ANCR-NUREG-1335 – RELAP4/MOD5
A COMPUTER PROGRAM FOR TRANSIENT THERMAL-HYDRAULIC ANALYSIS OF NUCLEAR REACTORS AND RELATED SYSTEMS

USER'S MANUAL

VOLUME III
CHECKOUT APPLICATIONS

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RELAP4/MOD5

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VOLUME III
CHECKOUT APPLICATIONS

AEROJET NUCLEAR COMPANY

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CHECKOUT APPLICATIONS

7. CHECKOUT OF RELAP4/MOD5

The development of Update 2 of the RELAP4/MOD5 code and options is treated in detail in Volume I of this document. Volume II follows with the application information. Volume III provides a description of the checkout process and the specific problems modeled to demonstrate the usability of the code. It should be noted that the checkout problems reported in this publication were run using Update 1 of RELAP4/MOD5. Six months of the use of Update 1 led to the identification of a number of minor errors in coding as well as some logic changes, additional Evaluation Model checks, and one model revision. These changes culminated in the development of an improved code identified as RELAP4/MOD5, Update 2. The differences between Updates 1 and 2 are outlined in Appendix I. The checkout of Update 2 is also discussed in Appendix I.

One of the eight checkout problems was a model actually tested in a Semiscale experiment. This is considered particularly significant as all other checkout problems reported herein were models of existing commerical plants for which instrumented LOCA results are not available. A comparison of the RELAP4/MOD5 and Semiscale Test S-02-9 results is given in Appendix H.

7.1 Introduction

The purpose of the checkout runs was to demonstrate that RELAP4/MOD5

(1) Operated as intended

(2) Was free of major programming errors

(3) Ran within an acceptable time for typical applications (60 min maximum for the Control Data Corporation (CDC) Model 7600 computer).

The eight problems chosen for checkout illustration are listed in Table I. These problems cover a wide range of geometric and physical conditions. Checkout was limited to the blowdown and refill phases of the transient for the eight system break response runs, since MOD5 was intended primarily as a blowdown code.

Specific Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR) plants (including scale models) were modeled for the checkout problem runs. The results of these runs are considered to represent general plant behavior, but should not be interpreted as "best estimate" blowdown analyses of the respective plants. Other modelers may have modeled these plants differently for "best estimate" analyses. The major purpose of the runs was to exercise the MOD5 version of the code and not to conduct in-depth analyses of the plants modeled.

TABLE I

SYSTEM MODELS FOR RELAP4/MOD5 CHECKOUT

Large Pressurized Water Reactor Plants

Oconee (B&W) - 200% cold leg break
Trojan (Westinghouse) - 6% cold leg break
Calvert Cliffs (CE)-1 ft^2 cold leg break, (Evaluation Model option)

Large Boiling Water Reactor Plants

Hope Creek (GE) - 200% recirculation line break
Hope Creek (GE) - 6% recirculation line break

Scale Models

Semiscale (INEL) - Small Cold leg break - equivalent to 6% break in large PWR
Semiscale (INEL) - Semiscale Test S-02-9 (200% cold leg break with ECC injection)

LOFT (INEL) - 200% cold leg break

The criteria for judging successful completion of each of the eight checkout runs are given in are Table II. In addition, it was required that MOD5 be operational on both the IBM-360 and the CDC-7600 computers. The Idaho National Engineering Laboratory (INEL) RELAP4 Code Advisory Group reviewed the results of each checkout run to ensure that the results were reasonable and that the acceptance criteria had been met. The results of all runs were accepted by this group. The overall results of the checkout calculations and the major conclusions drawn from the checkout are outlined in subsequent sections of this volume. Specific results and conclusions for each of the eight checkout runs are presented in separate appendices.

TABLE II

COMPLETION CRITERIA FOR RELAP4/MOD5 CHECKOUT RUNS

The following criteria must be met to the satisfaction of the INEL RELAP Code Advisory Group to constitute successful completion of RELAP4/MOD5 checkout runs

(1) All models operate as designed.
(2) All major logic and code errors be removed.
(3) Problem execution must extend through the refill period, for the eight blowdown runs, as defined below:[a]

    a. Breaks for which the core completely uncovers: time at which the lower plenum is completely refilled, i.e., when the water level reaches the bottom of the core.

    b. Breaks for which the core only partially uncovers: time when the core is completely recovered, i.e., when the water level reaches the top of the core. For BWR calculations, the maxmum recovered core water level need not exceed the level of jet pump suction.

(4) The code running time must be reasonable. (The target was one hour on the CDC-7600 for the eight blowdown problems.)

[a] RELAP4/MOD5 is capable of calculating core recovery within the limitations of the MOD5 models. However, these models will not adequately calculate all the reflood phenomena. MOD6 changes will address the reflood problem.

Twenty-eight additional checkout problems not illustrated within this document have also been completed. These were short problems designed to check out a broad spectrum of RELAP4 features. It was intended that they prevent coding additions to one part of the program from adversely affecting other parts and ensure a reasonable comparison of results between IBM and CDC versions. All 28 of the problems were successfully run on both the IBM and the CDC computers.

7.2 Results of Code Checkout

The eight MOD5 checkout runs were successfully completed, and the MOD5 models operate as designed. The code is free of known major programming errors. It ran smoothly and rapidly for typical application problems. RELAP4/MOD5 performed well during the checkout and is substantially improved over MOD3, not only in terms of new models added, but also in terms of general code operability. The new junction smoothing option (for mixture level crossing vertical slip junctions from above) enables the code to run through problem areas where it previously would have exhibited superheat, bogged down, or aborted. Improvements have decreased running time significantly under water packing conditions. RELAP4/MOD5 is operational on the IBM-360 at INEL, the CDC-7600 at Brookhaven National Laboratory, and the CDC-7600 at Berkeley. Some potential problems which could be encountered in using MOD5 are discussed in Section 7.3. The problems can be circumvented by judicious option use and/or system nodalization.

The completion criteria established by Aerojet Nuclear Company for checkout of MOD5 were satisfied for all eight checkout runs, with one exception. The exception was that the Semiscale Test S-02-9 application required 1.3 hours of CDC-7600 computer time to run through refill, whereas the target was one hour. MOD5 was judged acceptable for release as a production code despite this exception. All the RELAP4/MOD5 models are operational, and known coding and logic errors have been removed. Seven of the eight problems ran in less than one hour. In most cases, the CDC-7600 time was significantly less than one hour. Running times, transient times, and nodalization information for each checkout problem are given in Table III.

7.3 Problem Avoidance

The major coding and logic errors have been removed from RELAP4/MOD5. Application of the program requires considerable judgment due to the complexity of the internal calculations, the large number of individual component models, component model interactions, and nonequilibrium effects. The experience gained from those checkout runs where significant problems were encountered, is presented in the following subsections.

7.3.1 Momentum Equation. Potential problem areas exist which are associated with approximations made in the solution of the RELAP4 momentum equation. Under certain conditions, these can result in incorrect values for subcooled critical flow and/or increased running time requirements.

(1) Under conditions of extremely small break flow (on the order of 10 lb/sec), it is possible to encounter discrepancies in calculated subcooled critical flow values. This problem was encountered in the Semiscale run and is disucssed in Appendix F. The problem has not been encountered elsewhere and is thought to occur only in isolated cases. For situations in which a very low subcooled break flow occurs (on the order of tens to hundreds of pounds per second), the break flow values should be thoroughly examined. If a discrepancy is evident, a leak junction should be used at the break. Use of a leak junction was found to give correct flow values.

(2) Running time problems may be encountered at low pressures when momentum flux is used, due to oscillations in and out of choking. This is caused by an insufficiently accurate calculation of the time derivative of flow (dW/dT) for choked flows with small time step sizes. The problem was found to be significantly mitigated by the choking smoothing option.

TABLE III

SUMMARY OF TRANSIENT AND RUN TIMES FOR RELAP4/MOD5 CHECKOUT PROBLEMS

Appendix	Checkout Problem	Total Transient Time	CPU Time Requirements[a]	Nodalization
A	Babcock & Wilcox PWR Cold Leg Large Break	(1) 22 seconds with downcomer penetration model (2) 31.5 seconds with vertical slip only	(1) 15 minutes with downcomer penetration model (2) 24.2 minutes with vertical slip only	(1) 41 volumes, 59 junctions (2) 42 volumes, 60 junctions
B	Westinghouse PWR Cold Leg Small Break	900 seconds	50 minutes	22 volumes, 34 junctions
C	Combustion Engineering PWR Cold Leg Intermediate Sized Break	98 seconds	48 minutes	39 volumes, 56 junctions
D	General Electric BWR Recirculation Line Large Break	165 seconds	36.1 minutes	23 volumes, 33 junctions
E	General Electric BWR Recirculation Line Small Break	450 seconds	27 minutes	16 volumes, 25 junctions
F	INEL Semiscale Cold Leg Small Break	273 seconds	8.3 minutes	15 volumes, 20 junctions
G	INEL LOFT Cold Leg Large Break	35 seconds	50 minutes	34 volumes, 40 junctions
H	INEL Semiscale Test S-02-9	42 seconds	78.1 minutes	37 volumes, 43 junctions

[a]. All runs were made on the CDC-7600

(3) Extensive CPU running time sometimes occurs under strictly subcooled conditions at low pressure. This is independent of the choking-associated problem referred to in Item (2) above. Conditions required for occurrence of this problem have not been completely identified. While this has not been an impediment thus far, it could be a problem in reflood runs.

7.3.2 Running Time. A second running time problem sometimes occurs at the beginning of reflood when there was little mass in the core. There may be sufficient pressure differences to cause mass flow rates which would show an extraction of more than the existing mass in a volume when small time steps are used. This problem has not been completely defined and will be addressed in a future version of the code.

7.3.3 Superheating. The junction smoothing option greatly alleviates the superheating problem which sometimes occurs when a mixture level crosses a vertical slip junction from above. In cases when superheating had previously amounted to several hundred degrees, the junction smoothing option reduced the superheating to only a few degrees.

A solution to the corresponding case of a mixture level crossing a vertical slip junction from below has not been completed. Therefore, this may be a problem under certain conditions in MOD5 modeled runs.

7.3.4 Emergency Core Cooling (ECC) Bypass. The Evaluation Model (EM) logic appears to function properly. Calculation of ECC bypass requires special attention when making an EM run, since spurious flow spikes may prematurely signal end-of-bypass.

7.4 Conclusions

The following have been concluded from the RELAP4/MOD5 checkout:

(1) All eight of the MOD5 checkout runs were successfully completed.

(2) The completion criteria established for checkout of MOD5 were satisfied for all eight runs with one exception. The exception was that calculation of Semiscale Test S-02-9 required 1.3 hours of CDC-7600 computer time to run through refill, whereas the target was one hour.

(3) RELAP4/MOD5 is operational on the IBM-360 as well as the CDC-7600.

(4) RELAP4/MOD5 runs smoothly and rapidly and is a substantial improvement over MOD3. Improvement is not only in terms of new models added, but also in terms of general code operability and running time.

(5) Checkout of MOD5 identified a few potential problem areas that might be encountered during the course of a particular run. These problem areas were discussed in Section 7.3.

(6) Judicious use of MOD5 options and system nodalization must be made in order to circumvent running time and other problems.

(7) The primary purpose of the MOD5 checkout was to debug the code. The results should not be interpreted in terms of code or component model verification. Debugging of MOD5 did not qualify it as a verified computer code.

(8) It is possible that additional errors and problems may be identified as the code is further exercised. The MOD5 checkout process has, however, removed a large number of problems which would not otherwise have been removed until the code was in a production status.

APPENDIX A

PWR LARGE COLD LEG BREAK - BABCOCK & WILCOX PLANT

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APPENDIX A

PWR LARGE COLD LEG BREAK - BABCOCK & WILCOX PLANT

1. INTRODUCTION

A Babcock and Wilcox large Pressurized Water Reactor (PWR) (Oconee Plant) was modeled with RELAP4/MOD5 to represent a 200% offset shear break in the pump discharge side of one of the cold legs. Two cases were run for this plant:

Case 1: Downcomer penetration model based on the 1:15 scale glass vessel tests of the Battelle-Columbus Laboratory (BCL) experiments, described as the BCL downcomer model in Volume I, Subsection 3.6.4.

Case 2: Downcomer modeled with vertical slip only.

The system model and assumptions used, the calculated results, and the conclusions drawn in both cases are presented. Some interpretation of the results is based on digital data and plotted output which were too voluminous to be included in this appendix. The B&W model presented was used for program checkout and should not be considered a comprehensive study of the LOCA response of the actual plant.

2. SYSTEM MODELS AND ASSUMPTIONS

The RELAP4/MOD5 models used to describe the Babcock & Wilcox Plant are shown in Figures A-1 and A-2. Figure A-1 represents the plant model for Case 1 in which the downcomer penetration model based on Battelle-Columbus data was used. Figure A-2 represents the plant model for Case 2 in which vertical slip only was used in the downcomer. Tables A-I and A-II identify the nodalization and fill junctions for Case 1 and

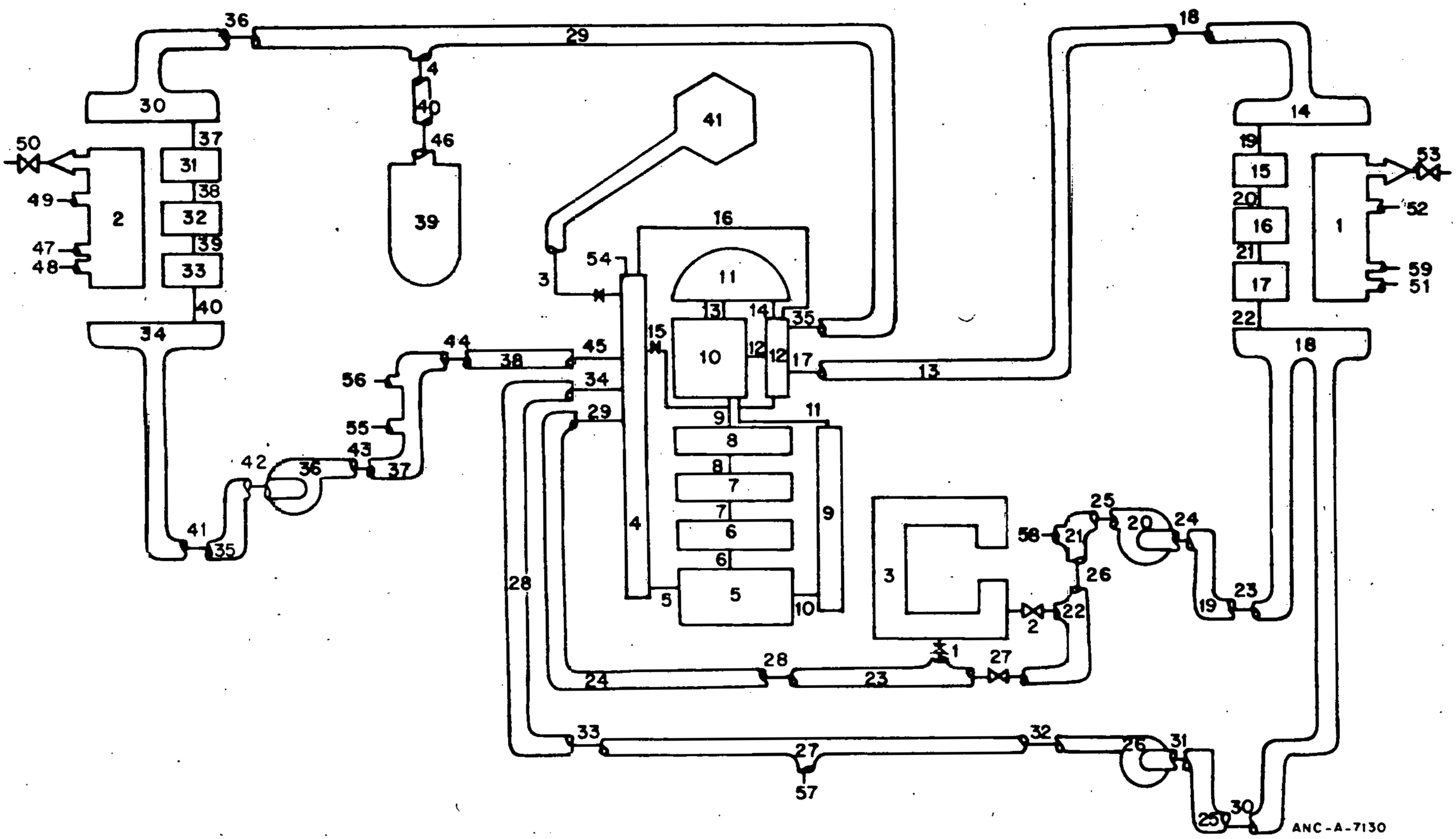

Fig. A-1 Nodalization for 200% break - Babcock and Wilcox Plant with downcomer penetration modeling.

