Attachment 2

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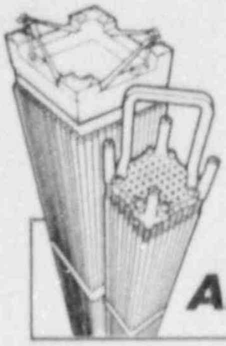

ADVANCED NUCLEAR FUELS CORPORATION

LOCA-ECCS ANALYSIS FOR DRESDEN UNITS DURING SINGLE LOOP OPERATION WITH ANF FUEL

SEPTEMBER 1987

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KWU

ADVANCED NUCLEAR FUELS CORPORATION

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LOCA-ECCS ANALYSIS FOR DRESDEN UNITS DURING SINGLE LOOP OPERATION WITH ANF FUEL

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TABLE OF CONTENTS

Section Page

1.0 INTRODUCTION.. 1
2.0 SUMMARY.. 2
3.0 JET PUMP BWR ECCS EVALUATION MODEL.. 3
3.1 LOCA During Single Loop Operation.. 3
3.2 EXEM/BWR Application To Dresden Units.. 3
4.0 ANALYSIS RESULTS.. 7
5.0 REFERENCES.. 9

LIST OF TABLES

Table Page

3.1 Dresden Reactor System Data 10
3.2 Comparison Of ANF MAPLHGP's On Equivalent Planar Power Basis...... 11
4.1 SLO LOCA Limiting Break Event Times.................................. 12
4.2 MAPLHGR Results Under SLO Conditions - 9x9 Fuel.................... 13

LIST OF FIGURES

Figure Page

3.1 Dresden 2/3 Power-Flow Map SLO Conditions......................... 14
3.2 System Blowdown Nodalization For BWR/3............................. 15
4.1 Blowdown System Pressure... 16
4.2 Blowdown Total Break Flow.. 17
4.3 Blowdown Average Core Inlet Flow..................................... 18
4.4 Blowdown Average Core Outlet Flow.................................... 19
4.5 Blowdown Hot Channel Inlet Flow...................................... 20
4.6 Blowdown Hot Channel Midplane Flow................................... 21
4.7 Blowdown Hot Channel Outlet Flow..................................... 22
4.8 Blowdown Intact Loop Jet Pump Suction Flow.......................... 23
4.9 Blowdown Intact Loop Jet Pump Exit Flow............................. 24
4.10 Blowdown Broken Loop Jet Pump Drive Flow........................... 25
4.11 Blowdown Broken Loop Jet Pump Suction Flow......................... 26
4.12 Blowdown Broken Loop Jet Pump Exit Flow............................ 27
4.13 Blowdown Upper Downcomer Mixture Level............................. 28

LIST OF FIGURES
(Continued)

Figure Page

4.14 Blowdown Middle Downcomer Mixture Level.......................... 29
4.15 Blowdown Lower Downcomer Mixture Level........................... 30
4.16 Blowdown Lower Downcomer Liquid Mass............................. 31
4.17 Blowdown Upper Plenum Liquid Mass................................ 32
4.18 Blowdown Upper Downcomer Liquid Mass............................. 33
4.19 Blowdown Lower Plenum Liquid Mass................................ 34
4.20 Refill/Reflood System Pressure................................... 35
4.21 Refill/Reflood Lower Plenum Mixture Level........................ 36
4.22 Refill/Reflood Relative Core Midplane Entrainment................ 37
4.23 BLowdown Hot Channel Center Volume Coolant Temperature........... 38
4.24 Blowdown Hot Channel Heat Transfer Coefficient................... 39
4.25 Blowdown Hot Channel Center Volume Quality....................... 40
4.26 Typical Hot Assembly Heatup Results For 9x9 Fuel................. 41

ACKNOWLEDGEMENT

The assistance of Chuck Hendrix of Intermountain Technologies, Inc. (ITI) in preparing this analysis is acknowledged.

1.0 INTRODUCTION

The results of a LOCA-ECCS analysis for the Dresden 2 and 3 nuclear power plants during single loop operation (SLO) are reported in this document. These calculations were performed with the generically approved Exxon Nuclear Company EXEM/BWR Evaluation Model (Ref. 1, 2) in accordance with Appendix K of 10 CFR 50 (Ref. 3), and the results comply with the U.S. NRC 10 CFR 50.46 criteria.

The initial operating condition selected for this analysis was 81.3% power/58.0% core flow. The analysis was performed using the Dresden Unit 3 conditions; however, the Dresden 2 and 3 Units are sufficiently similar so that the results of this analysis are applicable to both Units.

This analysis establishes the multiplier that is to be applied to the MAPLHGR's of the ANF fuel during single loop operation. The analysis was performed with 9x9 fuel to determine this multiplier and justification is provided for its applicability to both ANF 8x8 and 9x9 fuel.

2.0 SUMMARY

The results of the ECCS analysis presented herein support the use of a 0.91 SLO multiplier on the two-loop MAPLHGR's for ANF fuels when the Dresden Units are operating in single loop operation.

All calculations were performed with the NRC approved EXEM/BWR ECCS Evaluation Model, according to Appendix K of 10 CFR 50. Single loop operation of the Dresden Units with a multiplier of 0.91 on the two-loop ANF fuel MAPLHGR's assures that the emergency core cooling systems for the Dresden Units will meet the U.S. NRC acceptance criteria for loss-of-coolant accident breaks up to and including the double-ended severance of a reactor coolant pipe. That is:

1. The calculated peak fuel element clad temperature does not exceed the 2200 F limit.

2. The calculated total oxidation of the cladding nowhere exceeds 17% times the total cladding thickness before oxidation.

3. The calculated maximum hydrogen generation does not exceed 1% of the zircaloy associated with the active fuel cladding in the reactor.

4. The LOCA cladding temperature transient is calculated to be terminated at a time when the core is still amenable to cooling.

5. The system long-term cooling capabilities provided for the initial core and subsequent reloads remain applicable to ANF fuel.

3.0 JET PUMP BWR ECCS EVALUATION MODEL

3.1 LOCA During Single Loop Operation

Response to a loss-of-coolant accident (LOCA) is described in the previous analysis for two-loop operation (Ref. 4). This report addresses the instance of a LOCA during single loop operation (SLO).

During SLO the recirculation pump in the inactive loop is not operating and is isolated from the remainder of the system by a valve. Thus, there is no flow through the idle, intact loop. A break might occur in either loop. However, a break in the inactive loop would behave essentially like a break during two-loop operation except that substantial break flow would come from only one side of the break (because of the closed valve in the loop). System performance would then be like that resulting from a somewhat smaller break during two-loop operation. This scenario is already covered by the previous LOCA break spectrum analysis(5). Further consideration in this report will be given only to the case where a break occurs in the active loop. This case differs from the two-loop case in one important respect: there is no coastdown flow in the intact loop.

A previous SLO analysis (Ref. 6) assumed that the consequence of a lack of coastdown flow (which continues to supply liquid from the downcomer to the lower plenum, although at a decreasing rate, during two-loop operation) would be an almost immediate flow stagnation in the core and a very early CHF (0.1 sec); this resulted in poor heat transfer very early in the transient and required that a MAPLHGR reduction factor of 0.84 be imposed for SLO conditions on the MAPLHGR for GE 8x8 fuel.

3.2 EXEM/BWR Application To Dresden Units

The EXEM/BWR ECCS Evaluation Model codes(1) were used for this SLO LOCA-ECCS calculation. The codes which comprise the Evaluation Model consist of

RODEX2(7), RELAX(8), FLEX(9), and HUXY/BULGEX(10,11). The latest versions of these codes were used for this analysis. The only significant geometric modeling difference necessary was to simulate SLO in the RELAX model of the intact loop. The isolation valve in the intact loop is closed.

The approved ANF generic break spectrum analysis(5) for the BWR/3 reactors of which the Dresden Units are typical, identified the limiting break as the double-ended guillotine break of the recirculation pump suction pipe with a discharge coefficient of 1.0 (1.0 DEG/PS). This limiting break (including worst single failure) was used in this analysis.

If LOCA occurs during single loop operation, a rapid drop in core flow will occur during the early phase because the intact loop pump is not operating. The core flow transient during the early phase (0 - 5 seconds) of a LOCA during single loop is the principal event which will distinguish such an accident from a LOCA occurring during normal two-loop operation. As the break size increases, the magnitude of the initial drop in core flow also would increase, and the critical heat flux (CHF) will occur earlier in time due to the decreased core flow. This trend of a larger drop in core flow with increasing break size has been confirmed by ANF in sensitivity analyses on similar plants. Thus, the worst case LOCA for single loop operation would be expected to be with a break at least as large in area as the limiting break for two-loop operation.

Since the limiting break for normal (two-loop) operation is the break of the largest possible area, this break will also be the limiting one for single loop operation. The NSSS vendor also determined that this same break is limiting for two and single loop operation(6).

The 81.3% power/58% core flow (81.3/58) operating point was selected as the initial operating condition for this analysis. This condition lies on the APRM single pump rod block line on the current operating power flow map for the Dresden Units. This value was obtained by using the maximum core flow under SLO conditions of 58% and then selecting the appropriate power from the power-flow map. This condition was determined in Reference 6 to be a conservative upper bound for single loop operation. Figure 3.1 shows the power-flow map and the selected single loop operating point. The plant conditions used for the analysis are presented in Table 3.1. This data applies to both Dresden Unit 2 and Unit 3 because of the similarity between the two plants.

The system behavior during a LOCA is determined primarily by the LOCA break parameters: break location, break size, and break configuration, together with the system components and geometry. Variations in core parameters produce only secondary effects on the system behavior. Thus, by using bounding core neutronic parameters, the LOCA-ECCS results established by this analysis will apply for future cycles unless significant changes are made in the plant operating conditions, plant hardware, or core design such that the analysis no longer bounds the plant conditions.

The blowdown calculations made for this analysis differ from those for the previous two-loop analysis(4) in two important ways. An additional valve is included upstream of the pump in the intact loop and initial conditions are altered to correspond to the maximum power/flow conditions for SLO. The nodalization is shown in Figure 3.2. Consistent with plant procedures for SLO, this is closed during the entire calculation preventing any flow through the loop.

The average core blowdown calculations are followed by hot channel calculations. The hot channel geometry is identical with that used in the two-loop analysis (Ref. 4). A bounding radial peaking factor of 1.76 was used to set the assembly power for the hot channel analysis.

The nodalization and geometry used in the reflood calculation are also identical to those of the two-loop analysis(4). In the FLEX code the intact loop is not modeled in detail because intact loop flows are insignificant by the time of rated spray; thus no changes were required in the FLEX nodalization or geometry. The initial conditions for the reflood calculation are entirely determined by the blowdown calculation.

The HUXY/BULGEX heatup calculation of the hot plane was done as in the previous two-loop analyses(4): fuel stored energy, thermal gap conductivity and dimensions from RODEX2 as a function of power and exposure; time of rated spray, decay power, heat transfer coefficients and coolant conditions from RELAX; and time of hot-node-reflood from FLEX. Appendix K spray heat transfer coefficients are used for the spray cooling period. Peak clad temperature (PCT) and the cladding oxidation percentage are determined for ANF 9x9 fuel.

Table 3.2 shows the ANF 8x8 and 9x9 MAPLHGR's for the Dresden Units on the equivalent basis of bundle planar power (MAPLHGR times number of heated rods). As shown in this table, the 9x9 MAPLHGR's at lower exposures are significantly higher (on an equivalent bundle planar power basis) than 8x8 MAPLHGR's; at 5 GWd/MTU the equivalent 9x9 MAPLHGR is about 13% higher than the equivalent 8x8 MAPLHGR limit.

In preliminary SLO analyses it was determined that the high planar power of the 9x9 MAPLHGR at 5 GWd/MTU was sufficient to cause an early CHF; thus a reduction in the 9x9 MAPLHGR was indicated for SLO conditions to delay CHF. Preliminary analyses show that a reduction in the peak 9x9 MAPLHGR value by 1 kW/ft (9%) to 10.75 kW/ft was sufficient to significantly delay CHF. Thus, SLO analyses were performed with 10.75 kW/ft as the peak MAPLHGR.

4.0 ANALYSIS RESULTS

Analyses were performed for the assembly exposure (0-20 GWd/MTM) for which the two-loop MAPLHGR's had the highest PCT's (see Table 3.2). In all cases the MAPLHGR's justified in the single loop analysis were within 9% of the two-loop MAPLHGR's and the PCT's for the most limiting exposures (0-10 GWd/MTU) were not only less than acceptance criteria of 2200°F, but less than the PCT's from the two-loop analyses. Thus, a .91 multiplier on the two-loop 9x9 MAPLHGR curve assures that the 10 CFR 50.46 criteria are met under SLO conditions.

Calculated event time results are given in Table 4.1. System blowdown results are presented in Figures 4.1 through 4.19. System refill and reflood results are given in Figures 4.20 through 4.22. These system conditions are used as boundary conditions for a series of exposure dependent maximum power assembly heatup calculations. Results from a RELAX/HOT CHANNEL calculation are given in Figures 4.23 through 4.25 for 9x9 fuel at MAPLHGR values of 10.75 kW/ft. Resulting clad temperatures as calculated by HUXY/BULGEX are shown in Figure 4.26.

An examination of these plots reveals the following information:

1. The sudden loss of drive fluid in the jet pumps allowed a sudden drop in lower plenum pressure of sufficient magnitude to allow flow through the inactive jet pumps to "reverse" from the initial negative flow to a positive flow in the earlier part of the blowdown.

2. The lack of a pump coasting down in the intact loop allowed flow through the suction and exit junctions of the operating (broken loop) jet pumps to remain in the positive direction (the drive, of course, reversed to supply fluid to the break) during the earlier part of the blowdown.

3. There is an immediate plunge in core flow accompanied by a reduction in the heat transfer coefficient.

4. The plunge in core flow is not sufficient to cause CHF to immediately occur at the high powered plane for the MAPLHGR's analyzed. The flow in the high power planes continue in the upward direction as shown in Figure 4.6. CHF is delayed until about 9 seconds. This is because, while the hot channel inlet flow actually reverses, the lower part of the channel continues to supply a two phase liquid-vapor mixture to the high powered hot regions of the channel.

The peak MAPLHGR analyzed for the 9x9 fuel under SLO conditions (10.75 kW/ft) is about 5% higher than the two-loop ANF 8x8 MAPLHGR on an equivalent planar power basis; thus these analyses demonstrate that early CHF would not be expected to occur in the ANF 8x8 fuel; thus application of the same SLO multiplier (.91) to the two-loop ANF fuel MAPLHGR will conservatively protect the ANF 8x8 fuel from exceeding the 10 CFR 50.46 criteria during SLO conditions. Use of this multiplier (9% reduction) and the lower equivalent power of the 8x8 MAPLHGR (5%) result in an equivalent ANF 8x8 MAPLHGR for SLO conditions 14% lower than the peak bundle planar power analyzed in this report.

