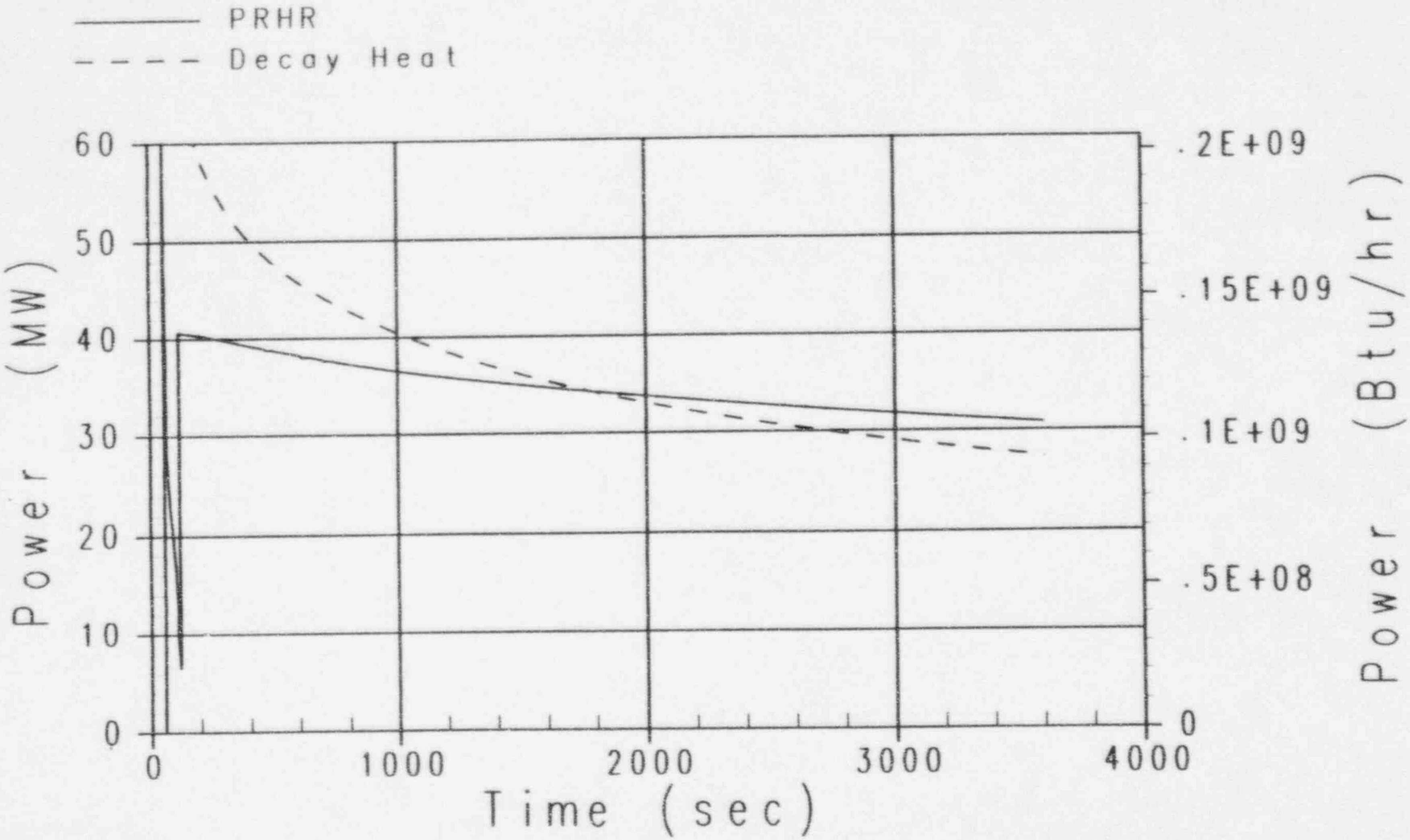


Figure 126

AP600 5 Tube Multiple SGTR with PORV Failure
RCS Water Level