TABLE A-I

CASE 1 - VOLUME AND FILL JUNCTION IDENTIFICATION FOR 200% BREAK - BABCOCK AND WILCOX PLANT WITH DOWNCOMER PENETRATION MODELING

Volume No.	Description	Junction No.	Description
1	Steam Generator Secondary Side	47	Steam Generator Auxiliary Feed
2	Steam Generator Secondary Side	48	Steam Generator Feed Water Inlet
3	Containment Building	49	Steam Outlet
4	Downcomer	50	Steam Generator Safety Valve
5	Lower Plenum	51	Steam Generator Feed Water Inlet
6	Lower 1/3 of Core	52	Steam Outlet
7	Middle 1/3 of Core	53	Steam Generator Safety Valve
8	Upper 1/3 of Core	54	Low Pressure Safety Injection Coolant
9	Core Bypass	55,56,57,58	High Pressure Safety Injection Coolant
10	Upper Plenum	59	Steam Generator Auxiliary Feed
11	Upper Head		
12	Exit Annulus		
13	Hot Leg to Maximum Elevation		
14	Steam Generator Inlet Plenum with Hot Leg to Maximum Elevation		
15,16,17	Steam Generator Active Tubes		
18	Steam Generator Exit Plenum with Pump Suction Legs to Minimum Elevation		
19	Pump Suction Leg from Minimum Elevation to Pump		
20	Pump		
21,22,23,24	Pump Discharge Leg		
25	Pump Suction Leg from Minimum Elevation to Pump		
26	Pump		
27,28	Pump Discharge Leg		
29	Hot Leg to Maximum Elevation		
30	Steam Generator Inlet Plenum with Hot Leg to Maximum Elevation		
31,32,33	Steam Generator Active Tubes		
34	Steam Generator Exit Plenum to Minimum Elevation		
35	Two Pump Suction Legs from Minimum Elevation		
36	Two Pumps		
37	Two Pump Discharge Lines		
38	Two Pump Discharge Lines		
39	Pressurizer		
40	Pressurizer Surge Line		
41	Two Acumulators (Flood Tanks)		

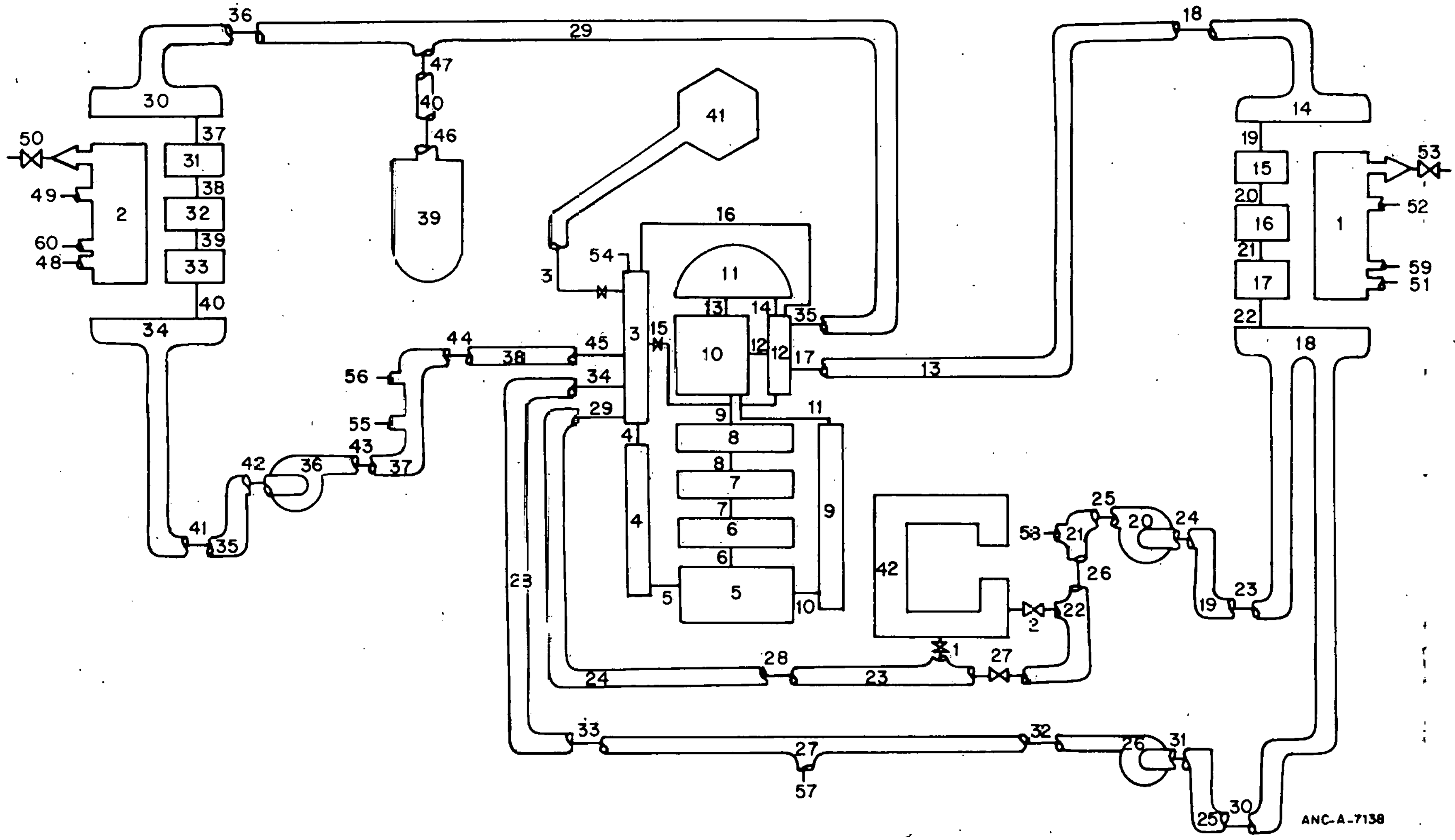

Fig. A-2 Nodalization for 200% break - Babcock and Wilcox Plant with vertical slip only downcomer modeling.

TABLE A-II

CASE 2 - VOLUME AND FILL JUNCTION IDENTIFICATION FOR 200% BREAK-BABCOCK AND WILCOX PLANT WITH VERTICAL SLIP ONLY DOWNCOMER MODELING

Volume No.	Description
1	Steam Generator Secondary Side
2	Generator Secondary Side
3	Upper Downcomer (Upper Annulus)
4	Lower Downcomer
5	Lower Plenum
6	Lower 1/3 of Core
7	Middle 1/3 of Core
8	Upper 1/3 of Core
9	Core Bypass
10	Upper Plenum
11	Upper Head
12	Exit Annulus
13	Hot Leg to Maximum Elevation
14	Steam Generator Inlet Plenum with Hot Leg to Maximum Elevation
15,16,17	Steam Generator Active Tubes
18	Steam Generator Exit Plenum with Pump Suction Leg to Minimum Elevation
19	Pump Suction Leg from Minimum Elevation to Pump
20	Pump
21,22,23,24	Pump Discharge Leg
25	Pump Suction Leg from Minimum Elevation to Pump
26	Pump
27,28	Pump Discharge Leg
29	Hot Leg to Maximum Elevation
30	Steam Generator Inlet Plenum with Hot Leg to Maximum Elevation
31,32,33,	Steam Generator Active Tubes
34	Steam Generator Exit Plenum with Pump Suction Legs to Minimum Elevation
35	Two Pump Suction Legs from Minimum Elevation to Pump
36	Two Pumps
37	Two Pump Discharge Lines
38	Two Pump Discharge Lines
39	Pressurizer
40	Pressurizer Surge Line
41	Two Accumulators (Flood Tanks)
42	Containment

Junction No.	Description
48	Steam Generator Feed Water Inlet
49	Steam Outlet
50	Steam Generator Safety Valve
51	Steam Generator Feed Water Inlet
52	Steam Outlet
53	Steam Generator Safety Valve
54	Low Pressure Safety Injection Coolant
55,56,57,58	High Pressure Safety Injection Coolant
59,60	Steam Generator Auxiliary Feed

Case 2, respectively. There is a difference between Cases 1 and 2 in terms of nodalization. The upper and lower downcomers are combined into a single volume for Case 1, while for Case 2, each is represented by a separate volume.

Additional modeling information and assumptions are given below. This information applies to both Case 1 and Case 2 unless otherwise indicated.

(1) Vertical slip was modeled at the junction between the lower downcomer and the lower plenum.

(2) A 1.0 multiplier was used for the Homogeneous Equilibrium Model (HEM) critical flow model. A 0.9 multiplier was used on both the Henry-Fauske flow and the extended Henry-Fauske critical flow models. The transition quality assumed at the junction between the Henry-Fauske and HEM models was 0.01.

(3) An input data ITCV=21 check valve was used for the reactor vessel vent valve. This valve opens and closes with appropriate differential pressure. A trip signal was not used.

(4) One check valve of the input data ITCV=22 through 40 type was used at the accumulator line. These valve types behave as a ITCV=21 check valve, opening and closing on pressure differentials, but having a trip signal which closes the valve. The trip was set to close the valve when the accumulator mixture level decreased to 0.01 ft.

(5) The downcomer penetration model was used only for Case 1, the run which had the upper annulus and the downcomer of the reactor vessel combined into one node.

(6) Vertical slip was used between the upper and lower downcomers for Case 2 because of the separate noding.

(7) Stagnation properties were used for the break flow calculation throughout each run.

An input error was detected in the High and Low Pressure Injection Systems (which were modeled as fills) after these two problem runs were completed. The error allowed a 4% excess coolant flow rate into the lower plenum after 25 sec of transient time. This error should not affect the refill stage of the blowdown, but should be noted if these inputs are to be used elsewhere.

A second error was also noted. The value of the resistance in Junction 16 between the upper downcomer (upper annulus) and the exit annulus was not correctly specified. Although the forward and reverse flow loss coefficients for Junction 16 should be equal, the coefficient in the reverse direction was inadvertently set to zero. The problem was later run for the vertical slip only case with the correct value of junction resistance. This increased the flow resistance between the exit annulus and the upper downcomer volumes. This in turn provided the core flows shown in Figures A-11 and A-13.

Upper plenum data are missing from the input listing (Section 6) per the Babcock and Wilcox Company request. These data are treated as proprietary information.

3. RESULTS

RELAP4/MOD5 ran smoothly and had a reasonable processing time. The transient time for Case 1 from break initiation to lower plenum refill, was 22 sec. Fifteen minutes of Central Processing Unit (CPU) time for the Control Data Corporation (CDC) 7600 computer at the Brookhaven National Laboratory was required. The refill and CPU times for Case 2 were 31.5 sec and 24.2 min respectively. An interpretation of the computed transients for both cases is provided.

Figures A-3 through A-17, contained in Section 5 of this appendix, illustrate the significant results of the two transients. The results from Cases 1 and 2 appear on each figure. Case 1 (downcomer penetration model) is indicated by crosses '+' and Case 2 (vertical slip only) by stars '*'. The downcomer penetration model run was terminated at 29.3 sec while the vertical slip only model was run until 35.8 sec. The general characteristics of both transients were similar, except that the downcomer penetration model predicted earlier lower plenum penetration than did the vertical slip only model. Some of the major events of the transient are discussed below with reference to Figure A-3. This is followed by a summary discussion of the following figures.

Figure A-3 illustrates the behavior of the total mass in the lower plenum during the course of the transient. Referring to this figure, the following events are related:

(1) 0.01 through 2.3 sec: System blowdown occurred. Flow traveled from the lower plenum, up the downcomer, and out the break.

(2) 2.3 through 5.3 sec: The intact loops injected coolant into the reactor vessel at a rate which exceeded the break flow. This, in turn, forced coolant back into the lower plenum.

(3) 5.3 through 8.2 sec: Coolant flow rate from the intact loops decreased. Net flow was again toward the cold leg break.

(4) 8.2 sec: Mixture level reached the junction elevation between the downcomer and the lower plenum. From this point on, depressurization removed lower plenum coolant at a slower rate, as noted by slope decrease in the plotted trace in Figure A-3.

(5) 13.1 sec: The accumulator turned on.

a. Using the downcomer penetration model, which actuated at this time, most of the injected accumulator coolant flowed directly into the lower plenum.

b. Using the vertical slip only model, the accumulator coolant bypassed the lower downcomer, began to fill the upper downcomer, and flowed out the break (also shown in Figure A-7).

(6) 22.0 sec: The lower plenum was refilled, when using the downcomer penetration model.

(7) 22.8 sec: The containment pressure began to exceed the system pressure for Case 2 (using vertical slip only to describe downcomer penetration). Flow entered the system through the break. The lower plenum began to refill. This can be seen as a slight negative flow on Figures A-7 and A-8. The fluid quality was high which accounts for the low mass flow rate.

(8) 25.0 sec: High Pressure Injection System (HPIS) and Low Pressure Injection System (LPIS) coolant entered the system for both cases.

(9) 29.3 seconds: Run for downcomer penetration model was terminated.

(10) 31.5 seconds: Lower plenum was full in the vertical slip only case.

(11) 31.5 through 35.5 sec: Flashing occurred in Case 2 when the lower plenum injected subcooled fluid into the core. This created pressure oscillations which forced the lower plenum mass up the downcomer. Pressure oscillations had not been as noticeable when the downcomer penetration model began injecting, because the downcomer pressure exceeded the system pressure sufficiently to override the flashing pulses.

Figures A-4 through A-15 illustrate additional characteristics of the transient. Notable occurrences in these plots are as follows:

(1) Figure A-6: Lower plenum zero quality occurred at 22 and 31 sec for Cases 1 and 2, respectively.

(2) Figure A-7: The increase in mass flux at the break for Case 2 was shortly after 13 sec when the accumulator initiated, thus illustrating ECC bypass. The break mass flux became negative for Case 2 at approximately 23 sec when the containment pressure exceeded system pressure. The oscillatory behavior seen primarily in the downcomer penetration model after 21 sec is discussed in connection with Figure A-9.

(3) Figure A-9: This illustrates accumulator initiation at 13 sec. The lower plenum was refilled at 22 sec when the downcomer penetration model was used (see Figures A-3 and A-6). Liquid then entered the bottom of the core and was vaporized. The core pressure increased slightly and this initiated oscillatory flow behavior at the core inlet (see Figure A-10). The effects of this behavior were propagated throughout the system, as can be seen in many of the figures following A-10.

(4) Figure A-10: The core flow was characteristic of a cold leg break. Severe oscillations began after 21 sec, as discussed above. Figure A-11 illustrates the core inlet mass flux after the Case 2 upper downcomer-exit annulus leak (J16) had been corrected to account for the reverse flow loss coefficient.

(5) Figure A-12: The core outlet flow oscillations began at 23 sec and were delayed from those at the inlet (see Figure A-9).

(6) Figure A-13: The core outlet flow with corrected Junction 16 loss coefficient can be seen.

(7) Figures A-14, -15, and -16: The temperature behavior can be correlated generally to the corresponding core mass flow behavior. Core temperature behavior with and without the downcomer penetration model is significantly different due to the delay in lower plenum refill.

(8) Figure A-17: shows the operation of input ITCV=21 check valve which modeled the reactor vessel vent valves.

4. CONCLUSIONS

In general, RELAP4/MOD5 ran smoothly and had no major difficulties. All models met expectations. Both cases ran well within the established time limit of one hour on the CDC 7600 computer. The completion criteria for the MOD5 checkout runs listed in Volume III, Section 7.2 were satisfied.

CPU running time increased significantly when the cold leg fluid quality approached zero. This did not cause significant problems for the two large breaks modeled. Renodalization to larger volumes may be required for smaller breaks in order to reduce running time requirements.

Use of the downcomer penetration model based on Battelle-Columbus (Case 1) data led to the occurrence of downcomer penetration (13.1 sec) significantly before that predicted with vertical slip only (23.4 sec). This led to significant differences in calculated system behavior for times after 13 sec. It is of interest that the Semiscale comparison (Section 4, Appendix H) shows vertical slip only modeling to be closer to experimental results for that case. The downcomer penetration model was in the reflood mode after 22 sec. This led to oscillatory behavior and the run was terminated at 29.3 sec.

Core inlet flow oscillations started for Case 1 at 22 sec when the lower plenum refilled. As fluid entered the bottom of the core at 22 sec it flashed, increased core pressure slightly, and initiated the observed oscillatory behavior. The effects of these oscillations are propagated throughout the modeled system, as illustrated in Figure A-7 and succeeding figures. The calculated oscillatory behavior is not interpreted to be correct in detail. It is considered to be the result of homogeneous modeling by RELAP4 which exposes the fluid to the full heat capacity of the core where in reality the fluid level would exist only at a low core elevation. As discussed in Volume I, Section 1, RELAP4/MOD5 does not calculate all reflood phenomena adequately.

5. OUTPUT DATA

The output data traces for the Babcock and Wilcox 200% break problem are included as Figures A-3 through A-17 in this section. Case 1 (downcomer penetration) data are traced by a '+', while Case 2 (vertical slip only) data are traced by a '*'.

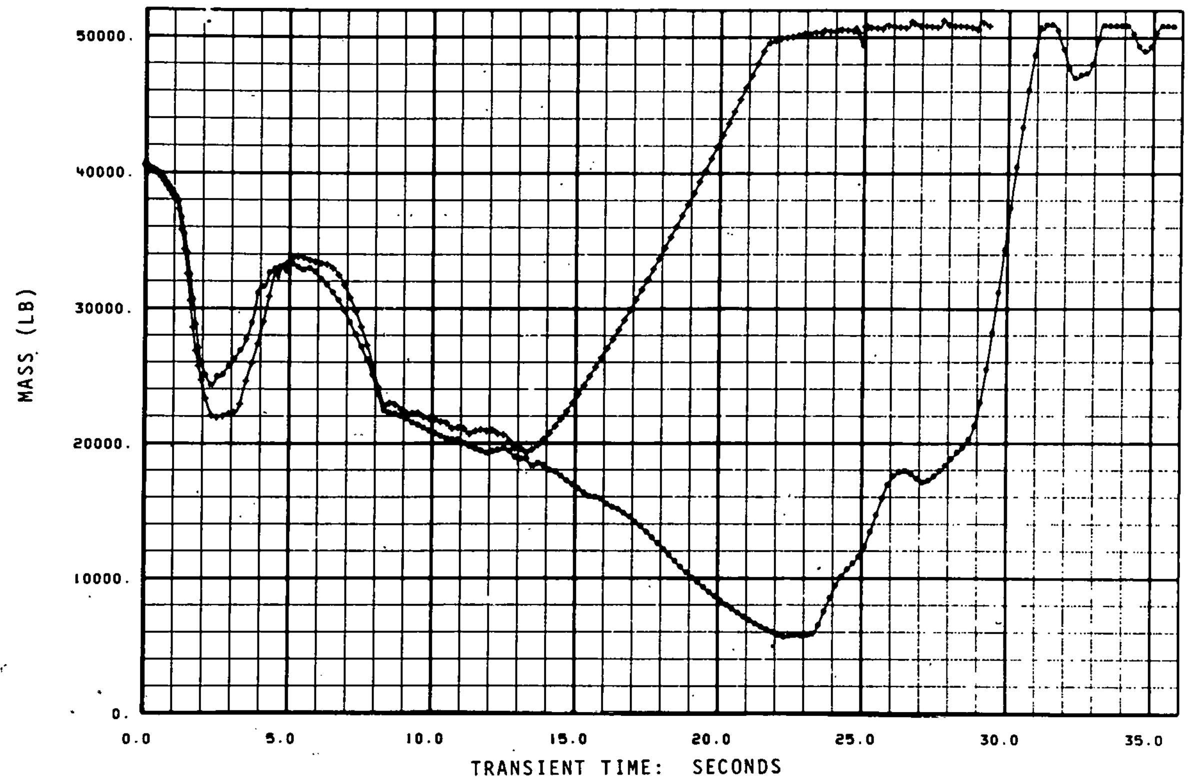

Fig. A-3 Total mass in lower plenum - Babcock and Wilcox Plant (200% break).