This application of a .91 multiplier during SLO conditions to all ANF fuel MAPLHGR's in the Technical Specifications will protect ANF fuel in the Dresden Units from exceeding 10 CFR 50.46 criteria.

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8. "RELAX: A RELAP4-Based Computer Code for Calculating Blowdown Phenomena," XN-NF-80-19(P), Volume 2A, Revision 1, Exxon Nuclear Company, June 1981.

9. "FLEX: A Computer Code for the Refill and Reflood Period of a LOCA," XN-NF-80-19(P), Volume 2B, Revision 1, Exxon Nuclear Company, June 1981.

10. "HUXY: A Generalized Multirod Heatup Code with 10 CFR 50 Appendix K Heatup Option - User's Manual," XN-CC-33(A), Revision 1, Exxon Nuclear Company, November 1, 1975.

11. "BULGEX: A Computer Code to Determine the Deformation and the Onset of Bulging of Zircaloy Fuel Rod Cladding," XN-74-21, Revision 2, and XN-NF-27, Revision 2, Exxon Nuclear Company, December 31, 1974.

TABLE 3.1 DRESDEN REACTOR SYSTEM DATA*

Primary Heat Output, MW	2095.54
Total Reactor System Volume, ft**3	20160.0
Total Reactor Flow Rate, lb/hr	56.84 x 10**6
Active Core Flow Rate, lb/hr	51.36 x 10**6
Nominal Reactor System Pressure (upper plenum) psia	995.46
Core Inlet Enthalpy, Btu/lb	506.87
Recirculation Loop Flow Rate, lb/hr	15.83 x 10**6
Steam Flow Rate, lb/hr	7.92 x 10**6
Feedwater Flow Rate, lb/hr	7.91 x 10**6
Rated Recirculation Pump Head, ft	570.00
Rated Recirculation Pump Speed, rpm	1,670.00
Moment of Inertia, lbm-ft**2/rad	10,950.00
Recirculation Suction Pipe I.D., in.	25.59
Recirculation Discharge Pipe I.D., in.	25.59
9x9 Fuel Assembly Rod Diameter, in	0.424
9x9 Fuel Assembly Rod Pitch, in	0.572
9x9 Active Core Height, in	145.24

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*81.3% of rated power/58% of rated core flow.

TABLE 3.2 COMPARISON OF ANF MAPLHGR'S ON EQUIVALENT PLANAR POWER BASIS

Bundle Average Exposure (GWd/MTU)	PCT (°F)		MAPLHGR (kW/ft)		Equivalent Planar Power (kW/ft)	
	8x8	9x9	8x8	9x9	8x8	9x9
0	1879	2006	13.0	11.4	819	900
5	1942	2045	13.0	11.75	819	928
10	2123	1893	13.0	11.4	819	900
15	2159	1805	12.85	10.55	810	833
20	2074	1710	12.6	9.7	794	766
25	2011	1623	11.95	8.85	753	649
30	1895	1529	11.2	8.00	706	632
35	1808	1421	10.45	7.15	658	565
40	--	1309	--	6.30	--	498

TABLE 4.1 SLO LOCA LIMITING BREAK EVENT TIMES

Event	Time (sec)
Start	0.00
Initiate Break	0.05
Feedwater Flow Stops	0.55
Steam Flow Stops	5.05
Low-Low Mixture Level	5.16
Jet Pumps Uncover	8.38
Recirculation Pipe Uncovers	12.05
Lower Plenum Flashes	14.16
HPCI Flow Starts	15.16
LPCS Starts	57.06
Rated Spray Calculated	60.70
Depressurization Ends	114.05
Start of Reflood	152.22
Time of Hot Node Reflood	163.05
Peak Clad Temperature Reached	163.05

TABLE 4.2 MAPLHGR RESULTS UNDER SLO CONDITIONS
9X9 FUEL

Single Loop Conditions

Assembly Average Burnup (GWd/MTU)	MAPLHGR (kW/ft)	Local MWR (%)	PCT (°F)
0	10.75	1.1	1898
5	10.75	1.0	1887
10	10.75	0.9	1874
15	10.55	0.8	1851
20	9.70	0.6	1750