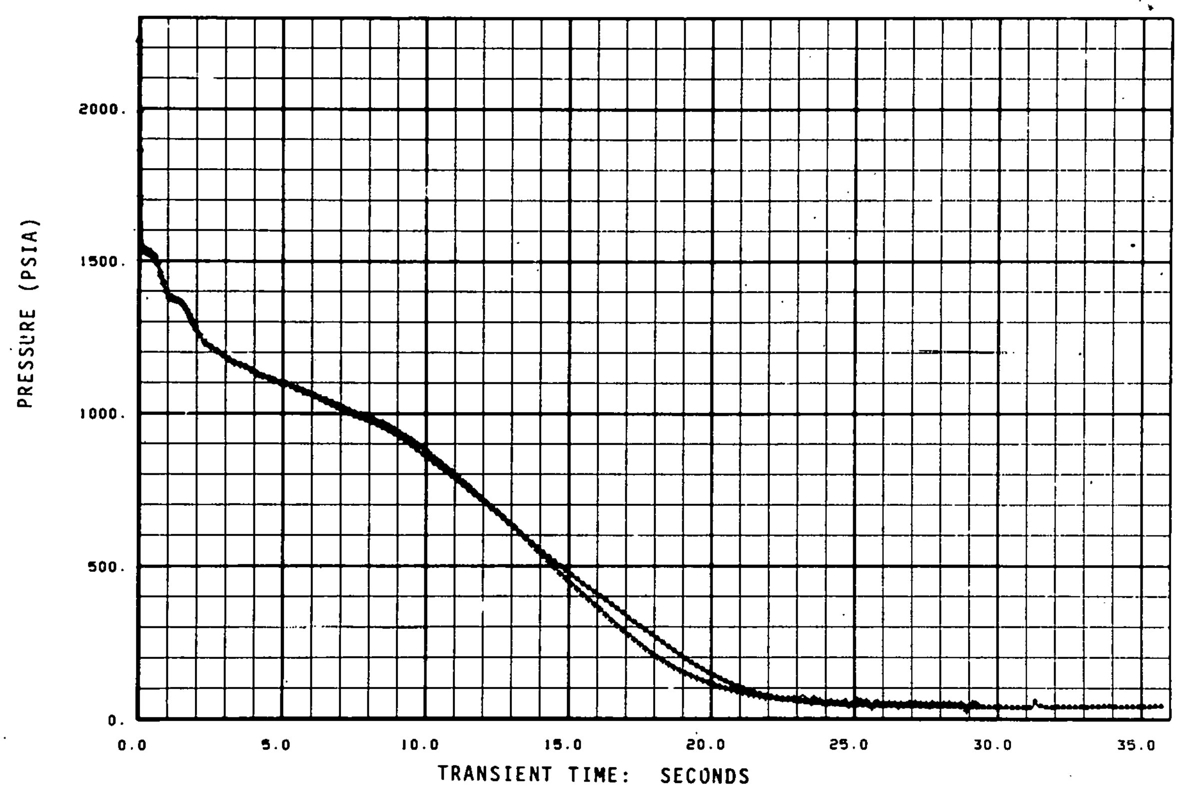

Fig. A-4 Average pressure in lower plenum - Babcock and Wilcox Plant (200% break).

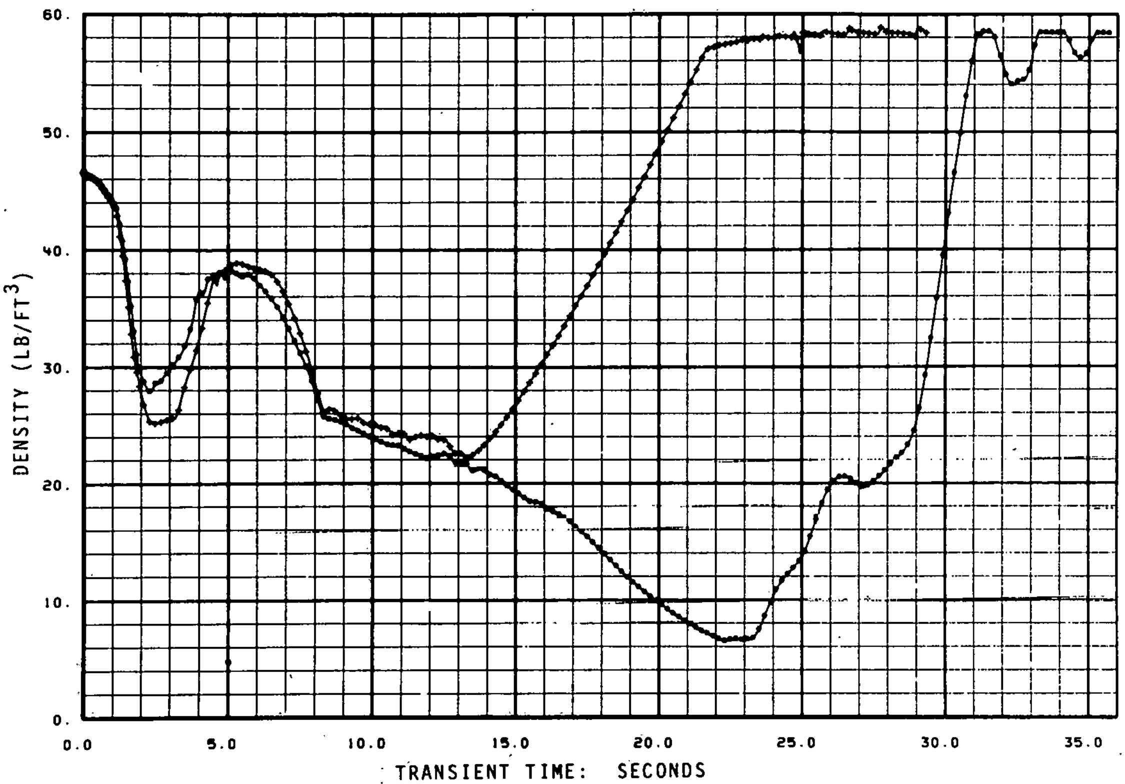

Fig. A-5 Average density in lower plenum - Babcock and Wilcox Plant (200% break).

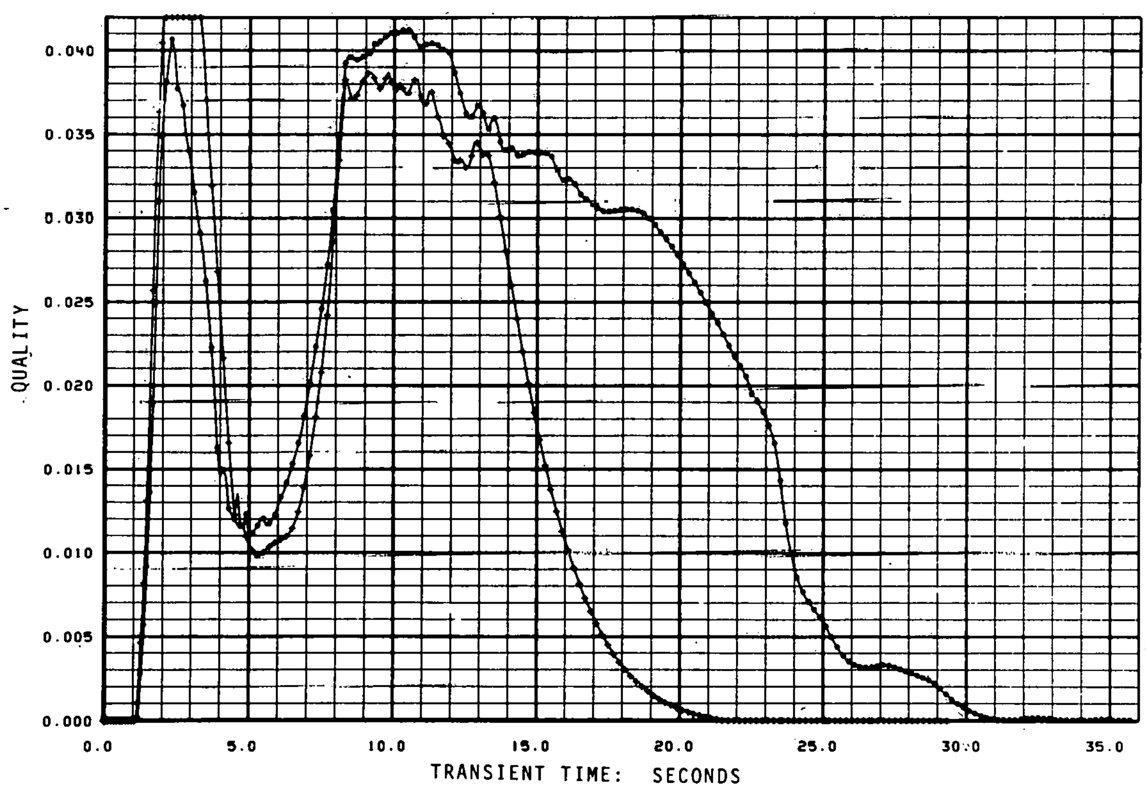

Fig. A-6 Average quality in lower plenum - Babcock and Wilcox Plant (200% break).

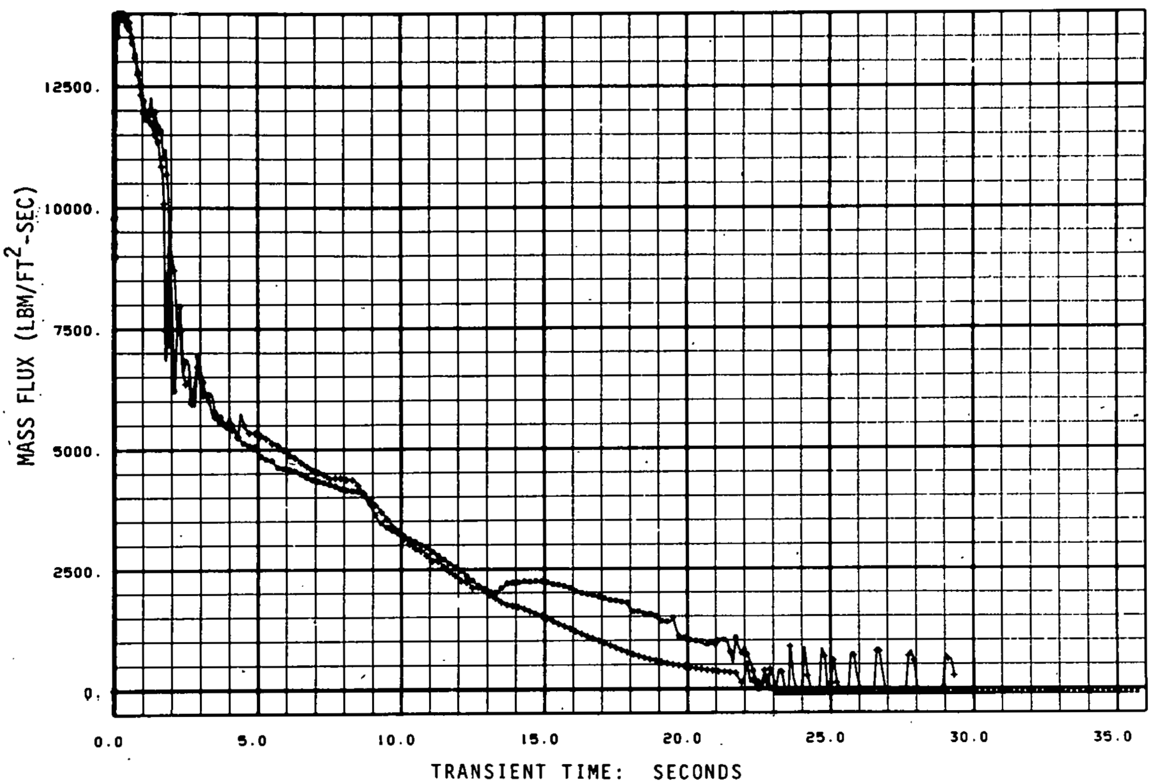

Fig. A-7 Mass flux at break - vessel side - Babcock and Wilcox Plant (200% break).

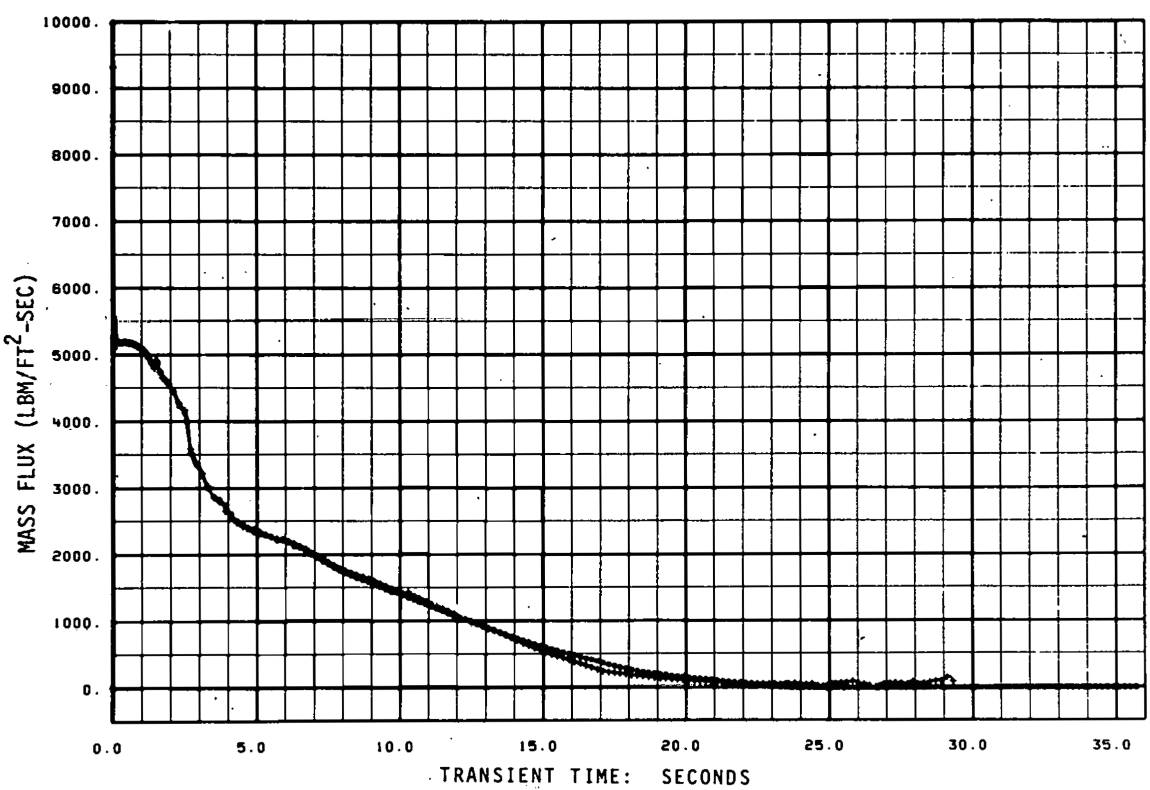

Fig. A-8 Mass flux at break - pump side - Babcock and Wilcox Plant (200% break).

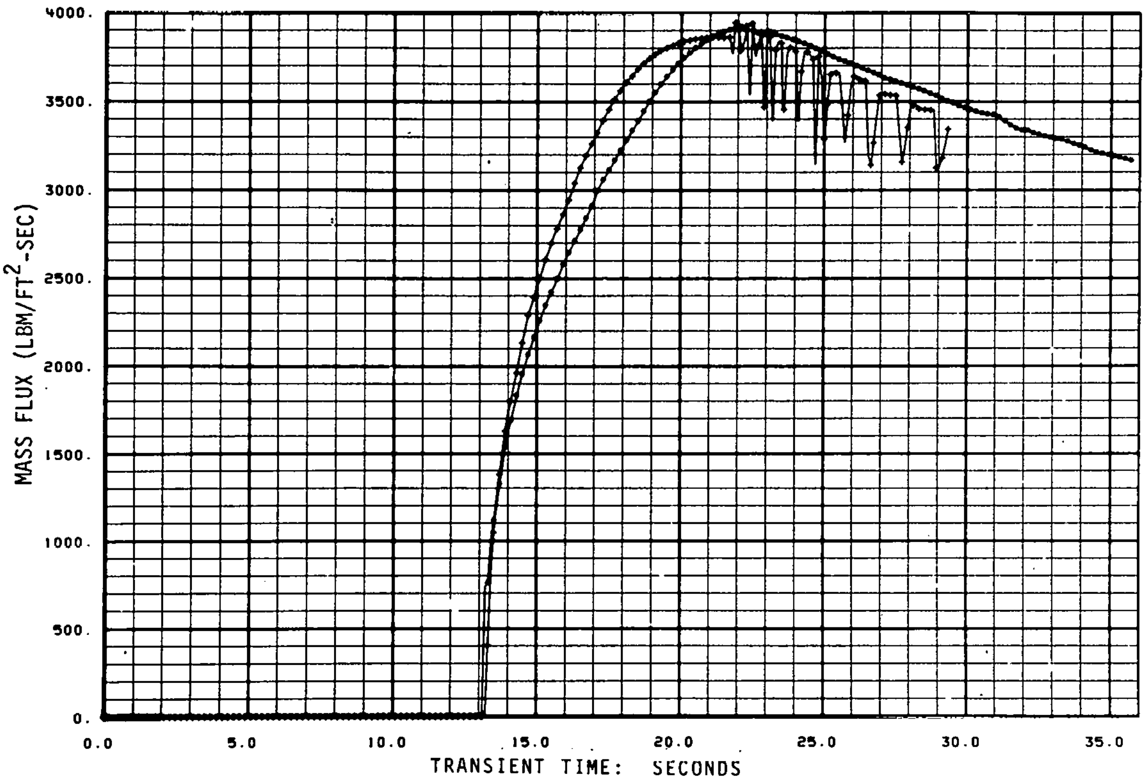

Fig. A-9 Mass flux from accumulator - Babcock and Wilcox Plant (200% break).

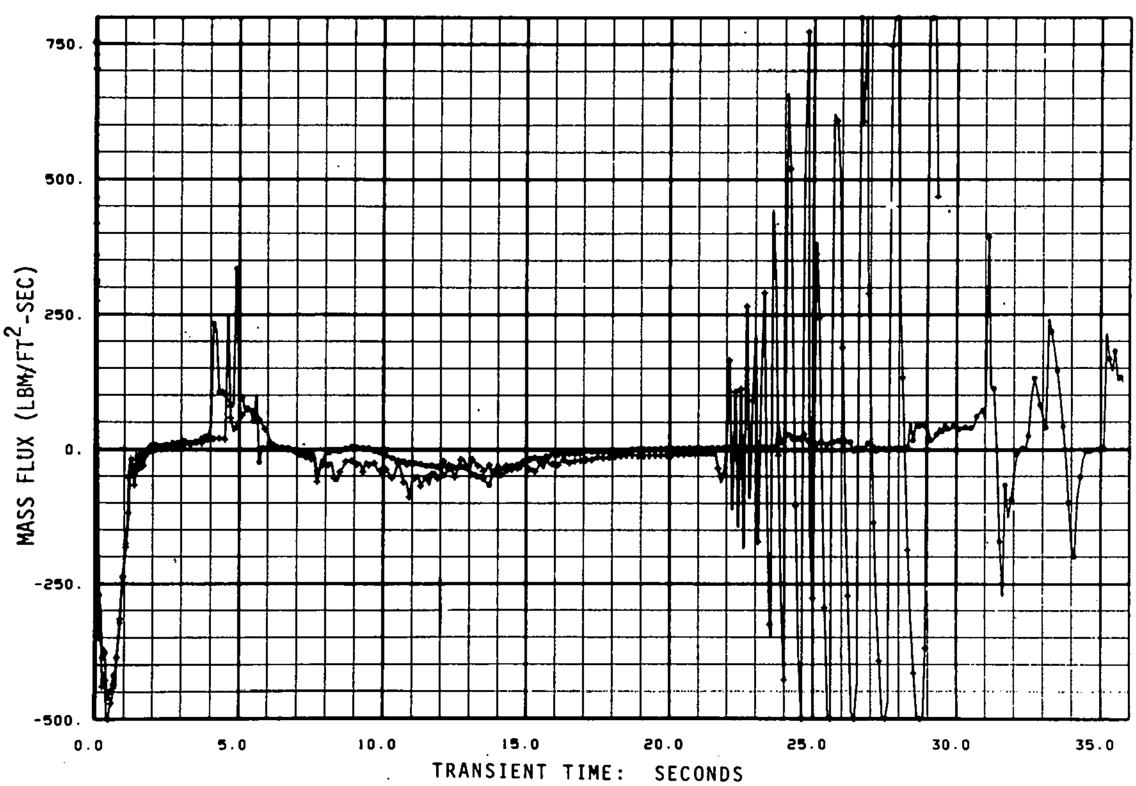

Fig. A-10 Core inlet mass flux - Babcock and Wilcox Plant (200% break).

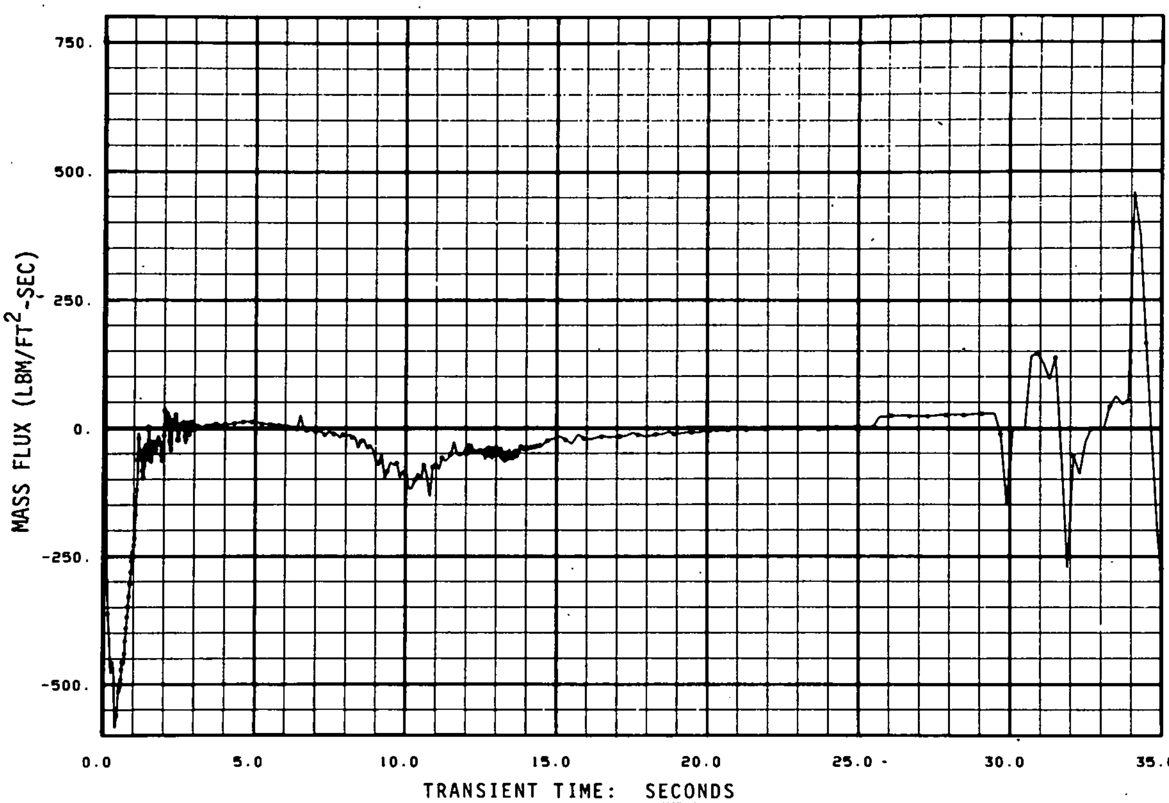

Fig. A-11 Core inlet mass flux - Babcock and Wilcox Plant (200% break) (corrected Junction 16 reverse flow loss coefficient).

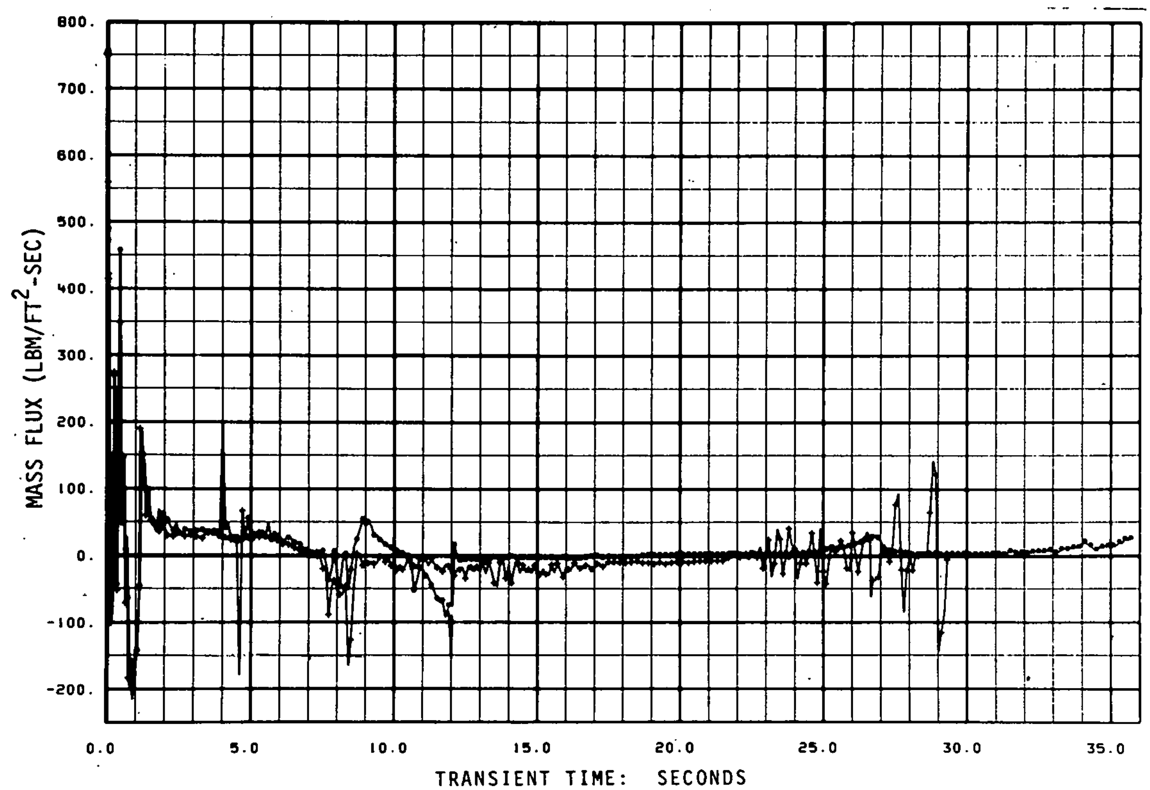

Fig. A-12 Core outlet mass flux - Babcock and Wilcox Plant (200% break).

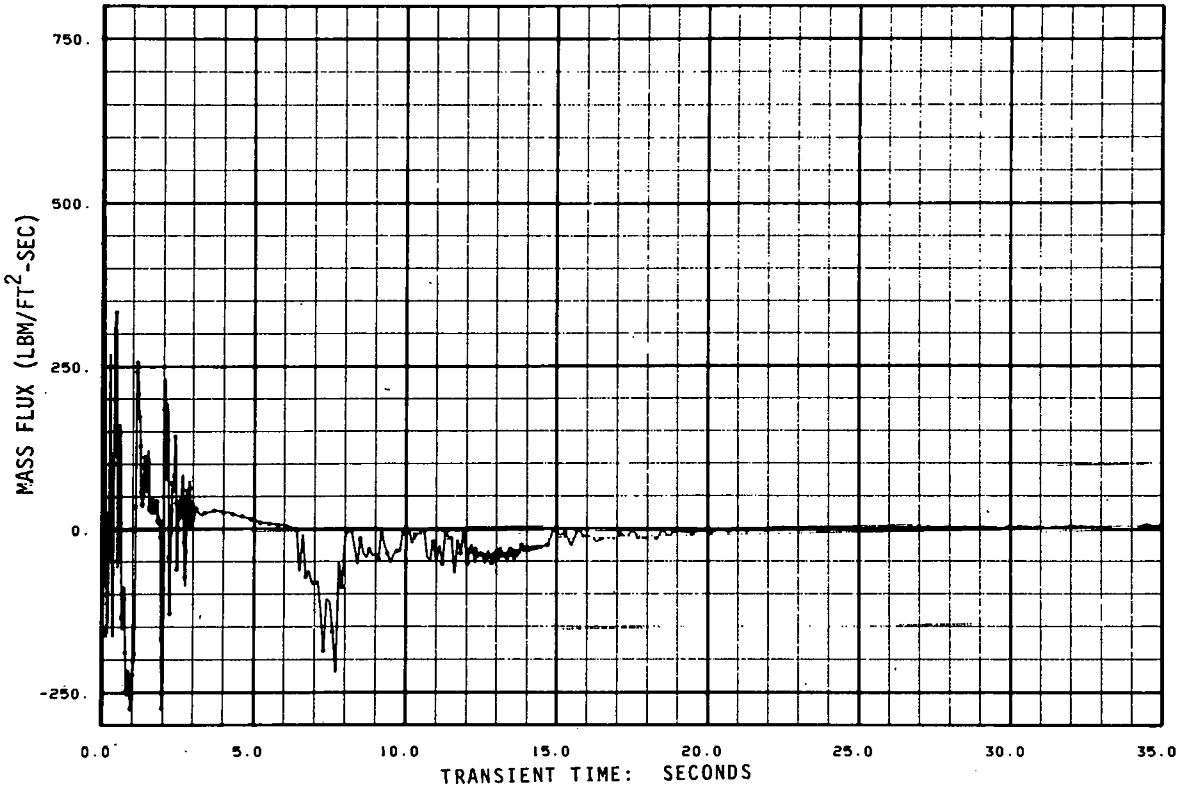

Fig. A-13 Core outlet mass flux - Babcock and Wilcox Plant (200% break) (corrected Junction 16 reverse loss flow coefficient).

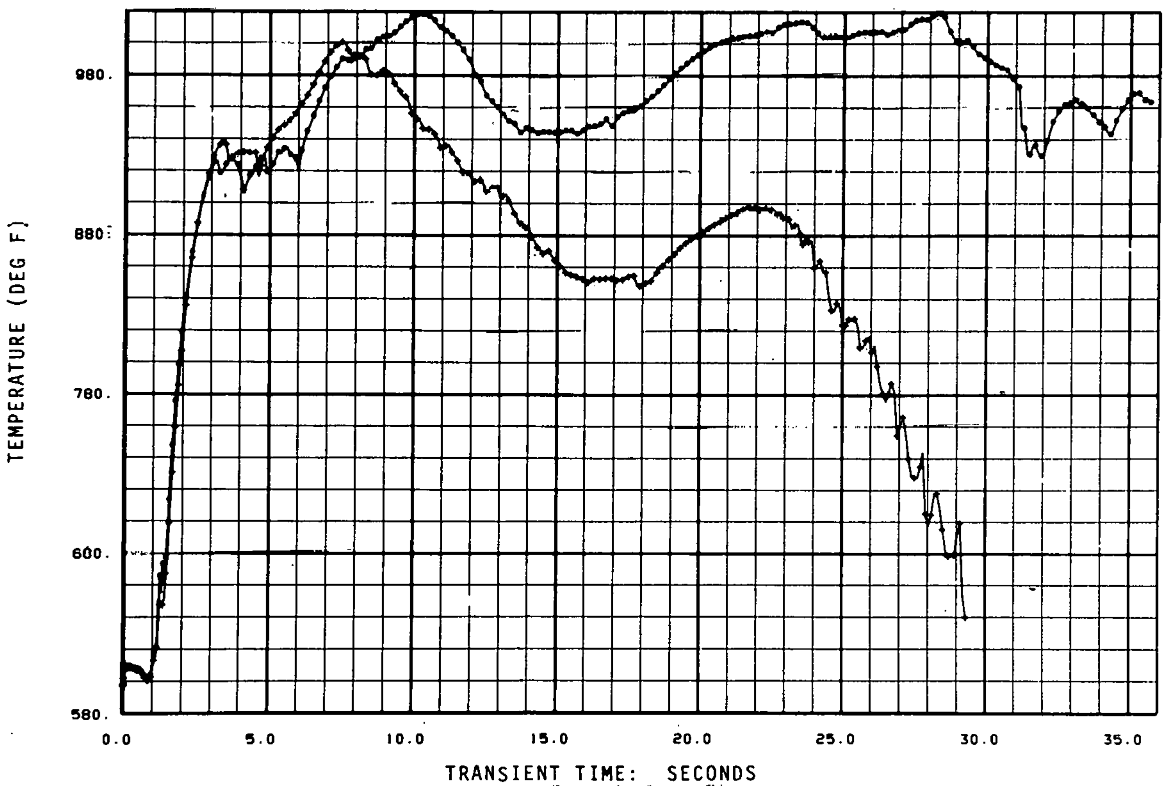

Fig. A-14 Cladding temperature - lower third - Babcock and Wilcox Plant (200% break).