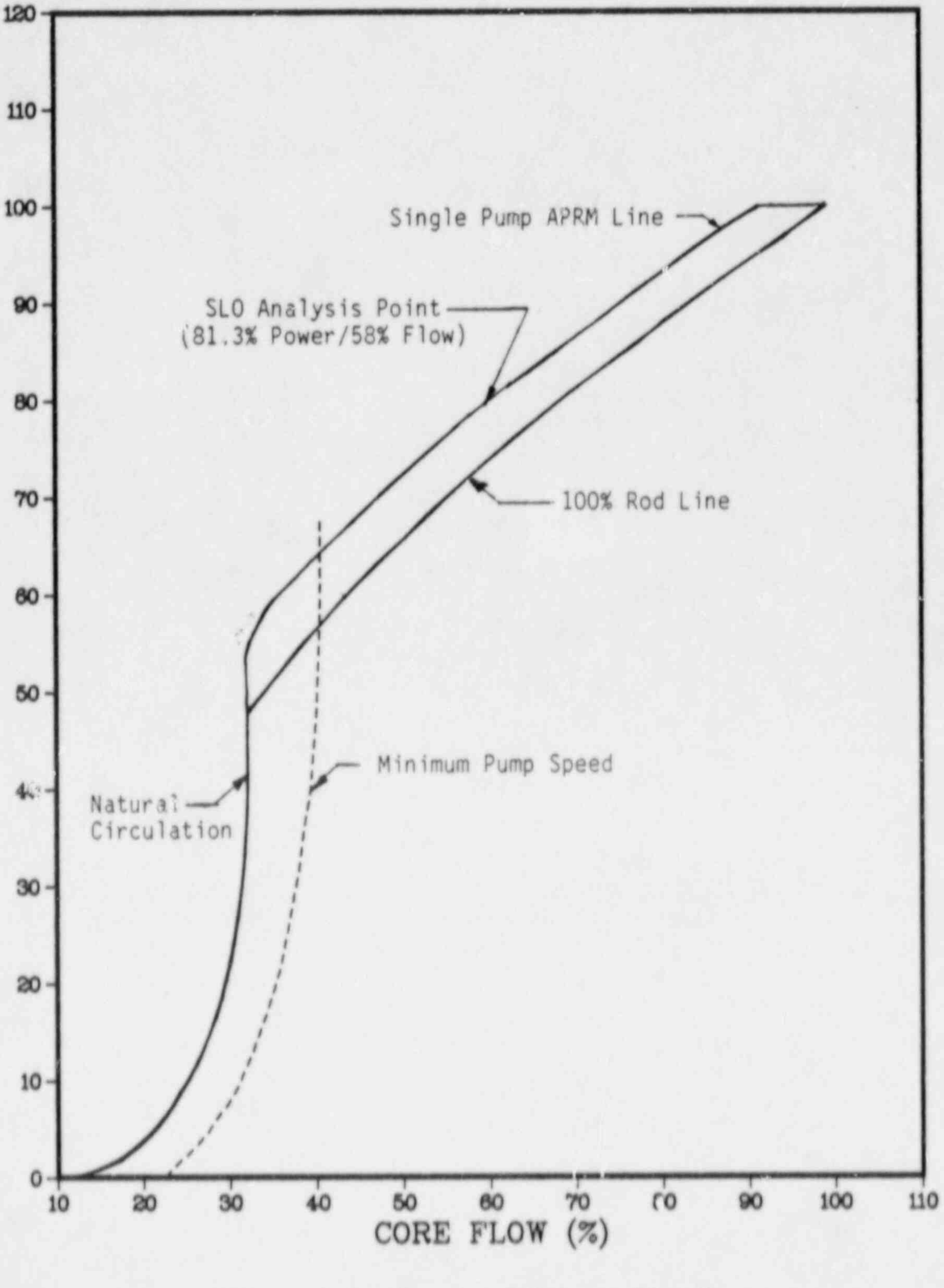


Figure 3.1 Dresden 2/3 Power-Flow Map SLO Conditions

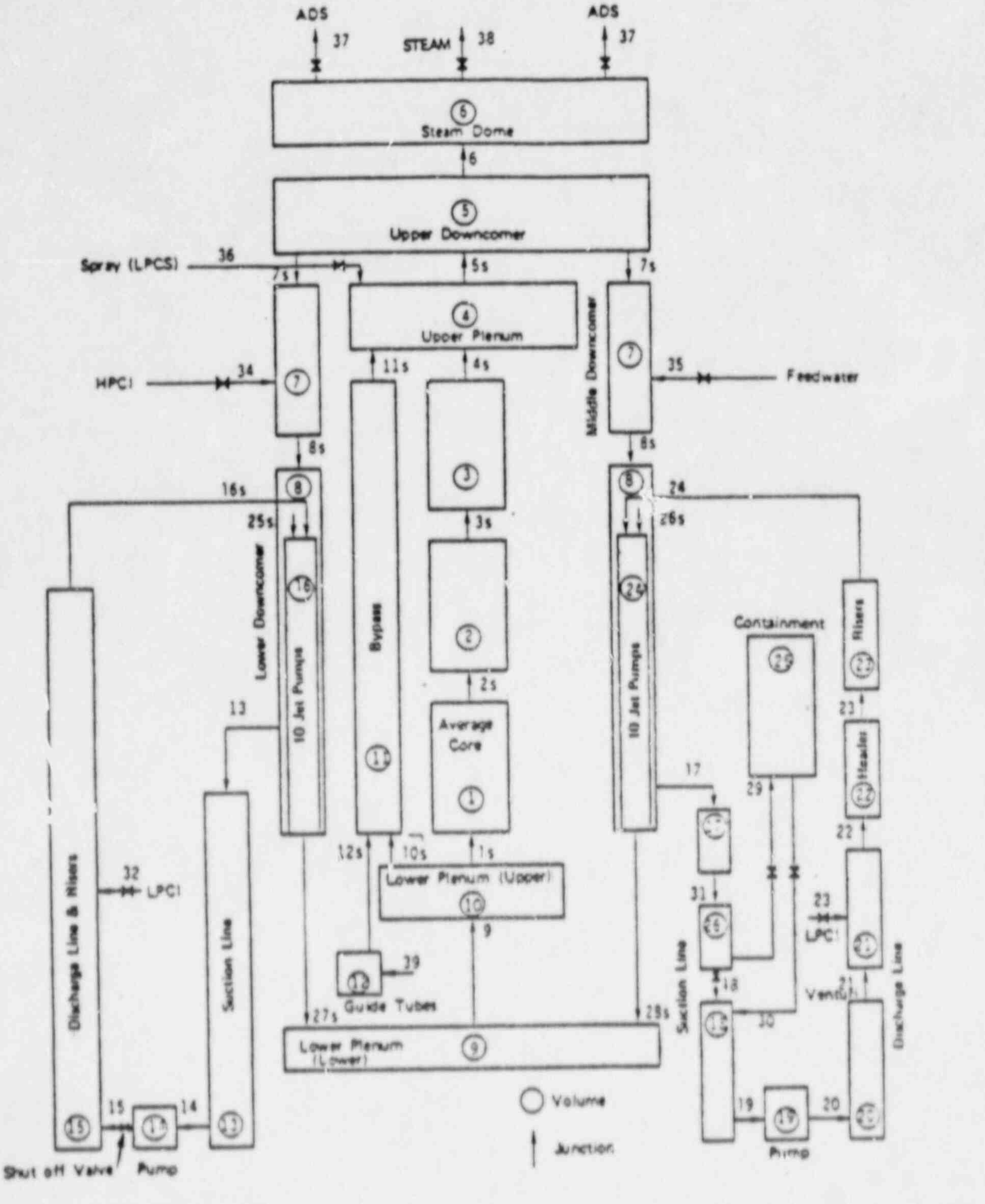


Figure 3.2 System Blowdown Nodalization For BWR/3

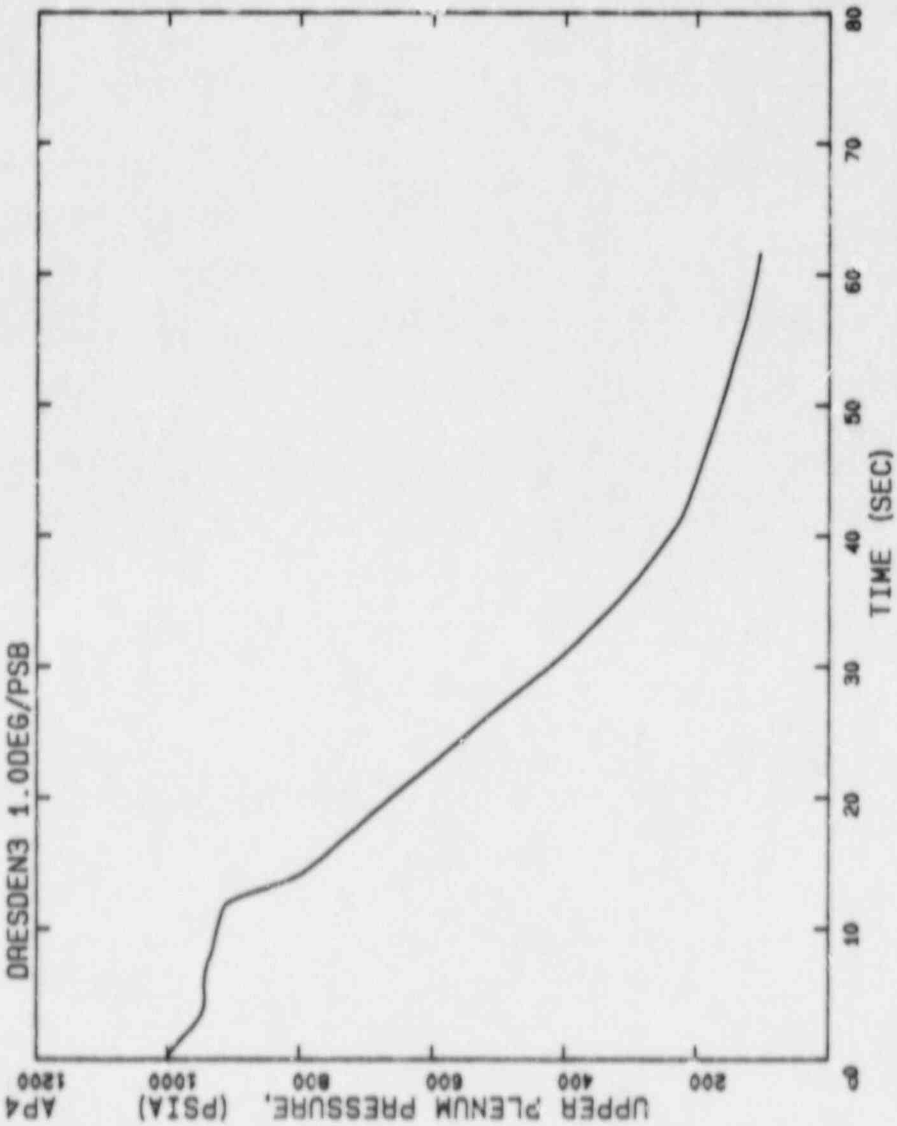


Figure 4.1 Blowdown System Pressure

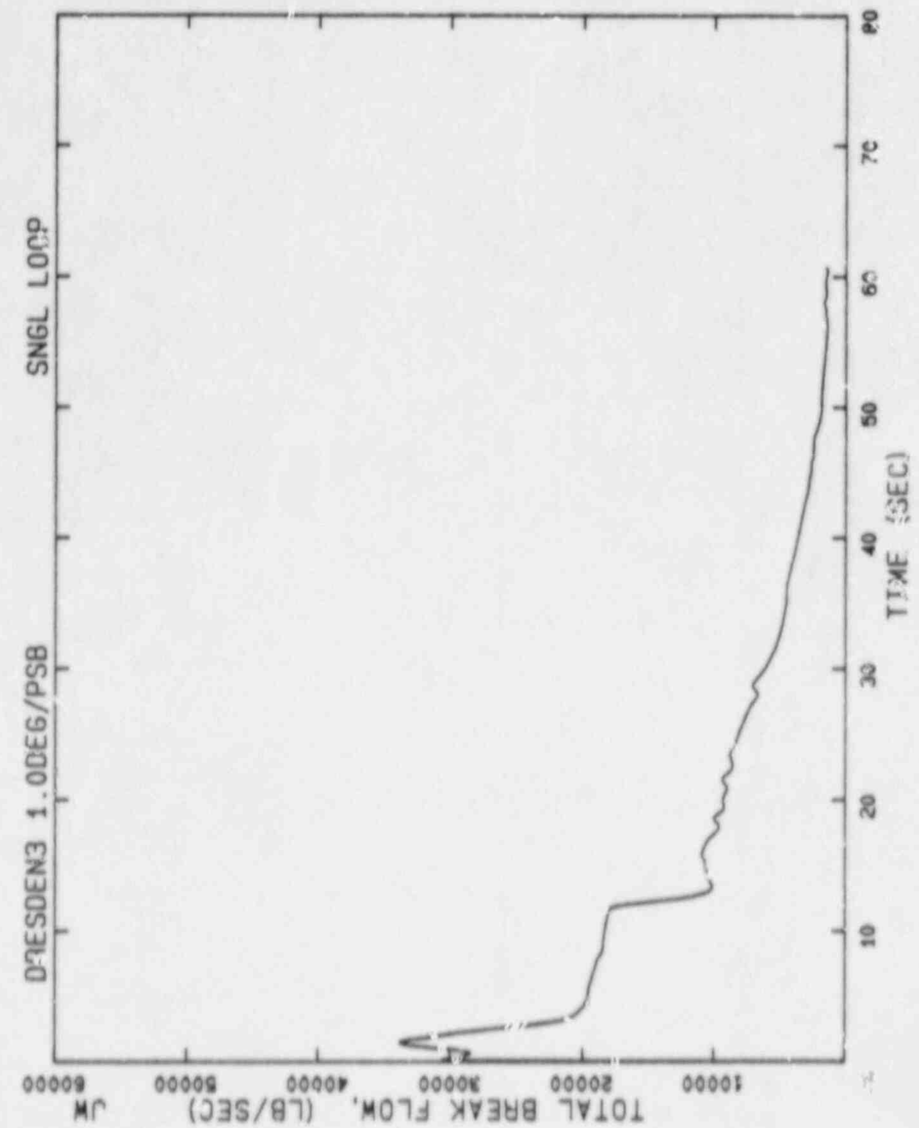


Figure 4.2 Blowdown Total Break Flow

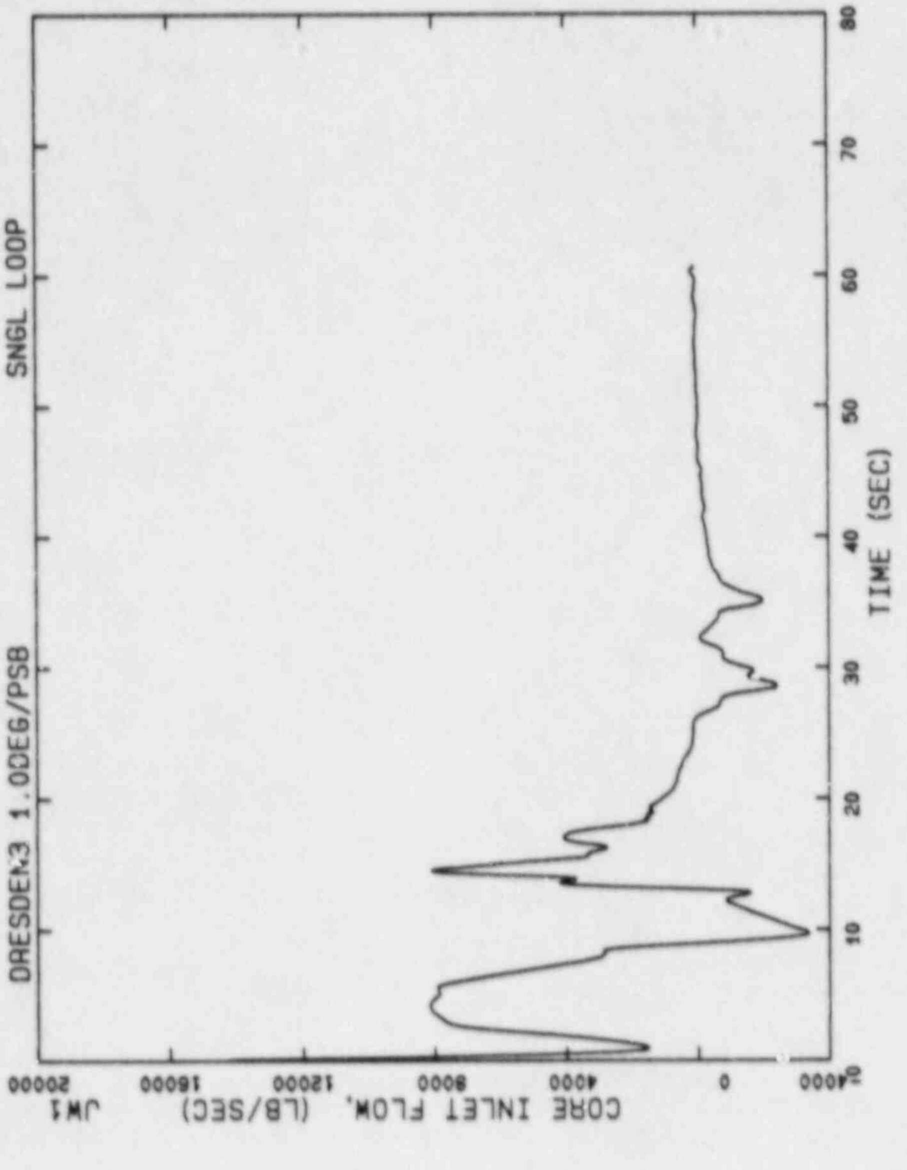


Figure 4.3 Blowdown Average Core Inlet Flow

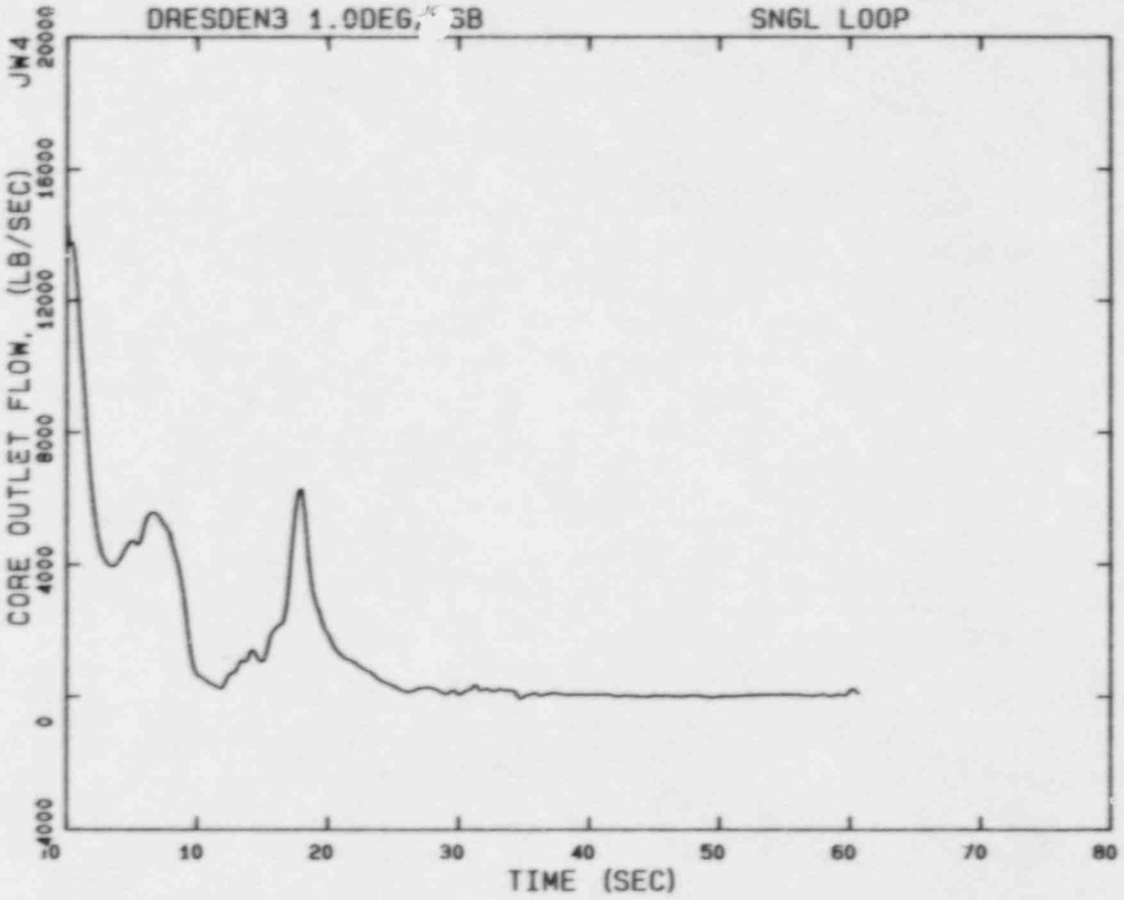


Figure 4.4 Blowdown Average Core Outlet Flow

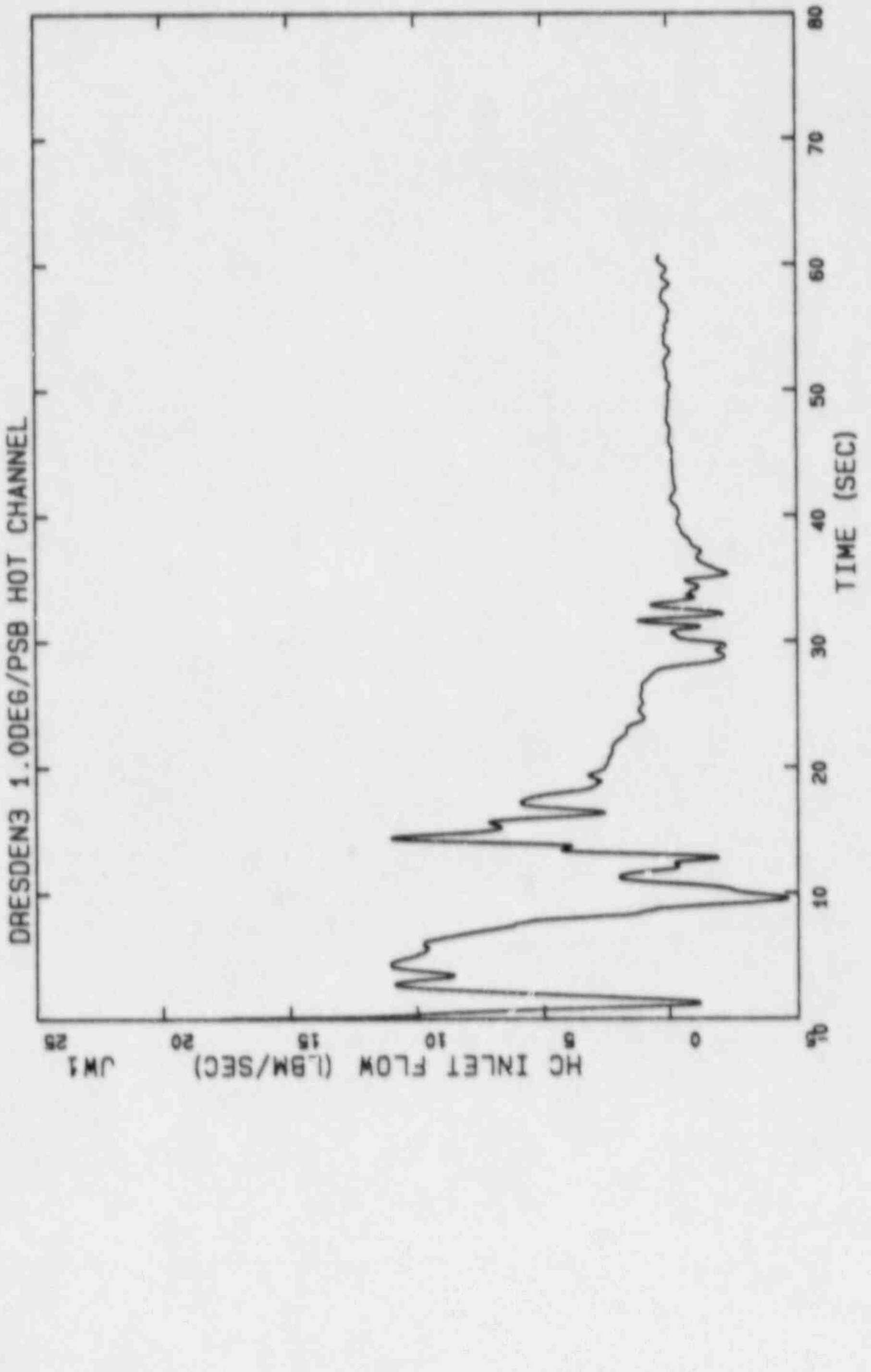


Figure 4.5 Blowdown Hot Channel Inlet Flow

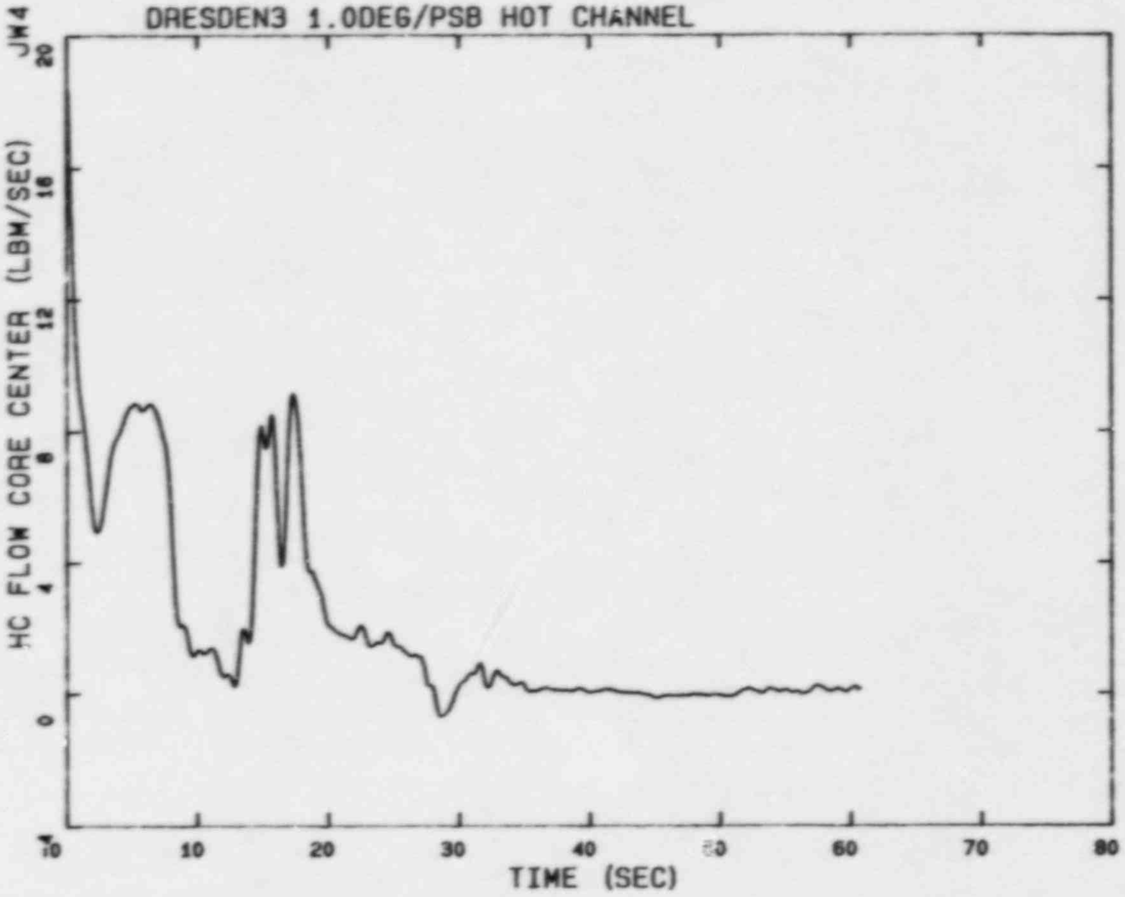


Figure 4.6 Blowdown Hot Channel Midplane Flow

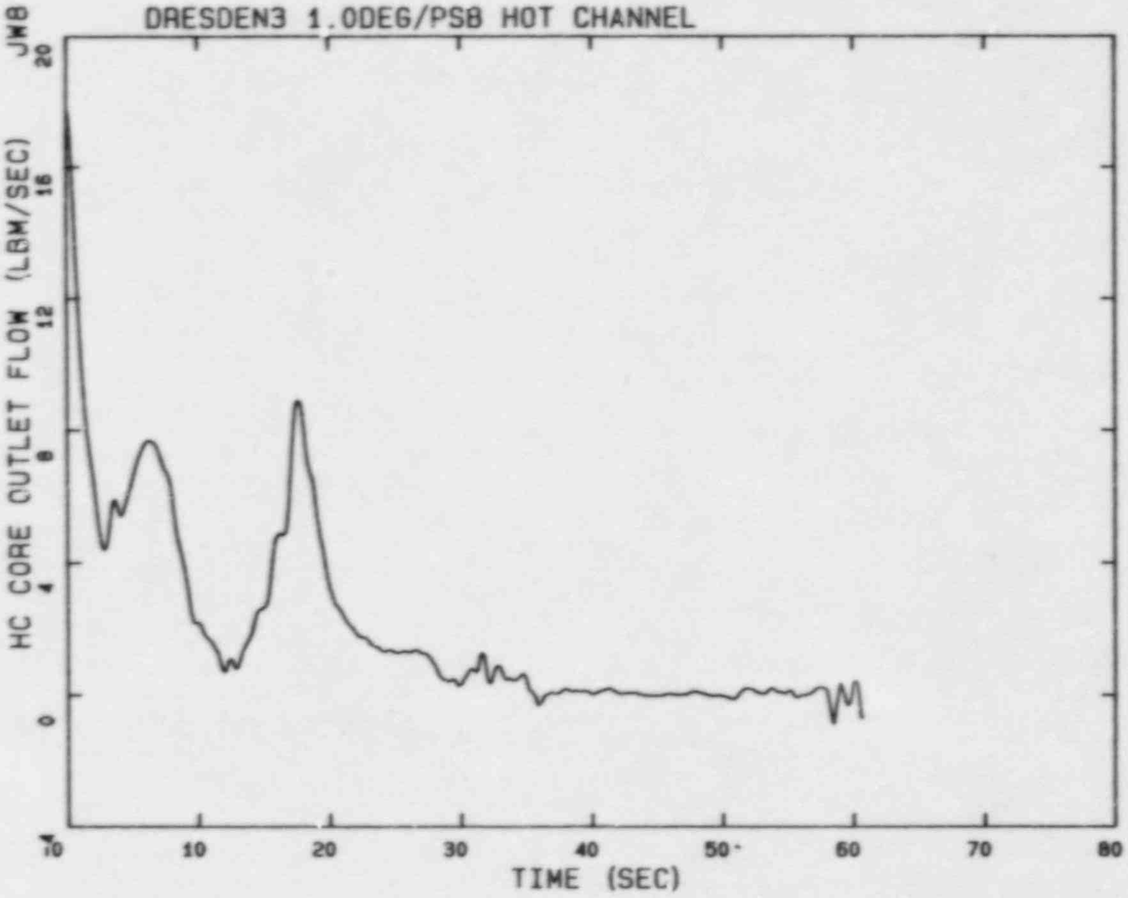


Figure 4.7 Blowdown Hot Channel Outlet Flow

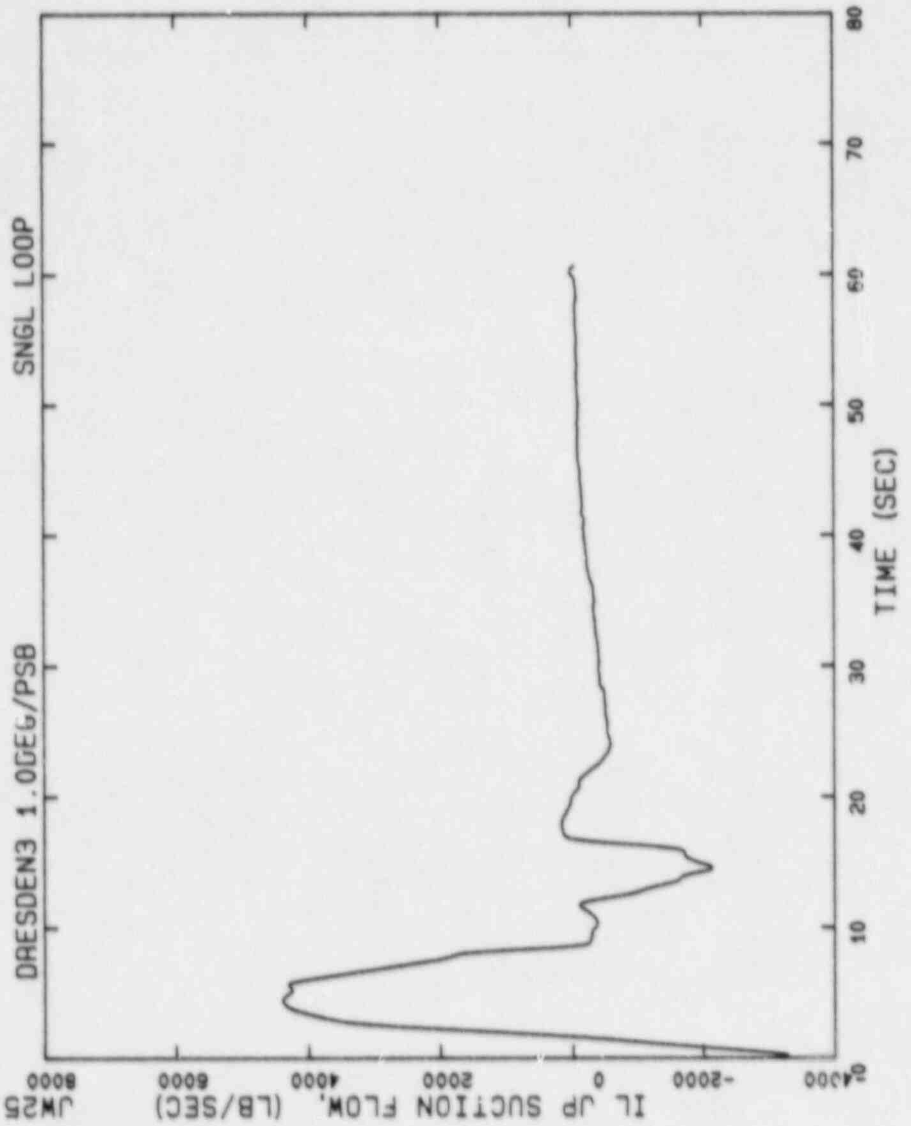


Figure 4.8 Blowdown Intact Loop Jet Pump Suction Flow

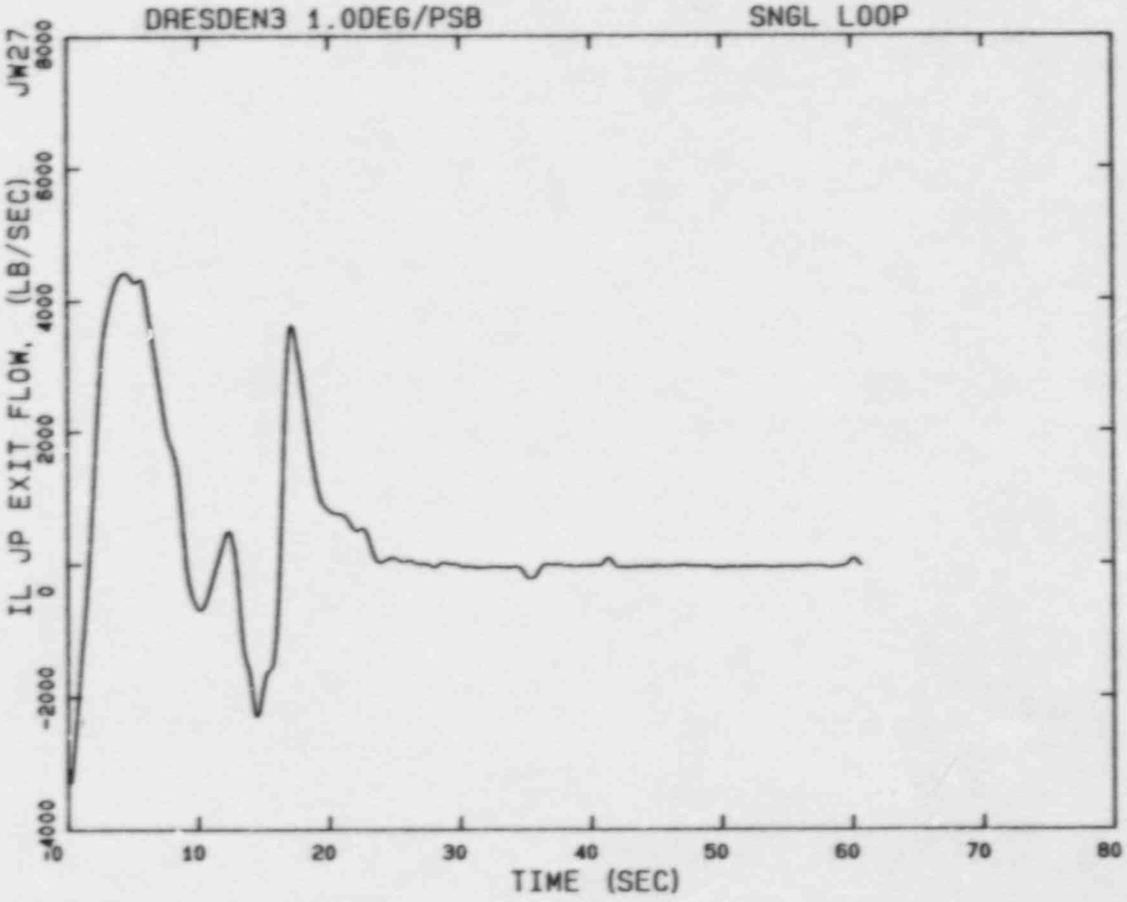


Figure 4.9 Blowdown Intact Loop Jet Pump Exit Flow

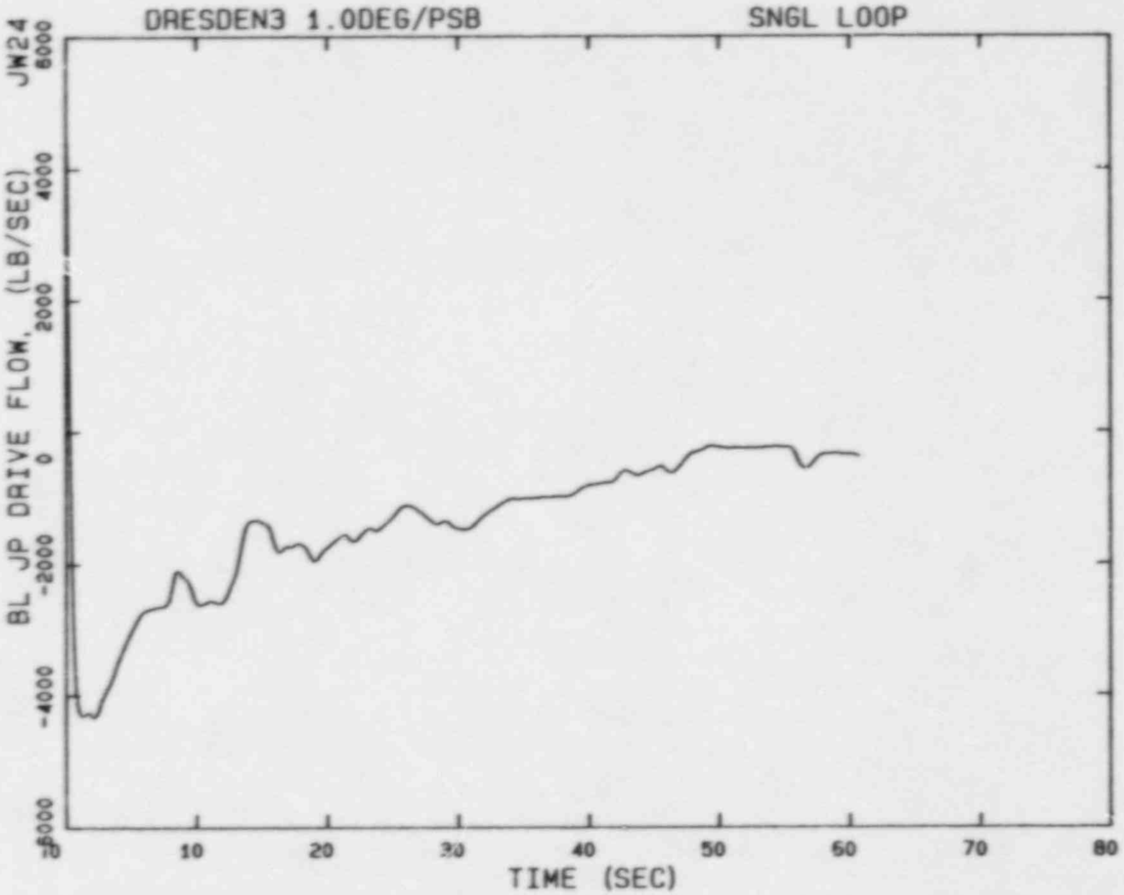