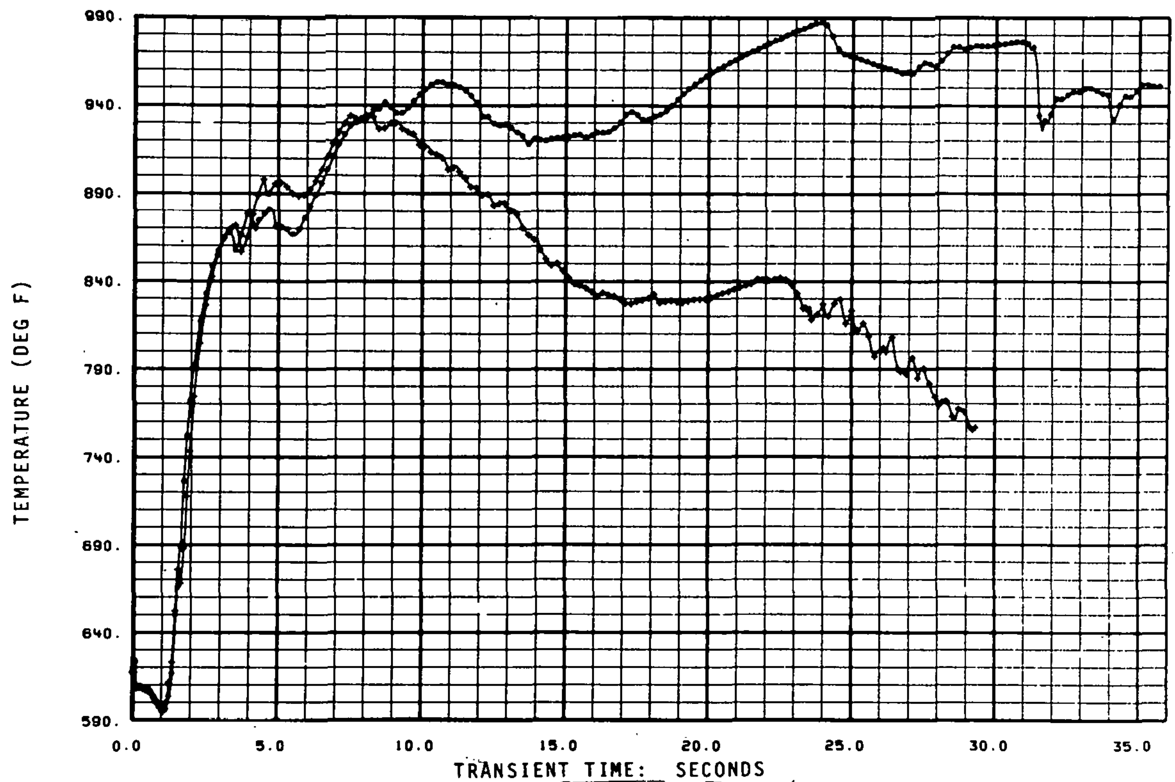

Fig. A-15 Cladding temperature - middle third - Babcock and Wilcox Plant (200% break).

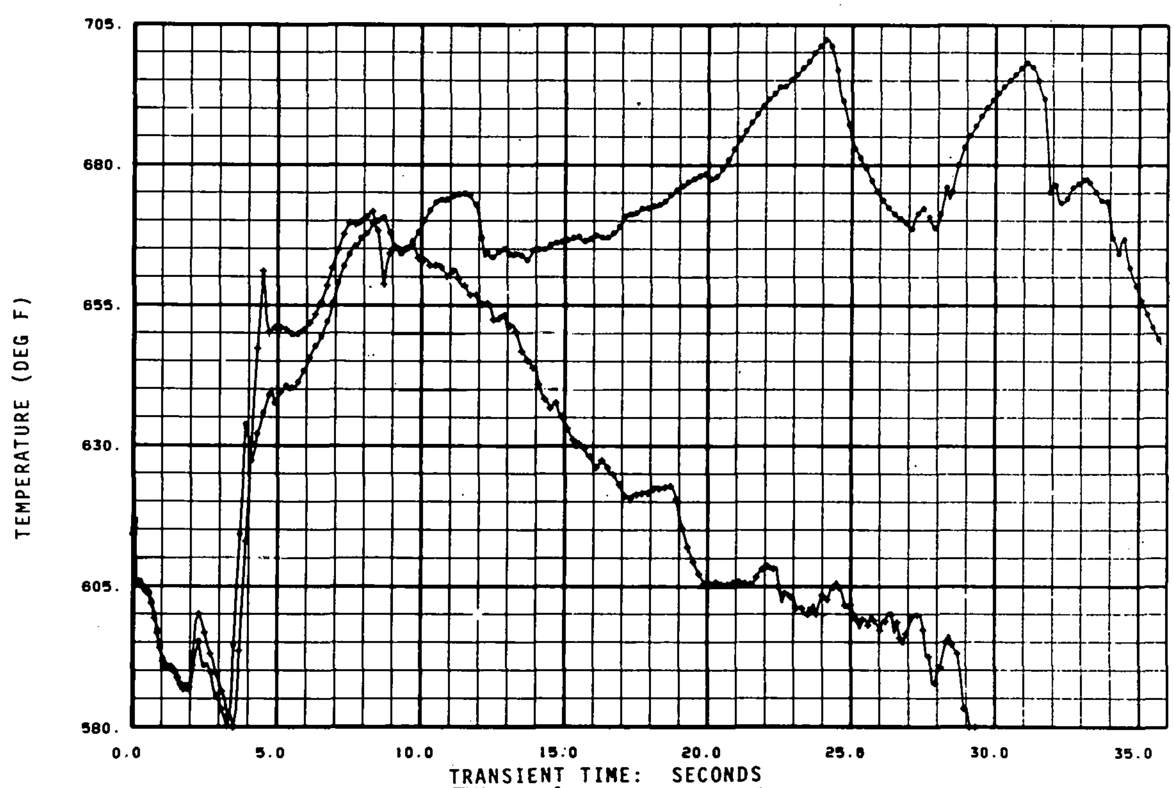

Fig. A-16 Cladding temperature - upper third - Babcock and Wilcox Plant (200% break).

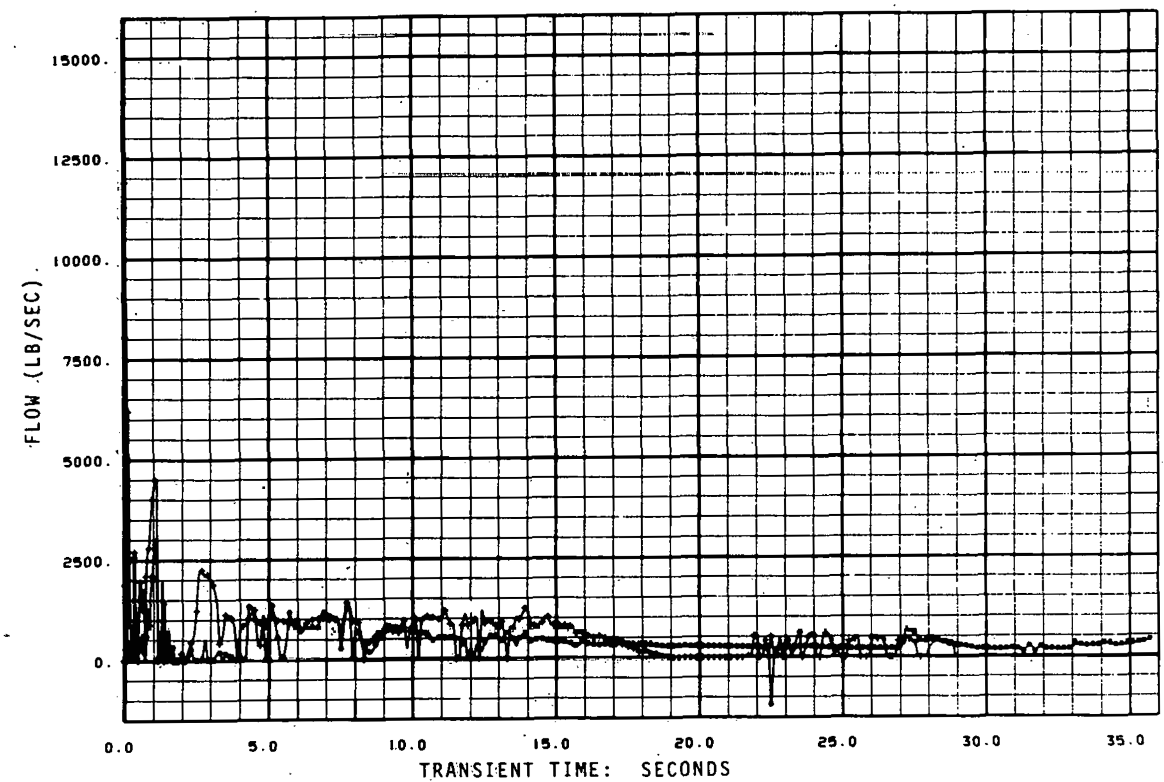

Fig. A-17 Flow through vent valves - Babcock and Wilcox Plant (200% break).

6. INPUT LISTING

Included in this section are input listings for both Cases 1 and 2 (Tables A-III and A-IV, respectively).

TABLE A-III

INPUT LISTING

```
= B&W OCONEE - 200% LOCA USING BATTELLE COLUMBUS DOWNCOMER PENETRATION MODEL
*
*
*********************************     WITH STAGP     ********************************
*
*
*
*    PUMP INLET AND OUTLET JUNCTION AREAS HAVE BEEN DIVIDED BY 2 TO ACCOUNT
*    FOR PUMP CHOKING    (REDUCED FLOW AREA INSIDE THE PUMP)
*
*
*
***********************************  010001  *************************************
*--TAPE CONTROL--# MINOR EDIT--TIME STEP--# TRIP CONTROLS--# VOLUMES--BUBBLE--
*--TIME DEP. VOLS.--# JUNCTIONS--# PUMPS--# CHECK VALVES--# LEAK AREA VS TIME--
*--# FILL CURVES--# HEAT SLABS--# HEAT SLAB GEOM.--# HEAT SLAB MATERIALS--# CORE
*  SECTIONS--# HEAT EXCHANGERS DATA SETS-- TYPE OF RELAP4 (1=EM, 0=BE)
*
010001  -2  9  5  11  41  3  0  59  3  5  0  6  22  7  6  3  0  0
*
*                     PROBLEM  CONSTANTS  DATA
***********************************  010002  *************************************
*--INITIAL POWER--IMPLICIT/EXPLICIT MULTIPLIER
*
010002    2568.0   1.0
*
*                     EDIT  VARIABLE  DATA
***********************************  020000  *************************************
*--JW=JUNCTION FLOW--ML=MIXTURE LEVEL--SR=RIGHT SURFACE TEMPERATURE--
*--NQ=NORMALIZED POWER--AP=AVERAGE PRESSURE
*
020000   AP 3   AP 23   AP 22   AP 3   JW 28   JW 1   JW 26   JW 2   JW 15
*
*        WATER PACKING INDICATOR
030003  50
*
*   MIXTURE LEVEL CROSSING FROM ABOVE
*        1- MAXIMUM NUMBER OF PRINTOUT    2- TIME AT WHICH OPTION BEGINS
030004   50   1.0
*
*                     TIME  STEP  DATA
***********************************  03XXY0  *************************************
*--# TIME STEPS / MINOR EDITS--# MINOR EDITS / MAJOR EDIT--# MAJOR EDITS /
*  RESTART TAPE EDIT--TIME STEP CONTROL--MAX. TIME STEP SIZE--MIN. SUB-TIME
*  STEP SIZE--END OF CURRENT TIME-STEP DATA
*
030010   1  10  1  0    0.005    0.0005    0.01
030020  10  10  1  0    .0005    .00001    .050
030030  25   5  2  0    0.002    .00005    0.50
030040   5  20  1  0    0.010    0.0001    2.00
030050   5  20  1  0    0.020    .00005    500.

*                     TRIP  CONTROL
*--ACTION TO BE TAKEN--SIGNAL BEING COMPARED--VOLUME OR JUNCTION INDEX--OPTIONAL
*  VOLUME--SIGNAL SET POINT--DELAY TIME
*
040010   1   1   0   0     60.00  0.0    * PROBLEM END TIME
040020   2   1   0   0   0.010002 0.0    * BREAK PATH INTO CONTAINMENT (VALVE 4)
040030   3   1   0   0   0.010002 0.0    * BREAK PATH INTO CONTAINMENT (VALVE 5)
040040   4   1   0   0   0.010002 0.0    * BREAK THE COLD LEG (VALVE 3)
*   SINGLE FAILURE CRITERION ASSUMES BOTH FLOOD TANKS OPERATE
*   (  FLOOD  TANKS  ARE  COMBINED  INTO  ONE  )
```

TABLE A-III (contd.)

```
040050    7    1    0    0    0.010002 0.0     * PUMP TRIP ON BREAK OPENING
                                               * ALSO SCRAM TRIP NUMBER
040060    8    1  0     0     0.0       0.0     * STM. GEN. RELIEF VALVE FOR VOLUME 1
*                                              * AND VOLUME 2  - MODELLED AS NEG. FILL
040070   10   -4   29   0     1514.7   25.0     * HIGH PRESSURE INJECTION
040080   11    1    0   0    0.0       0.0      * STEAM GEN. FLOW TRIP
*    SINGLE FAILURE CRITERION ASSUMES ONLY ONE LPIS OPERATES
040090   12   +4     3  0     18.7     25.      * LOW PRESS. INJECTION
040100    13    1     0     0     36.0        0.0        * STEAM GEN. AUX. FEED
040110    14   -5     41    0     0.01        0.0        * SHUT OFF ACCUMULATOR LINE  V2
*
*
*                     VOLUME   DATA
********************************** 05XXXY  **********************************
*
*
*
*     IBUB   IREAD  PRESSURE      TEMPERATURE      QUALITY          VOLUME
*   BUBBLE   VOLUME
*     DATA   DATA
*    INDEX   RETR-
*            IEVAL
*
*
*
*
*
*
*          STEAM  GENERATOR  SECONDARY SIDE
*
050011    3     0     0.0              536.7865         0.008318       3412.0
*
*          STEAM  GENERATOR  SECONDARY SIDE
*
050021    3     0     0.0              536.7865         0.008318       3412.0
*
*         DOWNCOMER
*
050041    0     0     2220.40          554.000         -1.0            883.85
*
*          LOWER PLENUM
*
050051    1     0     2222.50          554.000         -1.0            870.31

*          CORE
*
050061    0     0     2215.10          565.600         -1.0            196.81
050071    0     0     2207.00          589.800         -1.0            196.81
050081    0     0     2199.05          602.800         -1.0            196.81
*
*          BYPASS
*
050091    0     0     2207.00          554.000         -1.0            41.66
*
*          UPPER  PLENUM
*
*******************       CARD  050101  IS  PROPRIETARY     *********************
*******************       CARD  050111  IS  PROPRIETARY     *********************
*******************       CARD  050121  IS  PROPRIETARY     *********************
```

TABLE A-III (contd.)

```
*           HOT  LEG
*
050131   0    0    2156.09        604.700        -1.0            418.10
*
*           STEAM  GENERATOR
*           INLET PLENUM PLUS HOT LEG TO THE POINT OF MAXIMUM ELEVATION
*
050141   0    0    2142.39        604.700        -1.0            348.88
*
*           ACTIVE  TUBES
*
050151   0    0    2141.22        593.310        -1.0            491.51
050161   0    0    2137.59        575.680        -1.0            491.51
050171   0    0    2136.30        561.020        -1.0            491.51
*
*           OUTLET PLENUM PLUS PUMP SUCTION LEG TO MINIMUM ELEVATION POINT
*
050181   0    0    2136.24        553.323         1.0            341.88
*
*           COLD  LEG
*           PUMP  SUCTION  LEG  FROM  MIN.  ELEVATION  TO  PUMP
*
050191   0    0    2123.576       553.323        -1.0            157.51
*
*           PUMP
*
050201   0    0    2178.283       553.662        -1.0            98.0
*
*         PUMP  DISCHARGE  LEG
*
050211   0    0    2234.39        554.000        -1.0            20.45
050221   0    0    2232.25        554.000        -1.0            20.45
050231   0    0    2231.97        554.000        -1.0            20.45
050241   0    0    2229.66        554.000        -1.0            20.45
*           COLD  LEG
*           PUMP  SUCTION  LEG  FROM  MIN.  ELEVATION  TO  PUMP
*
050251   0    0    2123.576       553.323        -1.0            157.51
*
*           PUMP
*
050261   0    0    2178.283       553.662        -1.0            98.0
*
*         PUMP  DISCHARGE  LEG
*
050271   0    0    2234.39        554.000        -1.0            20.45
050281   0    0    2231.29        554.000        -1.0            61.35
*
*           HOT  LEG
*
050291   0    0    2156.09        604.700        -1.0            418.10
*
*           INLET PLENUM PLUS HOT LEG TO THE POINT OF MAXIMUM ELEVATION
*
050301   0    0    2142.39        604.700        -1.0            348.88
```

TABLE A-III (contd.)

```
*          ACTIVE   TUBES
*
050311   0      0      2141.22            593.310            -1.0                491.51
050321   0      0      2137.59            575.680            -1.0                491.51
050331   0      0      2136.30            561.020            -1.0                491.51
*
*          OUTLET PLENUM PLUS PUMP SUCTION LEG TO MINIMUM ELEVATION POINT
*
050341   0      0      2136.24            553.323            -1.0                341.88
*
*          COLD   LEG
*          PUMP   SUCTION   LEG   FROM   MIN.   ELEVATION   TO   PUMP
*
050351   0      0      2123.576           553.323            -1.0                315.02
*
*          PUMP                      (2)
*
050361   0      0      2178.283           552.662            -1.0                196.00
*
*          PUMP   DISCHARGE   LEG                   (2)
*
050371   0      0      2234.39            554.000            -1.0                40.90
050381   0      0      2231.29            554.000            -1.0                122.70
*
*          PRESSURIZER
*
050391   1      0      0.0                646.880            0.0                 1500.0
*
*          SURGE   LINE   (INTO THE PRESSURIZER)
*
050401   0      0      2164.38            622.500            -1.0                20.0
*          SAFETY   INJECTION   TANK       (ACCUMULATOR)
*
050411   2      0      614.700            110.000            0.0                 2820.0
*
*          CONTAINMENT
*
050031   2      0      14.7000            100.000            0.6                 1.9E+6
*
*
*
*
*  HEIGHT--MIX. LEVEL--2 PHASE FRICTION INDEX--FLOW AREA VOL.--EQUIVALENT DIA.
*  OF FLOW AREA--ELEVATION AT BOTTOM OF VOLUME--VERTICAL SLIP
*
050012      52.111    40.65      0      44.09      .0694      10.959         0
050022      52.111    40.65      0      44.09      .0694      10.959         0
050042      25.376    25.376     0      34.83      1.660      13.378         0
050052      8.082     8.082      0      107.68     11.71      8.419          0
050062      4.001     4.001      0      49.19      .0438      16.501         0
050072      4.001     4.001      0      49.19      .0438      20.502         0
050082      4.001     4.001      0      49.19      .0438      24.503         0
050092      12.003    12.003     0      3.471      .2745      16.501         0
******************     CARD   050102   IS    PROPRIETARY      **********************
******************     CARD   050112   IS    PROPRIETARY      **********************
******************     CARD   050122   IS    PROPRIETARY      **********************
050132      46.119    46.119     0      7.069      3.0        31.5           0
050142      12.55     12.55      0      27.80      0.240      65.068         0
050152      18.703    18.703     0      26.28      .0464      46.365         0
```