Figure 4.10 Blowdown Broken Loop Jet Pump Drive Flow

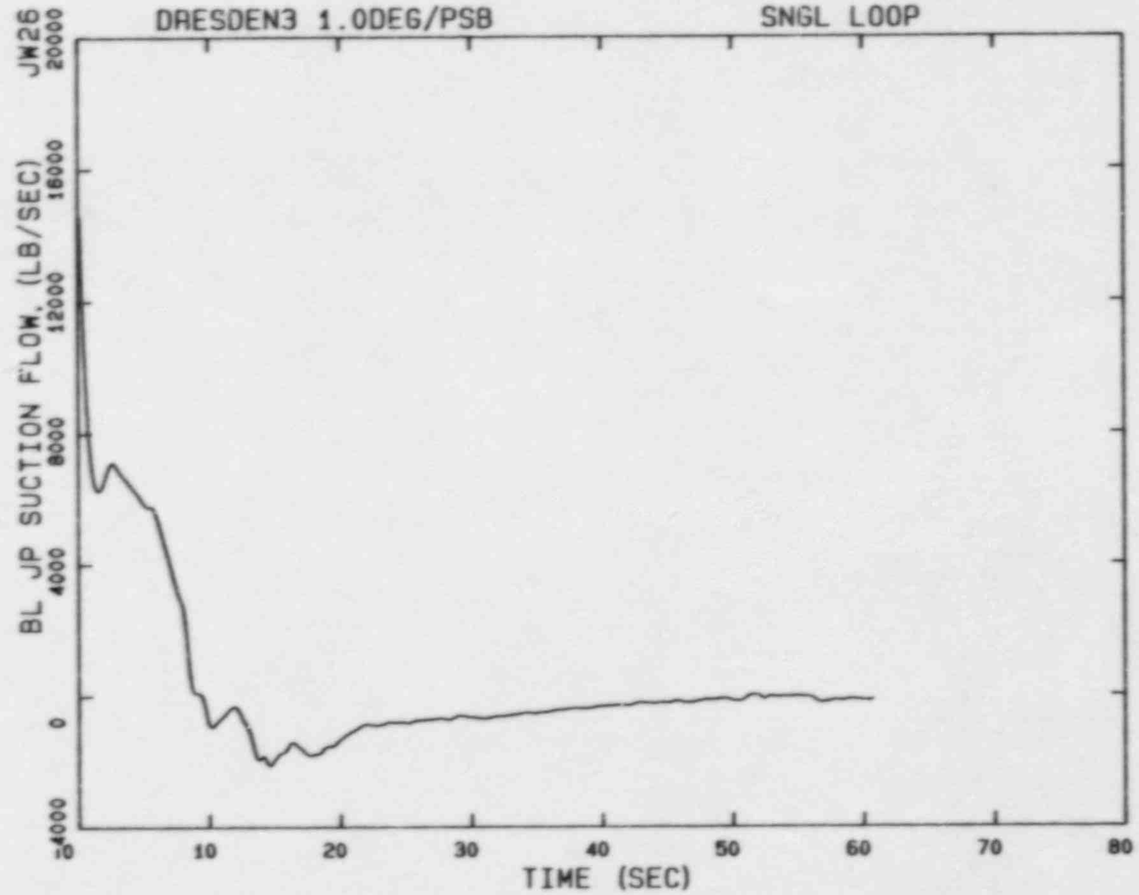


Figure 4.11 Blowdown Broken Loop Jet Pump Suction Flow

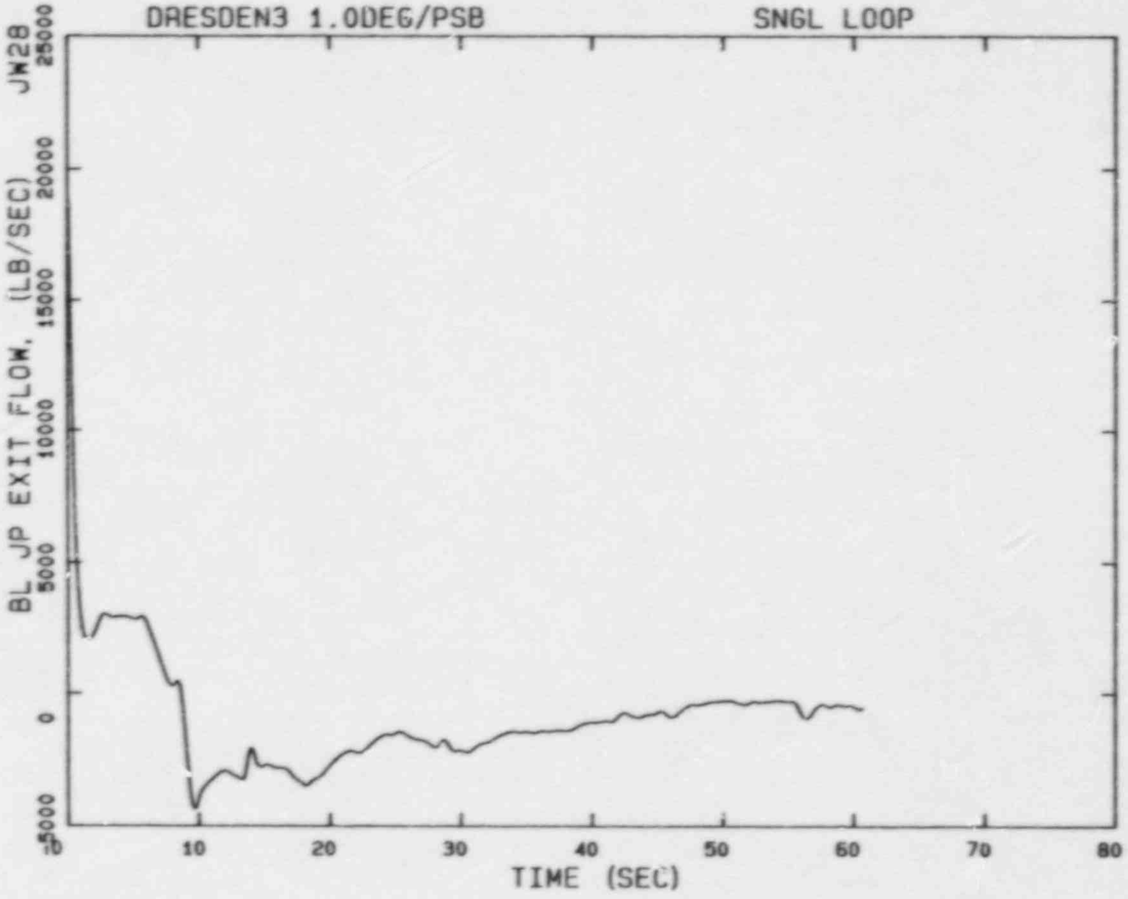


Figure 4.12 Blowdown Broken Loop Jet Pump Exit Flow

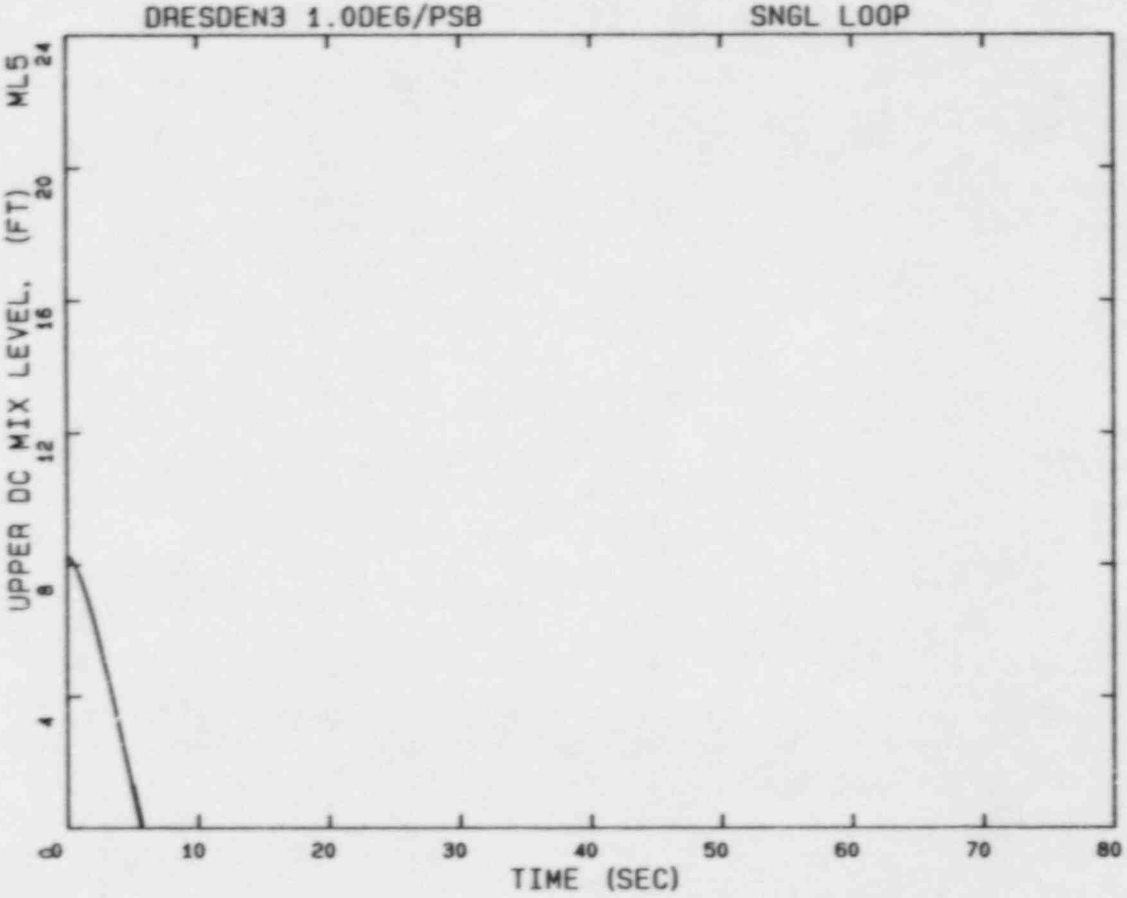


Figure 4.13 Blowdown Upper Downcomer Mixture Level

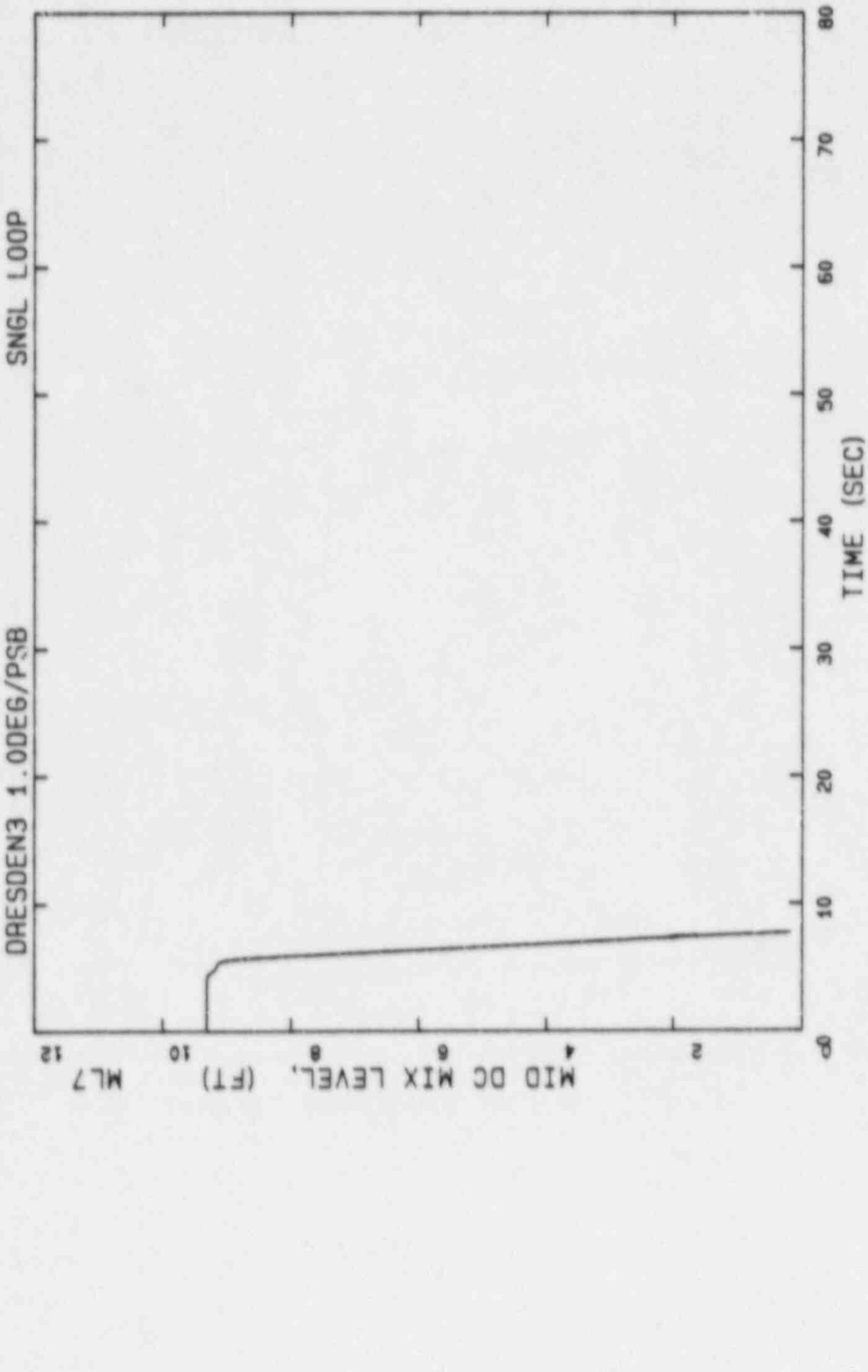


Figure 4.14 Blowdown Middle Downcomer Mixture Level

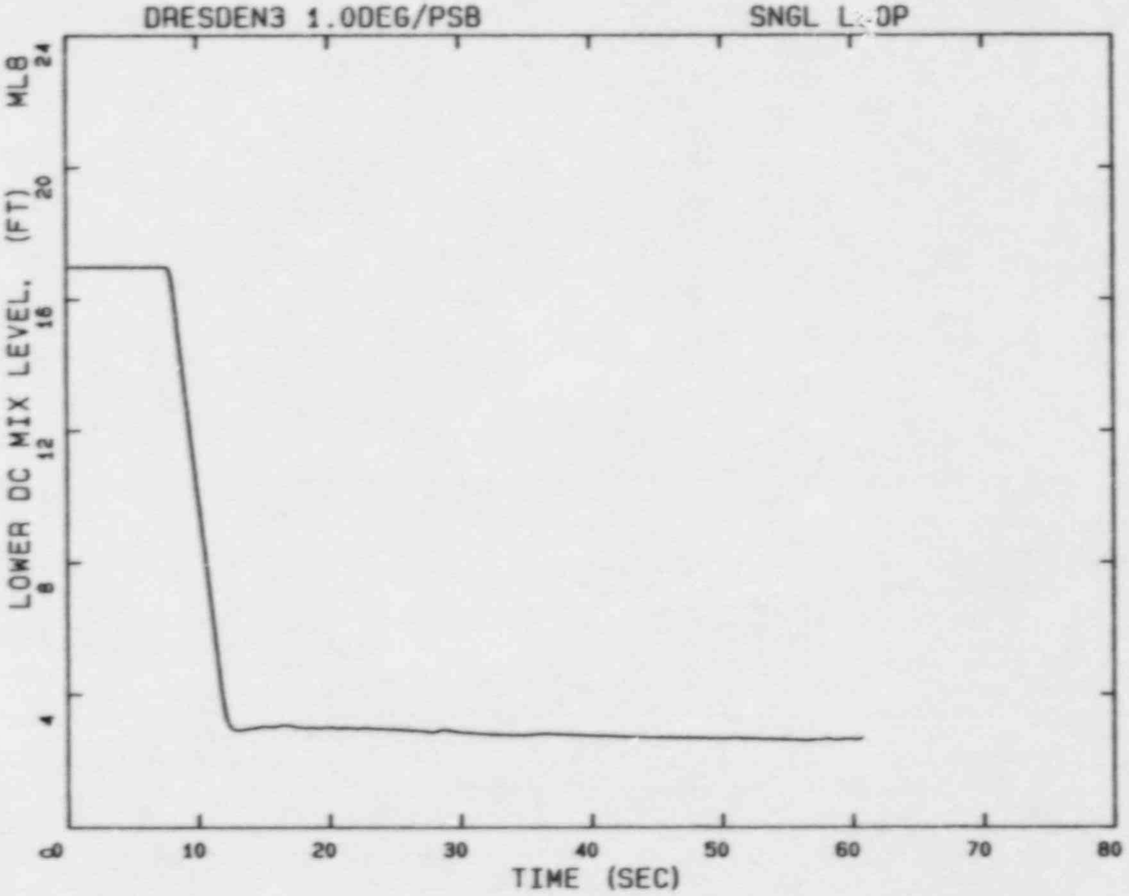


Figure 4.15 Blowdown Lower Downcomer Mixture Level

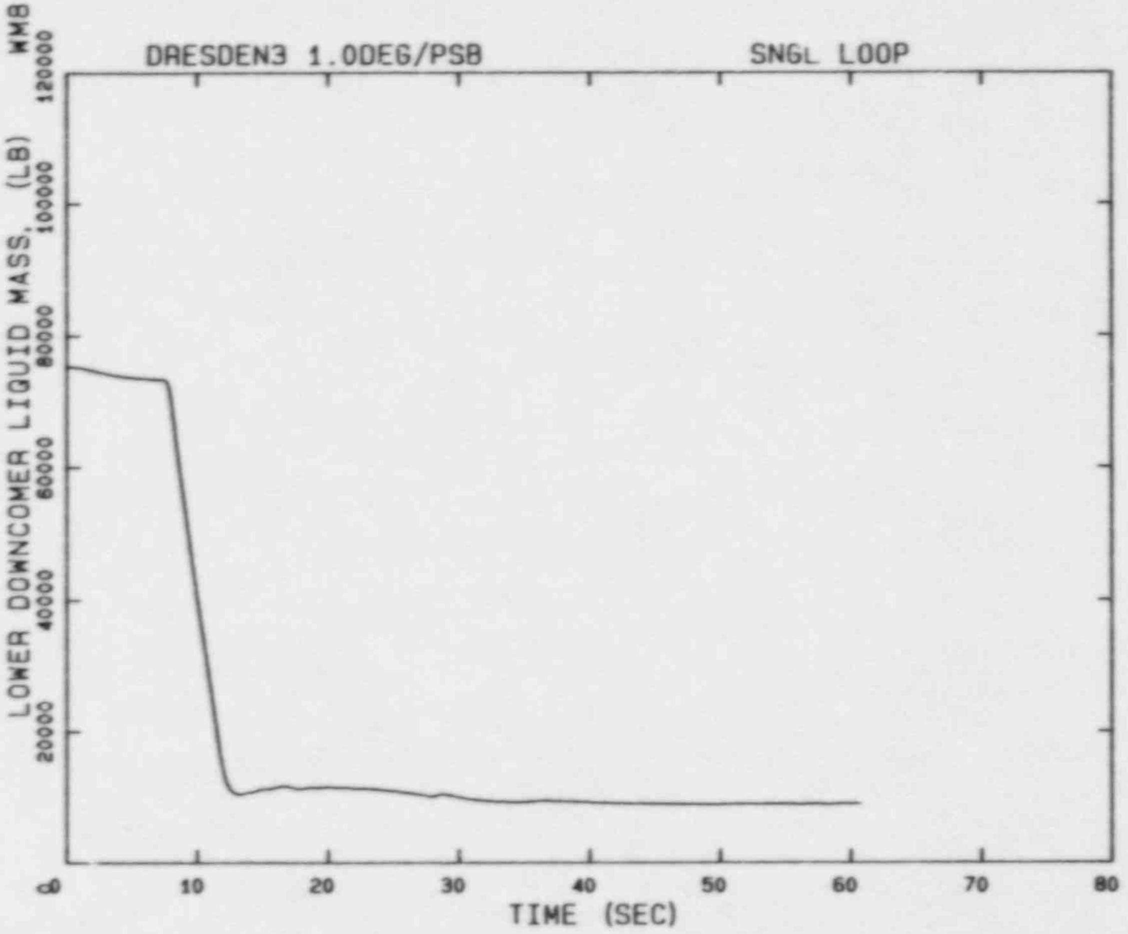


Figure 4.16 Blowdown Lower Downcomer Liquid Mass

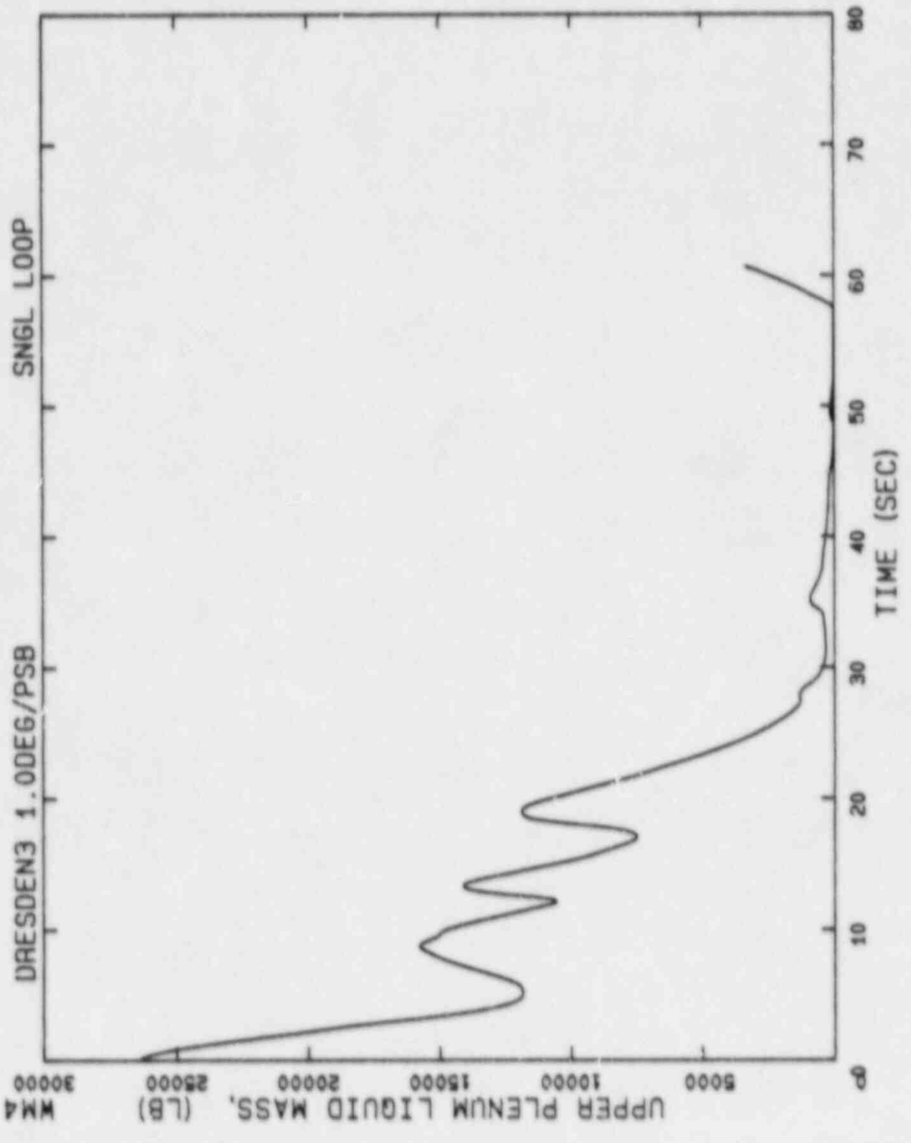


Figure 4.17 Blowdown Upper Plenum Liquid Mass

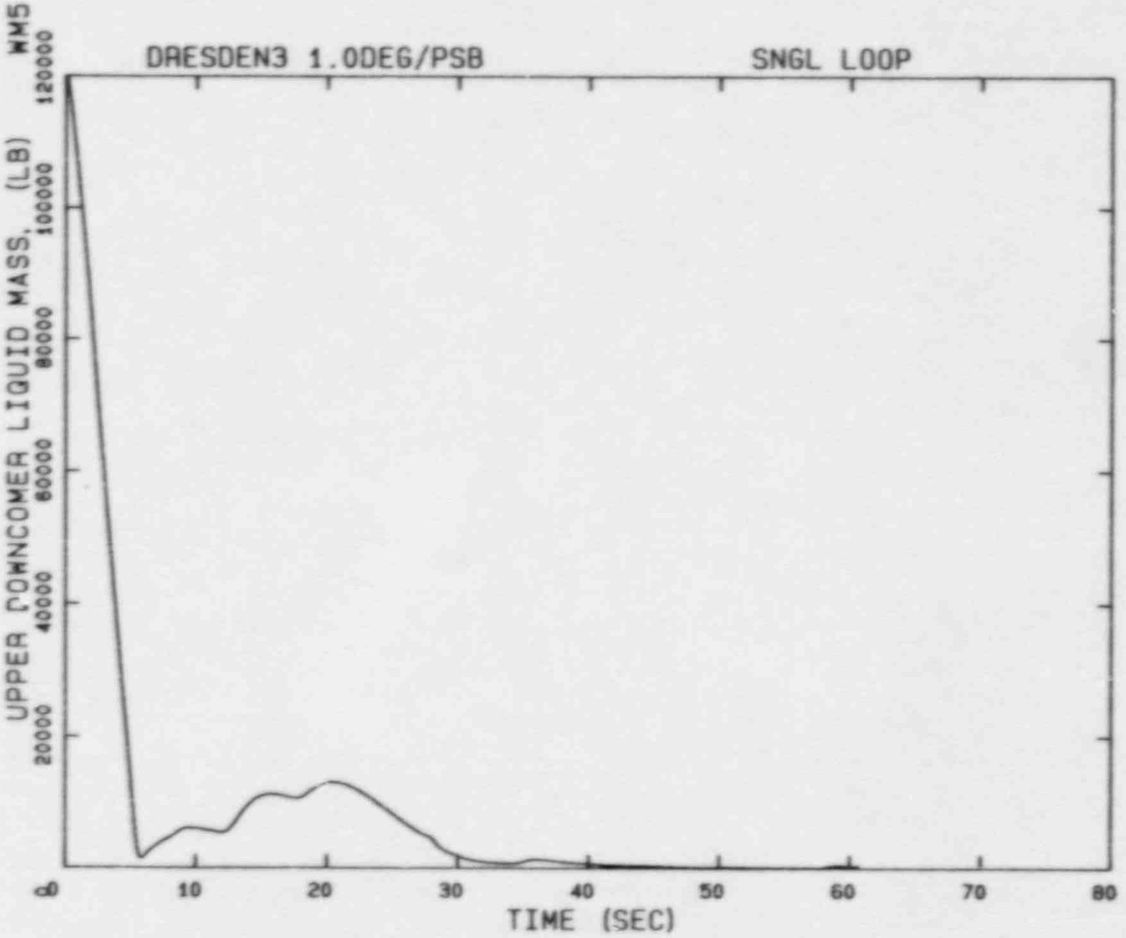


Figure 4.18 Blowdown Upper Downcomer Liquid Mass

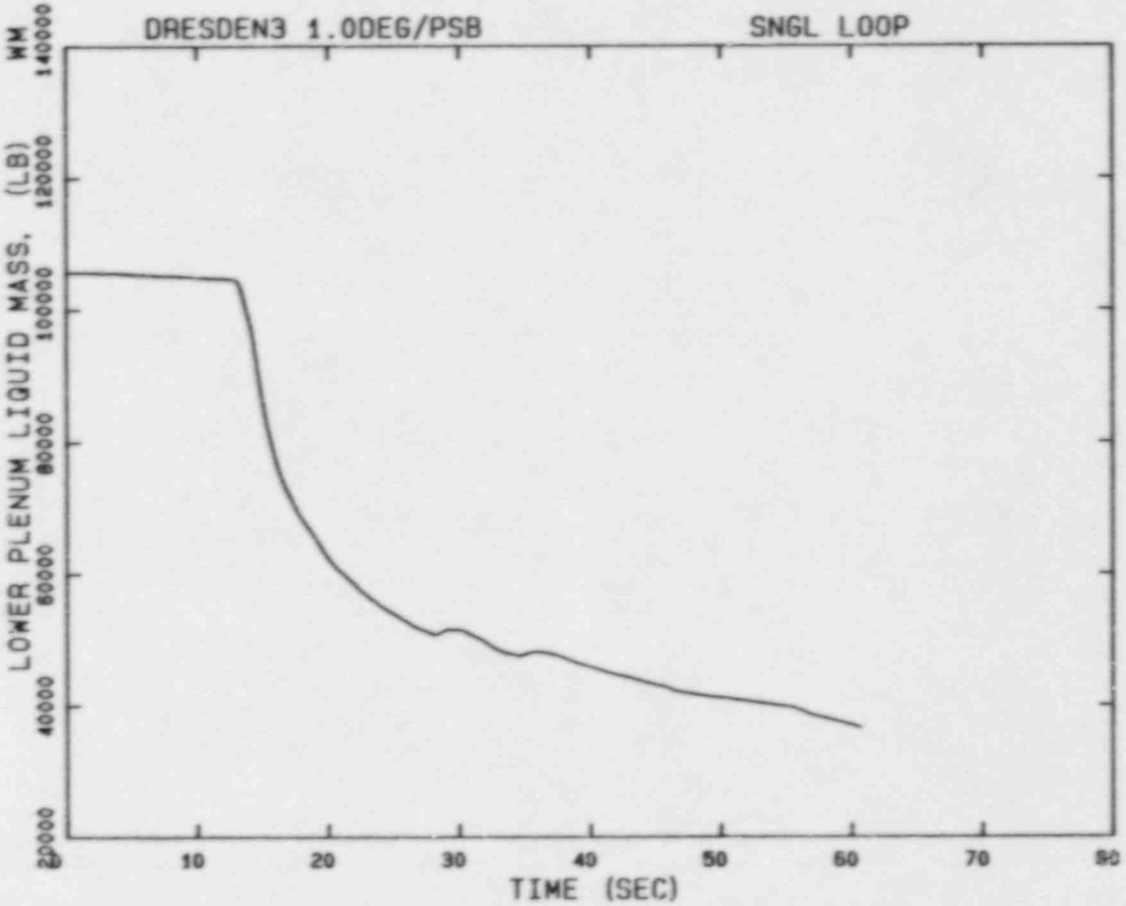


Figure 4.19 Blowdown Lower Plenum Liquid Mass

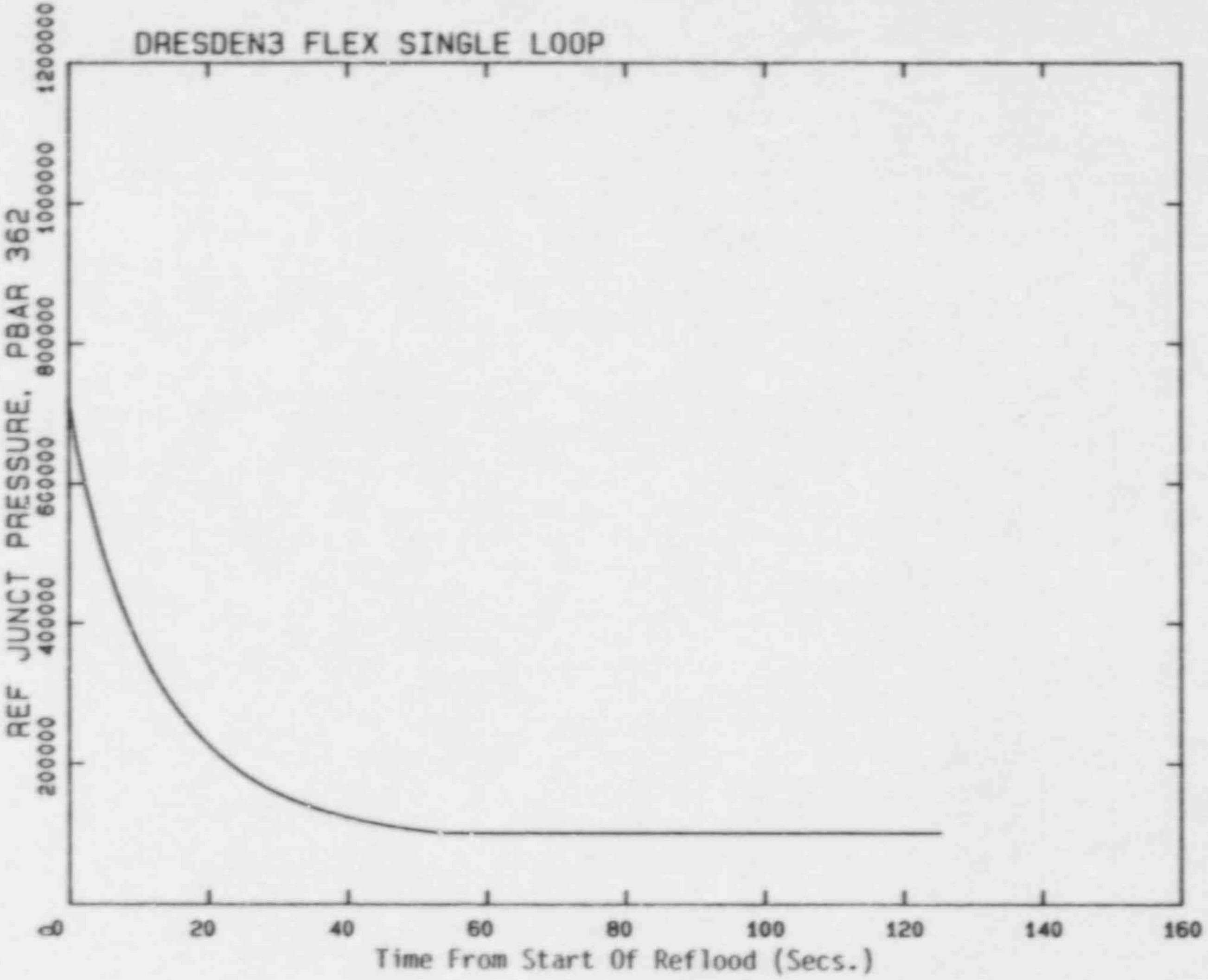


Figure 4.20 Refill/Reflood System Pressure