TABLE A-III (contd.)

```
050162    18.703    18.703    0    26.28     .0464     27.662       0
050172    18.703    18.703    0    26.28     .0464     8.959        0
050182    6.881     6.881     0    49.68     .793      2.078        0
050192    30.683    30.683    0    4.276     2.333     2.078        0
050202    5.953     5.953     0    4.276     2.333     32.761       0
050212    2.917     2.917     0    4.276     2.333     34.750       0
050222    2.917     2.917     0    4.276     2.333     31.833       0
050232    2.333     2.333     0    4.276     2.333     31.833       0
050242    2.333     2.333     0    4.276     2.333     31.833       0
050252    30.683    30.683    0    4.276     2.333     2.078        0
050262    5.953     5.953     0    4.276     2.333     32.761       0
050272    2.917     2.917     0    4.276     2.333     34.750       0
050282    2.917     2.917     0    4.276     2.333     31.833       0
050292    46.119    46.119    0    7.069     3.0       31.5         0
050302    12.55     12.55     0    27.80     0.240     65.068       0
050312    18.703    18.703    0    26.28     .0464     46.365       0
050322    18.703    18.703    0    26.28     .0464     27.662       0
050332    18.703    18.703    0    26.28     .0464     8.959        0
050342    6.881     6.881     0    49.68     .793      2.078        0
050352    30.683    30.683    0    8.552     2.333     2.078        0
050362    5.953     5.953     0    8.552     2.333     32.761       0
050372    2.917     2.917     0    8.552     2.333     34.750       0
050382    2.917     2.917     0    8.552     2.333     31.833       0
050392    39.64     21.14     0    37.84     6.941     30.279       0
050402    8.655     8.655     0    .499      .7561     26.75        0
050412    20.766    13.844    0    135.8     9.292     35.00        0
050032    172.41    0.0       0    11020.    121.5     0.0          0

                        TIME   DEPENDENT   VOLUMES
*                              N O N E
*
*
*
*                       BUBBLE   RISE   DATA
*
060011    0.8       3.0
060021    0.0     1.0E+6
060031    0.8       40.00
*
*
*        DOWNCOMER PENETRATION - LOWER ENTRAINMENT MODEL * BETTEL COLLUMBUS
*
060004    41   5    6    4    6    5    3     2    614.7    1.66
*
*                       JUNCTION   DATA   CARDS
*************************************  08XXXY  ************************************
*
*--INLET VOLUME--EXIT VOLUME--PUMP INDEX--VALVE INDEX--FLOW--JUNCTION FLOW AREA
*--JUNCTION ELEVATION--L/A--FORWARD FLOW LOSS COEFFICIENT--
*
*
080011     3    23    0    5    0.0          4.276        33.00        0.0     0.45
080021    22     3    0    4    0.0          4.276        33.00        0.0     1.0
080031    41     4    0    2    0.0          1.4426       35.00        0.0     6.5
080041    40    29    0    0    0.0          0.499        35.13        0.0     1.191
080051     4     5    0    0    37562.60     34.83        13.378       0.0     .61814
080061     5     6    0    0    36964.60     49.19        16.501       0.0     3.584
080071     6     7    0    0    36964.60     49.19        20.502       0.0     3.889
080081     7     8    0    0    36964.60     49.19        24.503       0.0     3.645
```

TABLE A-III (contd.)

080091	8	10	0	0	36964.60	49.19	28.504	0.0	3.217
080101	5	9	0	0	598.0	3.471	16.501	0.0	177.9
080111	9	10	0	0	598.0	3.471	28.504	0.0	174.2
****************** CARD 080121 IS PROPRIETARY *********************									
****************** CARD 080131 IS PROPRIETARY *********************									
****************** CARD 080141 IS PROPRIETARY *********************									
080151	12	4	0	1	0.0	8.50	36.89	1.14	0.0
****************** CARD 080161 IS PROPRIETARY *********************									
080171	12	13	0	0	19153.30	7.069	33.00	0.0	0.58708
080181	13	14	0	0	19153.30	7.069	76.118	0.0	1.2681
080191	14	15	0	0	19153.30	26.28	65.068	0.0	1.29698
080201	15	16	0	0	19153.30	26.28	46.365	0.0	1.75773
080211	16	17	0	0	19153.30	26.28	27.662	0.0	.2735
080221	17	18	0	0	19153.30	26.28	8.959	0.0	1.3237
080231	18	19	0	0	9576.65	4.276	3.245	0.0	.6599
* THE PUMP INLET AND OUTLET JUNCTION AREAS WERE DIVIDED BY 2 FOR CHOKING									
080241	19	20	-1	0	9576.65	2.138	32.761	0.0	.0366
080251	20	21	1	0	9576.65	2.138	36.50	0.0	.14506
080261	21	22	0	0	9576.65	4.276	34.75	0.0	0.2344
080271	22	23	0	3	9576.65	4.276	33.00	0.0	0.0
080281	23	24	0	0	9576.65	4.276	33.00	0.0	0.16772
080291	24	4	0	0	9576.65	4.276	23.00	0.0	0.90155
080301	18	25	0	0	9576.65	4.276	3.245	0.0	.6599
* THE PUMP INLET AND OUTLET JUNCTION AREAS WERE DIVIDED BY 2 FOR CHOKING									
080311	25	26	-2	0	9576.65	2.138	32.761	0.0	.0366
080321	26	27	2	0	9576.65	2.138	36.50	0.0	.14506
080331	27	28	0	0	9576.65	4.276	34.750	0.0	0.2997
080341	28	4	0	0	9576.65	4.276	33.00	0.0	1.0293
080351	12	29	0	0	19153.30	7.069	33.00	0.0	0.58706
080361	29	30	0	0	19153.30	7.069	76.118	0.0	1.2681
080371	30	31	0	0	19153.30	26.28	65.068	0.0	1.29698
080381	31	32	0	0	19153.30	26.28	46.365	0.0	1.75773
080391	32	33	0	0	19153.30	26.28	27.662	0.0	.2735
080401	33	34	0	0	19153.30	26.28	8.959	0.0	1.3237
080411	34	35	0	0	19153.30	8.552	3.245	0.0	.6599
* THE PUMP INLET AND OUTLET JUNCTION AREAS WERE DIVIDED BY 2 FOR CHOKING									
080421	35	36	-3	0	19153.30	4.276	32.761	0.0	.0366
080431	36	37	3	0	19153.30	4.276	36.50	0.0	.14506
080441	37	38	0	0	19153.30	8.552	34.750	0.0	0.2997
080451	38	4	0	0	19153.30	8.552	33.00	0.0	1.0293
080461	39	40	0	0	0.0	0.499	30.279	0.0	0.4441
080471	0	2	6	0	0.0	1.0	10.96	1.0	0.0
080481	0	2	4	0	1586.48501	1.0	10.96	1.0	0.0
080491	0	2	3	0	-1586.48501	1.0	63.06	1.0	0.0
080501	0	2	5	0	0.0	1.0	63.00	1.0	0.0
080511	0	1	4	0	1586.48501	1.0	10.96	1.0	0.0
080521	0	1	3	0	-1586.48501	1.0	63.06	1.0	0.0
080531	0	1	5	0	0.0	1.0	63.00	1.0	0.0
080541	0	4	1	0	0.0	1.0	35.00	1.0	0.0
080551	0	37	2	0	0.0	0.5	35.33	1.0	0.0
080561	0	37	2	0	0.0	0.5	35.33	1.0	0.0
080571	0	27	2	0	0.0	0.5	35.33	1.0	0.0
080581	0	21	2	0	0.0	0.5	35.33	1.0	0.0
080591	0	1	6	0	0.0	1.0	10.96	1.0	0.0

TABLE A-III (contd.)

```
*--REVERSE FLOW LOSS COEFFICIENT--VERTICAL JUNCTION INDEX--JUNCTION CHOKING
*  INDEX--INITIAL CONDITION CALCULATION INDEX--MOMENTUM EQUATION TYPE--JUNCTION
*  DIAMETER--CONTRACTION COEFFICIENT FOR LEAK--JUNCTION CHOKING INDEX TO CONTROL
*  TABLE CHOKING--ENTHALPY TRANSPORT INDEX--COSINE OF THE ANGLE FOR A SLIP
*  JUNCTION--ADJACENT JUNCTION NUMBER FOR HORIZONTAL SLIP
*
*
```

080012	0.450	0	5	2	0	0.0	0.0	0	0	0.0	0	
080022	0.450	0	5	2	0	0.0	0.0	0	0	0.0	0	
080032	0.0	0	5	2	3	0.0	0.0	0	0	0.0	0	
080042	0.6107	0	5	2	3	0.0	0.0	0	0	0.0	0	
080052	.42911	0	5	2	3	0.0	0.0	0	0	1.0	0	
080062	3.594	0	5	2	3	0.0	0.0	0	2	0.0	0	
080072	0.0	0	5	2	0	0.0	0.0	0	3	0.0	0	
080082	0.0	0	5	2	0	0.0	0.0	0	3	0.0	0	
080092	3.261	0	5	2	3	0.0	0.0	0	1	0.0	0	
080102	0.0	0	5	2	3	0.0	0.0	0	0	0.0	0	
080112	0.0	0	5	2	3	0.0	0.0	0	0	0.0	0	
******************					CARD	080122	IS	PROPRIETARY				*********************
******************					CARD	080132	IS	PROPRIETARY				*********************
******************					CARD	080142	IS	PROPRIETARY				*********************
080152	0.0	0	5	1	3	0.0	0.0	0	0	0.0	0	
******************					CARD	080162	IS	PROPRIETARY				*********************
080172	1.137	0	5	2	3	0.0	0.0	0	0	0.0	0	
080182	0.4271	0	5	2	0	0.0	0.0	0	0	0.0	0	
080192	1.394	0	5	2	0	0.0	0.0	0	2	0.0	0	
080202	0.0	0	5	2	0	0.0	0.0	0	3	0.0	0	
080212	0.0	0	5	2	0	0.0	0.0	0	3	0.0	0	
080222	0.0	0	5	2	0	0.0	0.0	0	1	0.0	0	
080232	0.995	0	5	2	3	0.0	0.0	0	0	0.0	0	
080242	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080252	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080262	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080272	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080282	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080292	.41554	0	5	2	3	0.0	0.0	0	0	0.0	0	
080302	0.995	0	5	2	3	0.0	0.0	0	0	0.0	0	
080312	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080322	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080332	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080342	.41554	0	5	2	3	0.0	0.0	0	0	0.0	0	
080352	1.137	0	5	2	3	0.0	0.0	0	0	0.0	0	
080362	0.4271	0	5	2	0	0.0	0.0	0	0	0.0	0	
080372	1.394	0	5	2	0	0.0	0.0	0	2	0.0	0	
080382	0.0	0	5	2	0	0.0	0.0	0	3	0.0	0	
080392	0.0	0	5	2	0	0.0	0.0	0	3	0.0	0	
080402	0.0	0	5	2	0	0.0	0.0	0	1	0.0	0	
080412	0.995	0	5	2	3	0.0	0.0	0	0	0.0	0	
080422	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080432	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080442	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0	
080452	.41554	0	5	2	3	0.0	0.0	0	0	0.0	0	
080462	0.9738	0	5	2	3	0.0	0.0	0	0	0.0	0	

```
080472     0.0   0  5   3   3    0.0    0.0   0    0   0.0    0
080482     0.0   0  5   3   3    0.0    0.0   0    0   0.0    0
080492     0.0   0  5   3  -2    0.0    0.0   0    0   0.0    0
080502     0.0   0  5   3  -2    0.0    0.0   0    0   0.0    0
080512     0.0   0  5   3   3    0.0    0.0   0    0   0.0    0
080522     0.0   0  5   3  -2    0.0    0.0   0    0   0.0    0
080532     0.0   0  5   3  -2    0.0    0.0   0    0   0.0    0
080542     0.0   0  5   3   3    0.0    0.0   0    0   0.0    0
080552     0.0   0  5   3   3    0.0    0.0   0    0   0.0    0
080562     0.0   0  5   3   3    0.0    0.0   0    0   0.0    0
080572     0.0   0  5   3   3    0.0    0.0   0    0   0.0    0
080582     0.0   0  5   3   3    0.0    0.0   0    0   0.0    0
080592     0.0   0  5   3   3    0.0    0.0   0    0   0.0    0
*
*
*    RELAP  CRITICAL  FLOW  OPTION
*
*          STAGNATION PROPERTIES          0=NON-USE;  1=USE FOR MACH.GT. 0.3
*
082000    1
*
*
*    FLOW RATE MULTIPLIER FOR HEM MODEL , FLOW RATE MULTIPLIER FOR HENRY
*    CRITICAL FLOW , FLOW RATE MULTIPLIER FOR EXTENDED HENRY CRITICAL FLOW,
*    TRANSITION QUALITY FOR THE MODEL
*
082003    1.0  0.9  0.9  0.01
*
*
*           PUMP  DESCRIPTION  DATA  CARDS
090011  1  7  0 1 0 1190.0 1.01   88000.0 396.0 39700.0   70000.0 0.0 0.0 0.0 0.0
090021  1  7  0 1 0 1190.0 1.01   88000.0 396.0 39700.0   70000.0 0.0 0.0 0.0 0.0
090031  1  7  0 1 0 1190.0 1.01  176000.0 396.0 79400.0  140000.0 0.0 0.0 0.0 0.0
*
*           PUMP  HEAD  MULTIPLIER
091001 -11  0.0  0.0  0.1  0.0  0.15  0.05  0.24  0.80  0.30  0.96  0.4  0.98
091002      0.6  0.97 0.8  0.9  0.90  0.80  0.96  0.50  1.00  0.00
*
*           PUMP  TORQUE  MULTIPLIER
092001  -2  0.0  0.0  1.0  0.0
*
*           PUMP  STOP  DATA  CARDS
095011      0.0  0.0  0.0
095021      0.0  0.0  0.0
095031      0.0  0.0  0.0
*
*           PUMP  CURVE  INPUT  INDICATOR
100000    0   0   0   0
*           VALVE  DATA  CARDS
*
*          VENT  VALVE  IN  REACTOR  VESSEL
110010  21    0    0    1.0E-8    4.0        1.0E21          1.0E21
*          INJECT EMERGENCY FLOOD  TANK  WATER
*   FIRST ENTRY FOR DELTA P  CHECK VALVE WITH TRIP = TRIP NUMBER + 20
110020  34    0    0    1.0E-8    4.0        1.0E21          1.0E21
*          BREAK  THE  PUMP  DISCHARGE  LINE
110030  4    0    0     0.0      0.0           0.0                0.0
*          BREAK  WATER  FLOWING  INTO  CONTAINMENT
110040  -2   0    0     0.0      0.0           0.0                0.0
*          BREAK  WATER  FLOWING  INTO  CONTAINMENT
110050  -3   0    0     0.0      0.0           0.0                0.0
```

TABLE A-III (contd.)

```
*          FILL  TABLE  DATA  CARDS
130100   12  2   9   4    'GAL/MIN'    14.7     110.0           * LPIS
130101        0.10      5000.0      80.00       4470.0      120.00      4050.0
130102      140.00      3750.0     160.00       3250.0      180.00      2250.0
130103      190.00      1200.0     192.70          0.0     3500.00         0.0
130200   10  2   7   4    'GAL/MIN'    14.7     110.0           * HPIS
130201        0.10       605.0    1000.00        527.0     2200.00       343.0
130202     2600.00       227.0    2800.00        122.0     2874.70         0.0
130203     3500.00         0.0
130300   11  1   5   4   'LBS/SEC'   950.0   570.0          * STEAM GEN. OUTLET
130301      0.0    -1586.48501      50.0    -1586.48501     100.0  -1586.48501
130301   0.0    -1586.48501        1.0     -1586.48501        2.0     0.0
130302    500.0         0.0                                  1000.0     0.0
130400   11  1   5   4   'LBS/SEC'   950.0   440.0          * STEAM GEN. INLET
130401      0.0      1586.48501      50.0     1586.48501     100.0   1586.48501
130401   0.0      1586.48501       1.0      1586.48501        2.0     0.0
130402     500.0        0.0                                  1000.0     0.0
*  NOTE:  THE PRESSURE SETTINGS FOR THE SG SAFETY VALVES WERE INCREASED BY 12.62
*    PSIA.  THIS CHANGE IS DUE TO THE SECONDARY SIDE TEMP. BEING ADJUSTED
*    FOR HEAT OUTPUT EQUAL TO CORE BTU/HR PLUS  PUMP BTU/HR  (TORQUE X RPM)
130500    8  2  10  4  'LBS/SEC'  14.7  120.0   *  STM. GEN. SAFETY VALVES
*                                                FOR VOLUMES 1  AND  2
130501   0.0  0.0    1077.62  0.0    1077.63  -270.5   1097.62  -270.5
130502   1097.63  -579.7    1107.62  -579.7    1107.63   -966.1    1117.62  -966.1
130503   1117.63  -1507.2    5000.0  -1507.2
130600   13   2    4    4     'LBS/SEC'       14.7       110.0      * SG AUX. FILL
130601   0.0  100.34     812.7  100.34     1136.2  69.2     1244.1  55.36

*          KINETICS  CONSTANTS  DATA
140000    3   0     300.0     0.0     0.8     0.0      0.0      0.0
*          SCRAM  TABLE  DATA
141001   -2    7     0.0        0.0         100.0       0.0
*          DENSITY  REACTIVITY  TABLE
142001 -18          0.0    -63.38    0.225    -38.45     0.300     -24.51
142002              0.4    -12.25    0.500     -7.46     0.600      -4.51
142003              0.67    -2.75    0.700     -2.20     0.750      -1.44
142004              0.80    -1.17    0.85      -0.49     0.900      -0.35
142005              0.95    -0.07    1.00       0.00     1.100      -0.07
142006              1.20    -0.42    1.40      -1.69     2.000      -1.69
*          KINETICS  CONSTANTS  DATA
140000    3   0     300.0     0.0     0.8     0.0      0.0      0.0
*          SCRAM  TABLE  DATA
141001   -2    7     0.0        0.0         100.0       0.0
*          DENSITY  REACTIVITY  TABLE
142001 -18          0.0    -63.38    0.225    -38.45     0.300     -24.51
142002              0.4    -12.25    0.500     -7.46     0.600      -4.51
142003              0.67    -2.75    0.700     -2.20     0.750      -1.44
142004              0.80    -1.17    0.85      -0.49     0.900      -0.35
142005              0.95    -0.07    1.00       0.00     1.100      -0.07
142006              1.20    -0.42    1.40      -1.69     2.000      -1.69
*
*          DOPPLER  TABLE  DATA
143000   -2         32.0    0.0      5000.0     -9.8
*
*          REACTIVITY  COEFFICIENT  DATA
140010   0.4464     0.4464     0.0     0.0
140020   0.3910     0.3910     0.0     0.0
140030   0.1626     0.1626     0.0     0.0
```