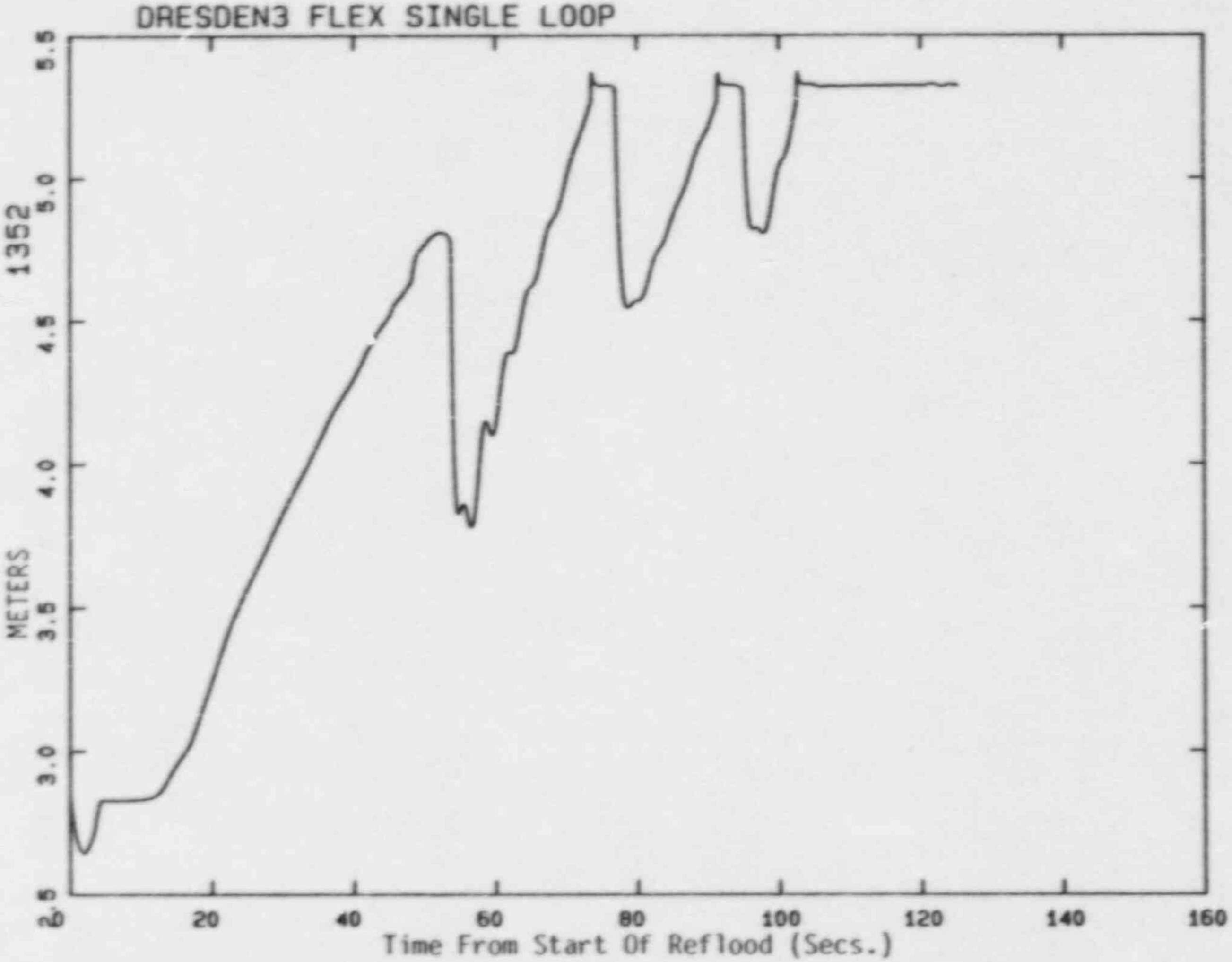


Figure 4.21 Refill/Reflood Lower Plenum Mixture Level

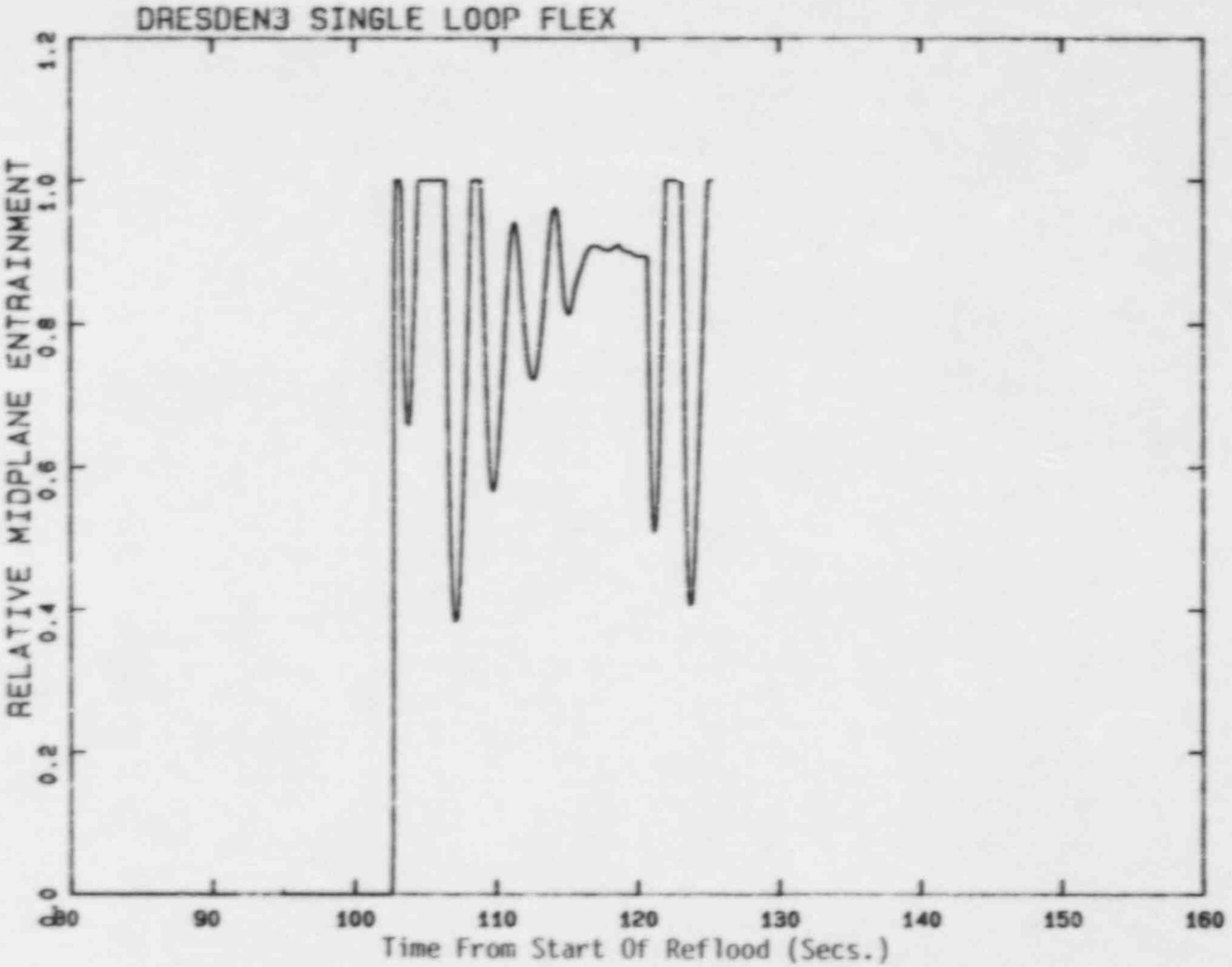


Figure 4.22 Refill/Reflood Relative Core Midplane Entrainment

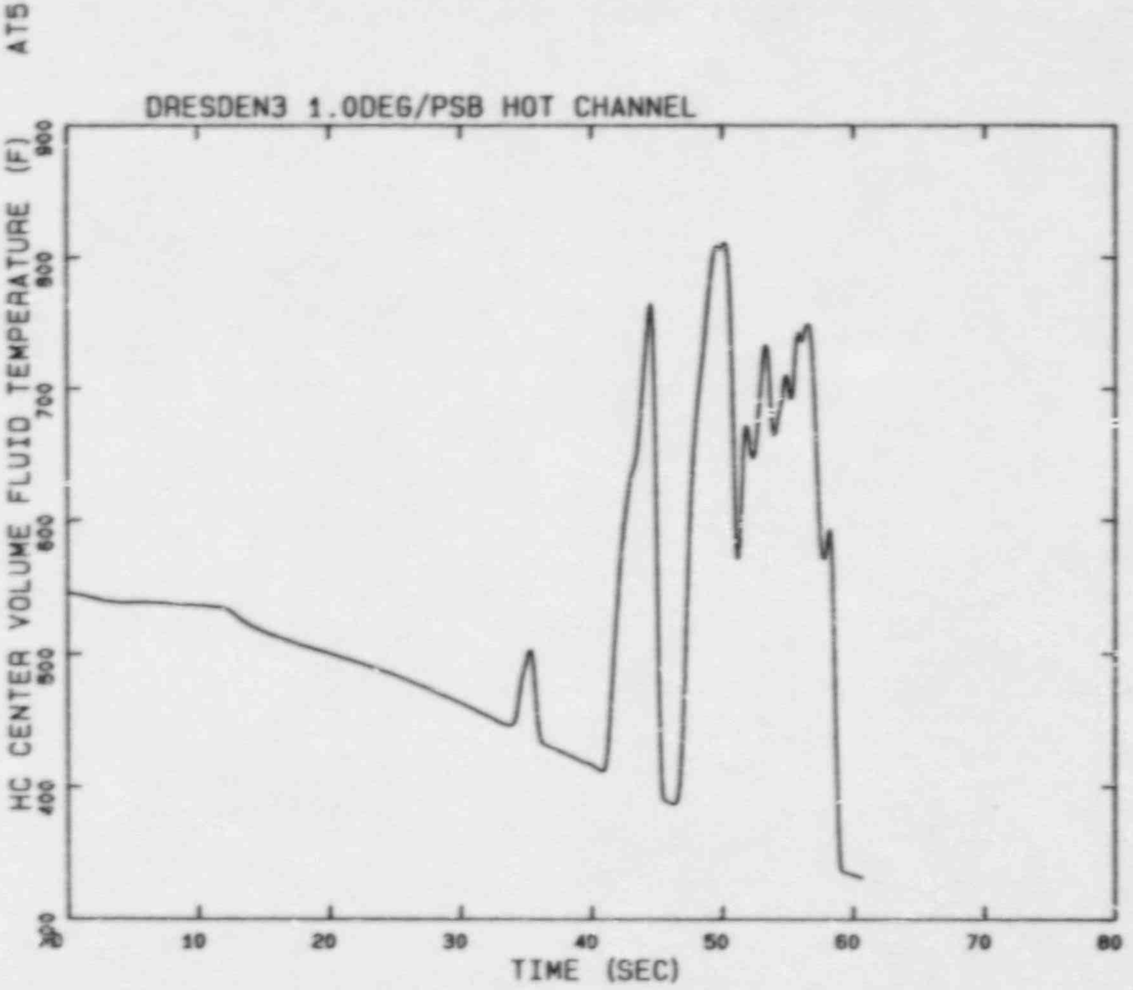


Figure 4.23 Blowdown Hot Channel Center Volume Coolant Temperature

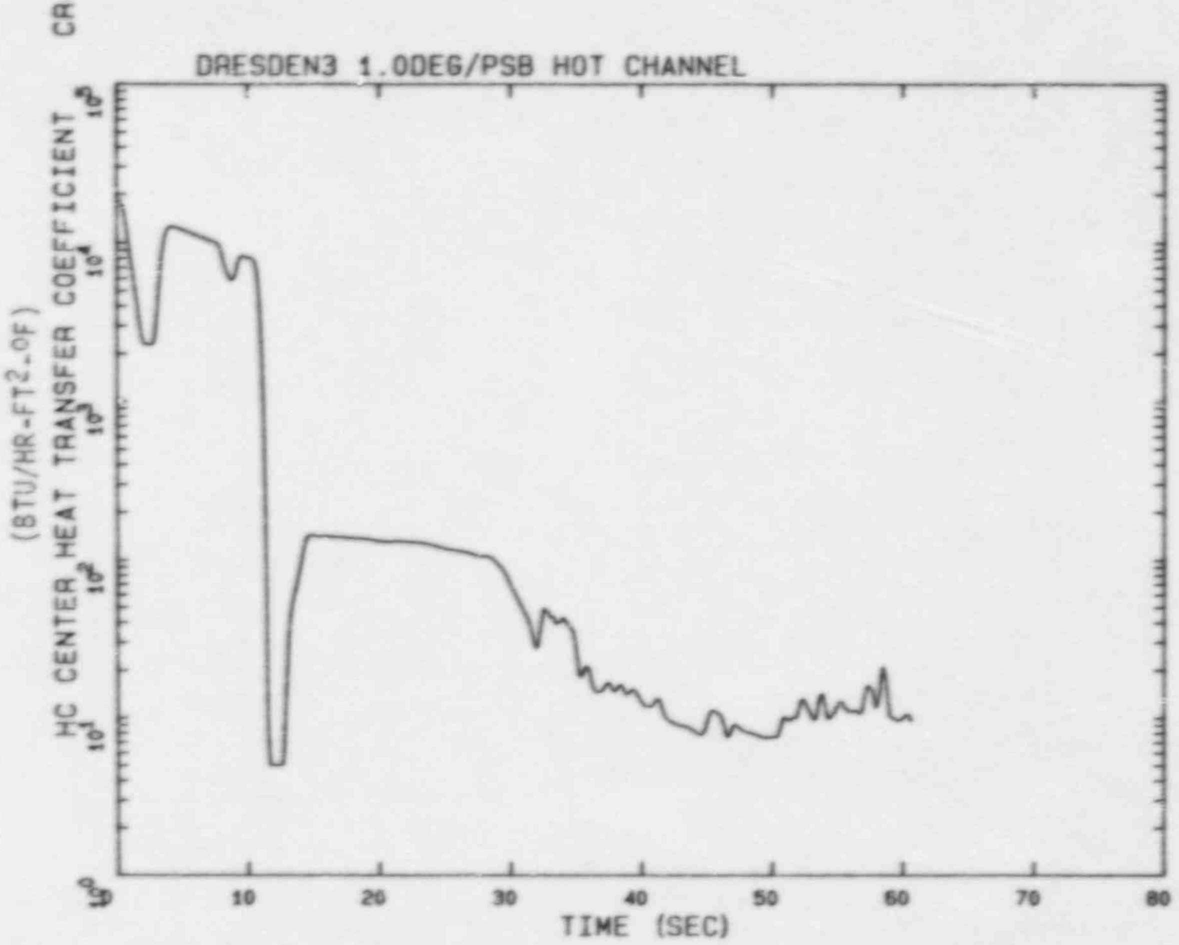


Figure 4.24 Blowdown Hot Channel Heat Transfer Coefficient

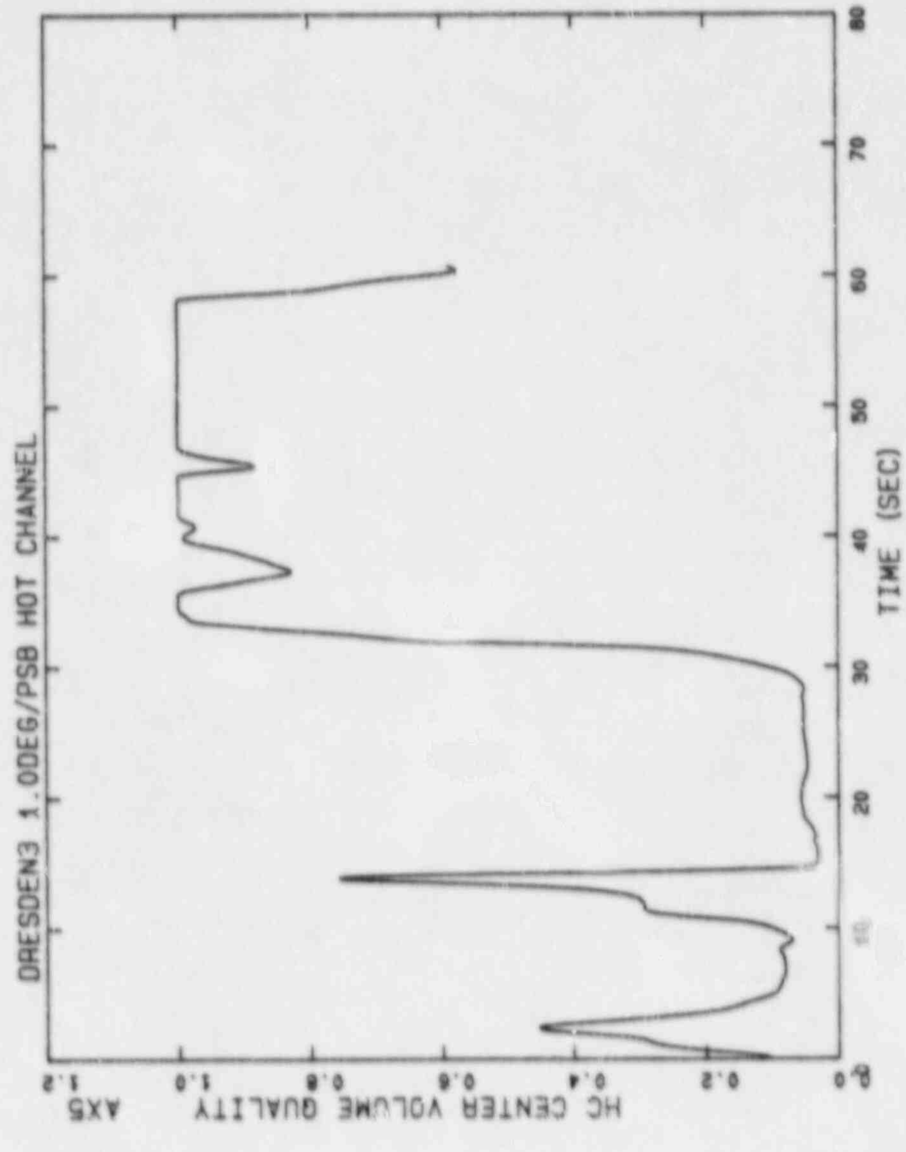
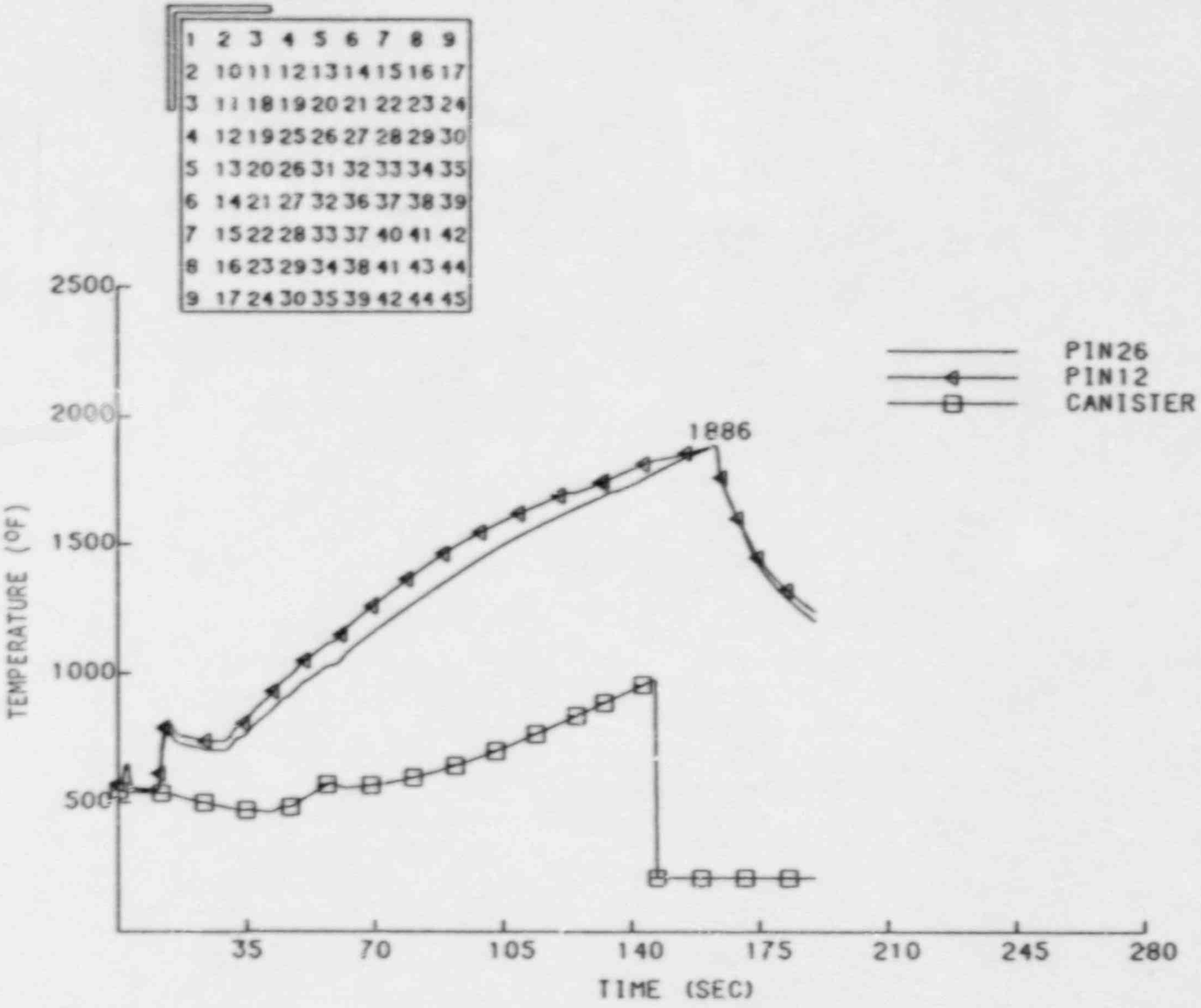


Figure 4.25 Blowdown Hot Channel Center Volume Quality



1	2	3	4	5	6	7	8	9
2	10	11	12	13	14	15	16	17
3	11	18	19	20	21	22	23	24
4	12	19	25	26	27	28	29	30
5	13	20	26	31	32	33	34	35
6	14	21	27	32	36	37	38	39
7	15	22	28	33	37	40	41	42
8	16	23	29	34	38	41	43	44
9	17	24	30	35	39	42	44	45

Figure 4.26 Typical Hot Assembly Heatup Results For 9x9 Fuel

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LOCA-ECCS ANALYSIS FOR DRESDEN UNITS DURING SINGLE LOOP OPERATION WITH ANF FUEL

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