TABLE A-III (contd.)

```
*
*        HEAT  SLAB  DATA
*    1=VOLUME # AT SLAB'S LEFT SURFACE, 2=VOLUME NUMBER AT SLAB'S RIGHT SURFACE,
*    3=GEOMETRY INDEX, 4=INDICATES IF SLAB IS STACKED ON TOP OF SLAB XXX-1,
*    5=CALCULATE SLAB QUALITY OPTION, 6=HEAT TRANSFER CORRELATION AT LEFT SIDE,
*    7=HEAT TRANSFER CORRELATION AT RIGHT SIDE, 8=LEFT SURFACE AREA,
*    9=RIGHT SURFACE AREA, 10=TOTAL SLAB VOLUME,
*    11=LEFT SIDE   ((DR*(DR+DHE)**1/2)-DR.
150011   0    6    1    0    0    0    0    0.0        16578.06  148.51    0.0
150021   0    7    1    1    0    0    0    0.0        16578.06  148.51     0.0
150031   0    8    1    1    0    0    0    0.0       16578.06  148.51    0.0
*         15,530 TUBES PER STEAM GENERATOR
150041  17    1    2    0    2    0    0    37826.66  42444.64  113.72    .01922
150051  16    1    2    1    2    0    0    42355.99  47526.93  127.33    .01922
150061  15    1    2    1    2    0    0    12555.29  14088.08  37.745    .01922
150071  15    1    2    1    2    0    0    12636.82  14179.59  37.99     .01922
150081  15    1    2    1    2    0    0    12627.76  14169.39  37.96     .01922
150091  33    2    2    0    2    0    0    37826.66  42444.64  113.72    .01922
150101  32    2    2    1    2    0    0    42355.99  47526.93  127.33    .01922
150111  31    2    2    1    2    0    0    12555.29  14083.08  37.745    .01922
150121  31    2    2    1    2    0    0    12636.82  14179.59  37.99     .01922
150131  31    2    2    1    2    0    0    12627.76  14169.39  37.96     .01922
150141   9    4    4    0    3    0    0    220.99    227.29    96.18     0.0
150151   4    0    3    0    0    0    0    1136.02   0.0       3892.86   0.0
150161   5    0    3    0    1    0    0    318.97    0.0       760.90    0.0
150171  11    0    3    0    1    0    0    318.97    0.0       882.09    0.0
150181  12    4    4    1    1    0    0    342.55    351.89    86.80     0.0
150191  10    4    4    0    1    0    0    40.57     47.80     18.41     0.0
150201  10   12    5    0    3    0    0    351.49    358.59    305.10    0.0
150211  10   11    6    0    0    0    0    123.51    123.51    92.630    0.0
150221   5    5    7    0    3    0    0    102.07    102.07    132.69    0.0

*    1=RIGHT SIDE ((DR*(DR+DHE)**1/2)-DR, 2=LEFT SIDE DHE, 3=RIGHT SIDE DHE,
*    4=LEFT SIDE CHANNEL LENGTH, 5=RIGHT SIDE CHANNEL LENGTH,
*    5=BOTTOM OF SLAB'S ELEVATION - ABOVE RIGHT VOLUME'S BOTTOM ELEVATION.
*    6=TOP OF SLAB'S ELEVATION - ABOVE RIGHT VOLUME'S BOTTOM ELEVATION.
*
150012   .01758    0.0  0.0   0.0       12.0      0.0       0.0
150022   .01758    0.0  0.0   0.0       12.0      0.0       0.0
150032   .01758    0.0  0.0   0.0       12.0      0.0       0.0
150042   .02746    0.0 .0694 16.703     3.0       0.0       16.703
150052   .02746    0.0 .0694 18.703     3.0       16.705    35.404
150062   .02746    0.0 .0694 5.544      3.0       35.408    40.952
150072   .02746    0.0 .0694 5.580      3.0       40.952    46.532
150082   .02746    0.0 .0694 5.576      3.0       46.532    52.109
150092   .02746    0.0 .0694 16.703     3.0       0.0  16.703
150102   .02746    0.0 .0694 16.703     3.0       16.705    35.404
150112   .02746    0.0 .0694 5.544      3.0       35.408    40.952
150122   .02746    0.0 .0694 5.580      3.0       40.952    46.532
150132   .02746    0.0 .0694 5.576      3.0       46.532    52.109
150142   0.0       0.0        0.0       12.0      12.0      3.14      15.1
```

TABLE A-III (contd.)

```
150152   0.0       0.0  0.0  0.0       0.0      0.0  0.0
150162   0.0       0.0  0.   4.96      4.96     0.0  4.96
150172   0.0       0.0  0.0  0.0       0.0      0.0  0.0
150182   0.0       0.0  0.0  9.043     9.043    16.317     0.0
150192   0.0       0.0  0.0  1.207     1.207    15.126     16.333
150202   0.0       0.0  0.0  10.31     10.31    0.0        10.3
150212   0.0       0.0  0.0  12.54     12.54    0.0        0.75
150222   0.0       0.0  0.0  11.4      11.4     4.7        6.0
*
*        CORE  SECTION  DATA
160010   1   7   9   15   0.002208   0.4464
160020   2   7   9   15   0.002208   0.3910
160030   3   7   9   15   0.002208   0.1626
*
*
*        SLAB  GEOMETRY  DATA  CARDS
170101   2   3   1   6   0.   0.015417   1.0
170102   1       2   2        0.00029167 0.0
170103   0       3   8        0.0022083  0.0
170201   2   1   4   6   0.023208   0.0028333   1.0
170301   2   2   5   6   7.125      0.015625    1.0
170302   0       6   6              0.703      0.0
170401   2   1   5   6   6.0288     0.208      0.0
170501   2   1   5   6   5.426      0.25       0.0
170601   1   1   5   6   0.0        0.75       0.0
170701   1   1   5   6   0.0        1.3       0.0
*        THERMAL  CONDUCTIVITY  DATA
*
180100 -20 500. 3.341 650. 2.671 800. 2.677 950. 2.439 1100. 2.242
180101     1250. 2.078 1400. 1.940 1550. 1.823 1700. 1.724 1850. 1.639
180102     2000. 1.568 2150. 1.507 2300. 1.457 2450. 1.415 2600. 1.382
180103 3100. 1.323 3600. 1.333 4100. 1.406 4600. 1.538 5100. 1.730
180200  2    32. .41562 5400. .41562
180300 -11 392. 6.936 752. 8.092 1112. 9.827 1472. 10.983 1832. 12.717
180301 2192. 14.451 2552. 17.341 2912. 20.809 3272. 25.433 3632. 31.792
180302 3992. 39.306
*
*   THE STEAM GENERATOR ACTIVE TUBES' THERMAL CONDUCTIVITY WAS DECREASED TO
*   ACCOUNT FOR SLUGE ON THE TUBE WALLS.
*  0.0003 WAS ADDED TO THE TOTAL RESISTIVITY.
*
180400  -6    100.0  4.658    200.0  4.769    400.0  5.007    600.0  5.243
180401        800.0  5.481    1000.0  5.699
180500 -4  32.  8.0  212.  9.4  572.  10.9  932.  12.4
180600 -4  32.  26.5  212.  26.  572.  25.0  932.  22.0
*
*
*        VOLUMETRIC  HEAT  CAPACITY
*
190100 16    32. 34.45 122. 38.35 212. 40.95
190101       392. 43.55 752. 46.8 2012. 51.35
190102      2732. 52.65 3092. 56.55 3452. 63.05
190103      3812. 72.8 4352. 87.7 4532. 94.25
190104      4712. 98.15 4892. 100.1 5144. 101.4
190105      8000. 101.4
190200   2   32. .000075 5400. .000075
190300   5   0.0   28.392
190301   1480.3   34.476   1675.0   65.176
190302   1787.5   34.476   3500.0   34.476
190401  -4 100. 57.18 400. 61.14 600. 63.77 800. 66.41
190500  -2  32.  53.79  500.  53.79
190600  -2  32.  53.79  500.  53.79
```

TABLE A-III (contd.)

```
*          LINEAR  EXPANSION  COEFFICIENT
*
200101  -2 0. .000003718 5000. .000012653
200201  -2 0. 0. 5000. 0.
200301 -4 0. .000003094 1652. .000004706 1653. .000005389 5000. .000005389
200401  -2 0. 0. 5000. 0.
200501  -2     0.0        0.0        5000.0    0.0
200601  -2     0.0        0.0        5000.0    0.0
*
```

TABLE A-IV

INPUT LISTING

```
= B&W OCONEE USING ONLY VERTICAL SLIP TO MODEL DOWNCOMER PENETRATION
* THIS RUN DIVIDED THE DOWNCOMER INTO TWO NODES-AN UPPER ANNULUS AND A DOWNCOMER
*
*
*******************************     WITH STAGP     ********************************
*
*
*
*   PUMP INLET AND OUTLET JUNCTION AREAS HAVE BEEN DIVIDED BY 2 TO ACCOUNT
*   FOR PUMP CHOKING   (REDUCED FLOW AREA INSIDE THE PUMP)
*
*
*
*********************************** 010001 ***********************************
*--TAPE CONTROL--# MINOR EDIT--TIME STEP--# TRIP CONTROLS--# VOLUMES--BUBBLE--
*--TIME DEP. VOLS.--# JUNCTIONS--# PUMPS--# CHECK VALVES--# LEAK AREA VS TIME--
*--# FILL CURVES--# HEAT SLABS--# HEAT SLAB GEOM.--# HEAT SLAB MATERIALS--# CORE
*  SECTIONS--# HEAT EXCHANGERS DATA SETS-- TYPE OF RELAP4 (1=EM, 0=BE)
*
010001  -2  9  5  11  42  3  0  60  3   5  0  6  23  7  6  3  0  0
*
*                    PROBLEM  CONSTANTS  DATA
*********************************** 010002 ***********************************
*--INITIAL POWER--IMPLICIT/EXPLICIT MULTIPLIER
*
010002     2568.0   1.0
*
*                    EDIT  VARIABLE  DATA
*********************************** 020000 ***********************************
*--JW=JUNCTION FLOW--ML=MIXTURE LEVEL--SR=RIGHT SURFACE TEMPERATURE--
*--NQ=NORMALIZED POWER--AP=AVERAGE PRESSURE
*
020000   AP 3    AP 23   AP 22   AP 42   JW 28   JW 1    JW 26   JW 2    JW 15
*
*          WATER PACKING INDICATOR
030003  50
*
*   MIXTURE LEVEL CROSSING FROM ABOVE
*        1- MAXIMUM NUMBER OF PRINTOUT   2- TIME AT WHICH OPTION BEGINS
030004    50   1.0
*
*                    TIME  STEP  DATA
*********************************** 03XXY0 ***********************************
*--# TIME STEPS / MINOR EDITS--# MINOR EDITS / MAJOR EDIT--# MAJOR EDITS /
*  RESTART TAPE EDIT--TIME STEP CONTROL--MAX. TIME STEP SIZE--MIN. SUB-TIME
*  STEP SIZE--END OF CURRENT TIME-STEP DATA
*
030010  1  10  1  0     0.005     0.0005    0.01
030020  10 10  1  0     .0005     .00001    .050
030030  25  5  2  0     0.002     .00005    0.50
030040   5 20  1  0     0.010     0.0001    2.0
030050   5 20  1  0     0.020     .00005   500.
*                    TRIP  CONTROL
*--ACTION TO BE TAKEN--SIGNAL BEING COMPARED--VOLUME OR JUNCTION INDEX--OPTIONAL
*  VOLUME--SIGNAL SET POINT--DELAY TIME
*
040010    1    1    0    0      40.00  0.0    * PROBLEM END TIME
040020    2    1    0    0   0.010002 0.0    * BREAK PATH INTO CONTAINMENT (VALVE 4)
040030    3    1    0    0   0.010002 0.0    * BREAK PATH INTO CONTAINMENT (VALVE 5)
040040    4    1    0    0   0.010002 0.0    * BREAK THE COLD LEG (VALVE 3)
```

TABLE A-IV (contd.)

```
*  SINGLE FAILURE CRITERION ASSUMES BOTH FLOOD TANKS OPERATE
*   ( FLOOD  TANKS  ARE  COMBINED  INTO  ONE  )
040050   7   1   0   0   0.010002 0.0     * PUMP TRIP ON BREAK OPENING
                                          * ALSO SCRAM TRIP NUMBER
040060   8   1  0    0     0.0      0.0    * STM. GEN. RELIEF VALVE FOR VOLUME 1
*                                          * AND VOLUME 2  - MODELLED AS NEG. FILL
040070  10  -4  29   0     1514.7  25.0    * HIGH PRESSURE INJECTION
040080  11   1   0   0   0.0       0.0     *. STEAM GEN. FLOW TRIP
*   SINGLE FAILURE CRITERION ASSUMES ONLY ONE LPIS OPERATES
040090  12  +4   42  0     18.7     25.    * LOW PRESS. INJECTION
040100   13   1    0    0    36.0       0.0       * STEAM GEN. AUX. FEED
040110   14  -5    41   0    0.01       0.0       * SHUT OFF ACCUMULATOR LINE  V2
*
*
*                    VOLUME   DATA
********************************** 05XXXY ***********************************
*
*
*
*     IBUB  IREAD  PRESSURE     TEMPERATURE     QUALITY          VOLUME
*   BUBBLE  VOLUME
*     DATA  DATA
*    INDEX  RETR-
*           IEVAL
*
*
*
*
*
*
*         STEAM  GENERATOR  SECONDARY SIDE
*
050011   3    0    0.0              536.7865        0.008318       3412.0
*
*         STEAM  GENERATOR  SECONDARY SIDE
*
050021   3    0    0.0              536.7865        0.008318       3412.0
*
*        UPPER  ANNULUS
*
050031   0    0    2218.52          554.000        -1.0            314.97
*
*        DOWNCOMER
*
050041   0    0    2221.44          554.000        -1.0            568.88
*
*         LOWER PLENUM
*
050051   1    0    2222.50          554.000        -1.0            870.31
*         CORE
*
050061   0    0    2215.10          565.600        -1.0            196.81
050071   0    0    2207.00          589.800        -1.0            196.81
050081   0    0    2199.05          602.800        -1.0            196.81
*
*         BYPASS
*
050091   0    0    2207.00          554.000        -1.0            41.66
*
*         UPPER  PLENUM
```

TABLE A-IV (contd.)

```
**********     CARD  050101  IS PROPRIETARY     ********************************
**********     CARD  050111  IS PROPRIETARY     ********************************
**********     CARD  050121  IS PROPRIETARY     ********************************
*
*         HOT  LEG
*
050131   0    0    2156.09        604.700       -1.0          418.10
*
*         STEAM  GENERATOR
*         INLET PLENUM PLUS HOT LEG TO THE POINT OF MAXIMUM ELEVATION
*
050141   0    0    2142.39        604.700       -1.0          348.88
*
*         ACTIVE  TUBES
*
050151   0    0    2141.22        593.310       -1.0          491.51
050161   0    0    2137.59        575.600       -1.0          491.51
050171   0    0    2136.30        561.020       -1.0          491.51
*
*         OUTLET PLENUM PLUS PUMP SUCTION LEG TO MINIMUM ELEVATION POINT
*
050181   0    0    2136.24        553.323       -1.0          341.88
*
*         COLD  LEG
*         PUMP  SUCTION  LEG  FROM  MIN.  ELEVATION  TO  PUMP
*
050191   0    0    2123.576       553.323       -1.0          157.51
*
*         PUMP
*
050201   0    0    2178.283       553.662       -1.0          98.0
*
*        PUMP  DISCHARGE  LEG
*
050211   0    0    2234.39        554.000       -1.0          20.45
050221   0    0    2232.25        554.000       -1.0          20.45
050231   0    0    2231.97        554.000       -1.0          20.45
050241   0    0    2229.66        554.000       -1.0          20.45
*         COLD  LEG
*         PUMP  SUCTION  LEG  FROM  MIN.  ELEVATION  TO  PUMP
*
050251   0    0    2123.576       553.323       -1.0          157.51
*
*         PUMP
*
050261   0    0    2178.283       553.662       -1.0          98.0
*
*        PUMP  DISCHARGE  LEG
*
050271   0    0    2234.39        554.000       -1.0          20.45
050281   0    0    2231.29        554.000       -1.0          61.35
*
*         HOT  LEG
*
050291   0    0    2156.09        604.700       -1.0          418.10
*
*         INLET PLENUM PLUS HOT LEG TO THE POINT OF MAXIMUM ELEVATION
*
050301   0    0    2142.39        604.700       -1.0          348.88
```

TABLE A-IV (contd.)

```
*         ACTIVE  TUBES
*
050311   0    0    2141.22        593.310        -1.0           491.51
050321   0    0    2137.59        575.680        -1.0           491.51
050331   0    0    2136.30        561.020        -1.0           491.51
*
*         OUTLET PLENUM PLUS PUMP SUCTION LEG TO MINIMUM ELEVATION POINT
*
050341   0    0    2136.24        553.323        -1.0           341.88
*
*         COLD  LEG
*         PUMP  SUCTION  LEG  FROM  MIN.  ELEVATION  TO  PUMP
*
050351   0    0    2123.576       553.323        -1.0           315.02
*
*         PUMP               (2)
*
050361   0    0    2178.283       553.662        -1.0           196.00
*
*        PUMP  DISCHARGE  LEG               (2)
*
050371   0    0    2234.39        554.000        -1.0           40.90
050381   0    0    2231.29        554.000        -1.0           122.70
*
*         PRESSURIZER
*
050391   1    0    0.0            646.880         0.0           1500.0
*
*         SURGE  LINE  (INTO THE PRESSURIZER)
*
050401   0    0    2164.38        622.500        -1.0           20.0
*
*         SAFETY  INJECTION  TANK     (ACCUMULATOR)
*
050411   2    0    614.700        110.000         0.0           2820.0
*
*         CONTAINMENT
*
050421   2    0    14.7000        100.000         0.6           1.9E+6
*  HEIGHT--MIX. LEVEL--2 PHASE FRICTION INDEX--FLOW AREA VOL.--EQUIVALENT DIA.
*  OF FLOW AREA--ELEVATION AT BOTTOM OF VOLUME--VERTICAL SLIP
*
050012   52.111    40.65    0    44.09    .0694    10.959      0
050022   52.111    40.65    0    44.09    .0694    10.959      0
050032   9.043     9.043    0    34.83    1.660    29.711      0
050042   16.333    16.333   0    34.83    1.660    13.378      0
050052   8.082     8.082    0    107.68   11.71    8.419       0
050062   4.001     4.001    0    49.19    .0438    16.501      0
050072   4.001     4.001    0    49.19    .0438    20.502      0
050082   4.001     4.001    0    49.19    .0438    24.503      0
050092   12.003    12.003   0    3.471    .2745    16.501      0
**********     CARD  050102  IS PROPRIETARY     ********************************
**********     CARD  050112  IS PROPRIETARY     ********************************
**********     CARD  050122  IS PROPRIETARY     ********************************
050132   46.119    46.119   0    7.069    3.0      31.5        0
050142   12.55     12.55    0    27.80    0.240    65.060      0
050152   18.703    18.703   0    26.28    .0464    46.365      0
050162   18.703    18.703   0    26.28    .0464    27.662      0
050172   18.703    18.703   0    26.28    .0464    8.959       0
050182   6.881     6.881    0    49.68    .793     2.078       0
```

TABLE A-IV (contd.)

```
050192     30.683    30.683    0     4.276      2.333      2.078           0
050202     5.953     5.953     0     4.276      2.333      32.761          0
050212     2.917     2.917     0     4.276      2.333      34.750          0
050222     2.917     2.917     0     4.276      2.333      31.833          0
050232     2.333     2.333     0     4.276      2.333      31.833          0
050242     2.333     2.333     0     4.276      2.333      31.833          0
050252     30.683    30.683    0     4.276      2.333      2.078           0
050262     5.953     5.953     0     4.276      2.333      32.761          0
050272     2.917     2.917     0     4.276      2.333      34.750          0
050282     2.917     2.917     0     4.276      2.333      31.833          0
050292     46.119    46.119    0     7.069      3.0        31.5            0
050302     12.55     12.55     0     27.80      0.240      65.068          0
050312     18.703    18.703    0     26.28      .0464      46.365          0
050322     18.703    18.703    0     26.28      .0464      27.662          0
050332     18.703    18.703    0     26.28      .0464      8.959           0
050342     6.881     6.881     0     49.68      .793       2.078           0
050352     30.683    30.683    0     8.552      2.333      2.078           0
050362     5.953     5.953     0     8.552      2.333      32.761          0
050372     2.917     2.917     0     8.552      2.333      34.750          0
050382     2.917     2.917     0     8.552      2.333      31.833          0
050392     39.64     21.14     0     37.84      6.941      30.279          0
050402     8.655     8.655     0     .499       .7561      26.75           0
050412     20.766    13.844    0     135.8      9.292      35.00           0
050422     172.41    0.0       0     11020.     121.5      0.0             0
*                    TIME  DEPENDENT  VOLUMES
*                            N O N E
*
*
*
*                    BUBBLE  RISE  DATA
*
060011     0.8       3.0
060021     0.0     1.0E+6
060031     0.8       40.00
*
*
*
*                    JUNCTION  DATA  CARDS
***********************************  08XXXY  ************************************
*
*--INLET VOLUME--EXIT VOLUME--PUMP INDEX--VALVE INDEX--FLOW--JUNCTION FLOW AREA
*--JUNCTION ELEVATION--L/A--FORWARD FLOW LOSS COEFFICIENT--
*
*
080011    42    23    0    5    0.0            4.276        33.00         0.0     0.45
080021    22    42    0    4    0.0            4.276        33.00         0.0     1.0
080031    41     3    0    2    0.0            1.4426       35.00         0.0     6.5
080041     3     4    0    0    37562.60       34.83        29.711        0.0     .33667
080051     4     5    0    0    37562.60       34.83        13.378        0.0     .61814
080061     5     6    0    0    36964.60       49.19        16.501        0.0     3.584
080071     6     7    0    0    36964.60       49.19        20.502        0.0     3.889
080081     7     8    0    0    36964.60       49.19        24.503        0.0     3.645
080091     8    10    0    0    36964.60       49.19        28.504        0.0     3.217
080101     5     9    0    0    598.0          3.471        16.501        0.0     177.9
080111     9    10    0    0    598.0          3.471        28.504        0.0     174.2
**********      CARD  080121  IS PROPRIETARY     ************************************
**********      CARD  080131  IS PROPRIETARY     ************************************
**********      CARD  080141  IS PROPRIETARY     ************************************
080151    12     3    0    1    0.0            8.50         36.89         1.14    0.0
**********      CARD  080161  IS PROPRIETARY     ************************************
```

TABLE A-IV (contd.)

```
080171   12   13    0   0   19153.30     7.069      33.00      0.0   0.58708
080181   13   14    0   0   19153.30     7.069      76.118     0.0   1.2681
080191   14   15    0   0   19153.30     26.28      65.068     0.0   1.29698
080201   15   16    0   0   19153.30     26.28      46.365     0.0   1.75773
080211   16   17    0   0   19153.30     26.28      27.662     0.0   .2735
080221   17   18    0   0   19153.30     26.28      8.959      0.0   1.3237
080231   18   19    0   0   9576.65      4.276      3.245      0.0   .6599
*   THE PUMP INLET AND OUTLET JUNCTION AREAS WERE DIVIDED BY 2 FOR CHOKING
080241   19   20   -1   0   9576.65      2.138      32.761     0.0   .0366
080251   20   21    1   0   9576.65      2.138      36.50      0.0   .14506
080261   21   22    0   0   9576.65      4.276      34.75      0.0   0.2344
080271   22   23    0   3   9576.65      4.276      33.00      0.0   0.0
080281   23   24    0   0   9576.65      4.276      33.00      0.0   0.16772
080291   24    3    0   0   9576.65      4.276      33.00      0.0   0.90155
080301   18   25    0   0   9576.65      4.276      3.245      0.0   .6599
*   THE PUMP INLET AND OUTLET JUNCTION AREAS WERE DIVIDED BY 2 FOR CHOKING
080311   25   26   -2   0   9576.65      2.138      32.761     0.0   .0366
080321   26   27    2   0   9576.65      2.138      36.50      0.0   .14506
080331   27   28    0   0   9576.65      4.276      34.750     0.0   0.2997
080341   28    3    0   0   9576.65      4.276      33.00      0.0   1.0293
080351   12   29    0   0   19153.30     7.069      33.00      0.0   0.58706
080361   29   30    0   0   19153.30     7.069      76.118     0.0   1.2681
080371   30   31    0   0   19153.30     26.28      65.068     0.0   1.29698
080381   31   32    0   0   19153.30     26.28      46.365     0.0   1.75773
080391   32   33    0   0   19153.30     26.28      27.662     0.0   .2735
080401   33   34    0   0   19153.30     26.28      8.959      0.0   1.3237
080411   34   35    0   0   19153.30     8.552      3.245      0.0   .6599
*   THE PUMP INLET AND OUTLET JUNCTION AREAS WERE DIVIDED BY 2 FOR CHOKING
080421   35   36   -3   0   19153.30     4.276      32.761     0.0   .0366
080431   36   37    3   0   19153.30     4.276      36.50      0.0   .14506
080441   37   38    0   0   19153.30     8.552      34.750     0.0   0.2997
080451   38    3    0   0   19153.30     8.552      33.00      0.0   1.0293
080461   39   40    0   0   0.0          0.499      30.279     0.0   0.4441
080471   40   29    0   0   0.0          0.499      35.13      0.0   1.191
080481    0    2    4   0   1586.48501   1.0        10.96      1.0   0.0
080491    0    2    3   0  -1586.48501   1.0        63.06      1.0   0.0
080501    0    2    5   0   0.0          1.0        63.00      1.0   0.0
080511    0    1    4   0   1586.48501   1.0        10.96      1.0   0.0
080521    0    1    3   0  -1586.48501   1.0        63.06      1.0   0.0
080531    0    1    5   0   0.0          1.0        63.00      1.0   0.0
080541    0    3    1   0   0.0          1.0        35.00      1.0   0.0
080551    0   37    2   0   0.0          0.5        35.33      1.0   0.0
000561    0   37    2   0   0.0          0.5        35.33      1.0   0.0
080571    0   27    2   0   0.0          0.5        35.33      1.0   0.0
080581    0   21    2   0   0.0          0.5        35.33      1.0   0.0
080591    0    1    6   0   0.0          1.0        10.96      1.0   0.0
080601    0    2    6   0   0.0          1.0        10.96      1.0   0.0
*
*
*--REVERSE FLOW LOSS COEFFICIENT--VERTICAL JUNCTION INDEX--JUNCTION CHOKING
*  INDEX--INITIAL CONDITION CALCULATION INDEX--MOMENTUM EQUATION TYPE--JUNCTION
*  DIAMETER--CONTRACTION COEFFICIENT FOR LEAK--JUNCTION CHOKING INDEX TO CONTROL
*  TABLE CHOKING--ENTHALPY TRANSPORT INDEX--COSINE OF THE ANGLE FOR A SLIP
*  JUNCTION--ADJACENT JUNCTION NUMBER FOR HORIZONTAL SLIP
*
*
080012  1.0     0  5  2  0   0.0   0.0   0   0   0.0   0
080022  0.450   0  5  2  0   0.0   0.0   0   0   0.0   0
080032  6.5     0  5  2  3   0.0   0.0   0   0   0.0   0
080042  .33667  0  5  2  3   0.0   0.0   0   0   1.0   0
```

TABLE A-IV (contd.)

080052	.42911	0	5	2	3	0.0	0.0	0	0	1.0	0
080062	3.594	0	5	2	3	0.0	0.0	0	2	0.0	0
080072	3.889	0	5	2	0	0.0	0.0	0	3	0.0	0
080082	3.645	0	5	2	0	0.0	0.0	0	3	0.0	0
080092	3.261	0	5	2	3	0.0	0.0	0	1	0.0	0
080102	177.9	0	5	2	3	0.0	0.0	0	0	0.0	0
080112	174.2	0	5	2	3	0.0	0.0	0	0	0.0	0
**********	CARD 080122 IS PROPRIETARY **********************************										
**********	CARD 080132 IS PROPRIETARY **********************************										
**********	CARD 080142 IS PROPRIETARY **********************************										
080152	0.0	0	5	1	3	0.0	0.0	0	0	0.0	0
**********	CARD 080162 IS PROPRIETARY **********************************										
080172	1.137	0	5	2	3	0.0	0.0	0	0	0.0	0
080182	0.4271	0	5	2	0	0.0	0.0	0	0	0.0	0
080192	1.394	0	5	2	0	0.0	0.0	0	2	0.0	0
080202	1.75773	0	5	2	0	0.0	0.0	0	3	0.0	0
080212	.2735	0	5	2	0	0.0	0.0	0	3	0.0	0
080222	1.3237	0	5	2	0	0.0	0.0	0	1	0.0	0
080232	0.995	0	5	2	3	0.0	0.0	0	0	0.0	0
080242	.0366	0	5	2	0	0.0	0.0	0	0	0.0	0
080252	.14506	0	5	2	0	0.0	0.0	0	0	0.0	0
080262	.2344	0	5	2	0	0.0	0.0	0	0	0.0	0
080272	0.0	0	5	2	0	0.0	0.0	0	0	0.0	0
080282	.16772	0	5	2	0	0.0	0.0	0	0	0.0	0
080292	.41554	0	5	2	3	0.0	0.0	0	0	0.0	0
080302	0.995	0	5	2	3	0.0	0.0	0	0	0.0	0
080312	.0366	0	5	2	0	0.0	0.0	0	0	0.0	0
080322	.14506	0	5	2	0	0.0	0.0	0	0	0.0	0
080332	.2997	0	5	2	0	0.0	0.0	0	0	0.0	0
080342	.41554	0	5	2	3	0.0	0.0	0	0	0.0	0
080352	1.137	0	5	2	3	0.0	0.0	0	0	0.0	0
080362	0.4271	0	5	2	0	0.0	0.0	0	0	0.0	0
080372	1.394	0	5	2	0	0.0	0.0	0	2	0.0	0
080382	1.75773	0	5	2	0	0.0	0.0	0	3	0.0	0
080392	.2735	0	5	2	0	0.0	0.0	0	3	0.0	0
080402	1.3237	0	5	2	0	0.0	0.0	0	1	0.0	0
080412	0.995	0	5	2	3	0.0	0.0	0	0	0.0	0
080422	.0366	0	5	2	0	0.0	0.0	0	0	0.0	0
080432	.14506	0	5	2	0	0.0	0.0	0	0	0.0	0
080442	.2997	0	5	2	0	0.0	0.0	0	0	0.0	0
080452	.41554	0	5	2	3	0.0	0.0	0	0	0.0	0
080462	0.9738	0	5	2	3	0.0	0.0	0	0	0.0	0
080472	0.6107	0	5	2	3	0.0	0.0	0	0	0.0	0
080482	0.0	0	5	3	3	0.0	0.0	0	0	0.0	0
080492	0.0	0	5	3	-2	0.0	0.0	0	0	0.0	0
080502	0.0	0	5	3	-2	0.0	0.0	0	0	0.0	0
080512	0.0	0	5	3	3	0.0	0.0	0	0	0.0	0
080522	0.0	0	5	3	-2	0.0	0.0	0	0	0.0	0
080532	0.0	0	5	3	-2	0.0	0.0	0	0	0.0	0
080542	0.0	0	5	3	3	0.0	0.0	0	0	0.0	0
080552	0.0	0	5	3	3	0.0	0.0	0	0	0.0	0
080562	0.0	0	5	3	3	0.0	0.0	0	0	0.0	0
080572	0.0	0	5	3	3	0.0	0.0	0	0	0.0	0
080582	0.0	0	5	3	3	0.0	0.0	0	0	0.0	0
080592	0.0	0	5	3	3	0.0	0.0	0	0	0.0	0
080602	0.0	0	5	3	3	0.0	0.0	0	0	0.0	0

TABLE A-IV (contd.)

```
*   RELAP  CRITICAL  FLOW  OPTION
*
*        STAGNATION PROPERTIES        0=NON-USE;  1=USE FOR MACH.GT. 0.3
*
082000   1
*
*
*   FLOW RATE MULTIPLIER FOR HEM MODEL , FLOW RATE MULTIPLIER FOR HENRY
*   CRITICAL FLOW , FLOW RATE MULTIPLIER FOR EXTENDED HENRY CRITICAL FLOW,
*   TRANSITION QUALITY FOR THE MODEL
*
082003   1.0  0.9  0.9  0.01
*
*
*          PUMP  DESCRIPTION  DATA  CARDS
090011  1  7  0 1 0 1190.0 1.01   88000.0 396.0 39700.0  70000.0 0.0 0.0 0.0 0.0
090021  1  7  0 1 0 1190.0 1.01   88000.0 396.0 39700.0  70000.0 0.0 0.0 0.0 0.0
090031  1  7  0 1 0 1190.0 1.01 176000.0 396.0 79400.0 140000.0 0.0 0.0 0.0 0.0
*
*          PUMP  HEAD  MULTIPLIER
091001 -11  0.0  0.0  0.1  0.0  0.15  0.05  0.24  0.80  0.30  0.96  0.4  0.98
091002      0.6  0.97 0.8  0.9  0.90  0.80  0.96  0.50  1.00  0.00
*
*          PUMP  TORQUE  MULTIPLIER
092001  -2  0.0  0.0  1.0  0.0
*
*          PUMP  STOP  DATA  CARDS
095011      0.0  0.0  0.0
095021      0.0  0.0  0.0
095031      0.0  0.0  0.0
*
*          PUMP  CURVE  INPUT  INDICATOR
100000    0   0   0   0
*
*          VALVE  DATA  CARDS
*
*        VENT  VALVE  IN  REACTOR  VESSEL
110010  21    0    0    1.0E-8    4.0       1.0E21          1.0E21
*        INJECT EMERGENCY FLOOD  TANK  WATER
*   FIRST ENTRY FOR DELTA P  CHECK VALVE WITH TRIP = TRIP NUMBER + 20
110020  34    0    0    1.0E-8    4.0       1.0E21          1.0E21
*        BREAK  THE  PUMP  DISCHARGE  LINE
110030   4    0    0    0.0       0.0            0.0              0.0
*        BREAK  WATER  FLOWING  INTO  CONTAINMENT
110040  -2    0    0    0.0       0.0            0.0              0.0
*        BREAK  WATER  FLOWING  INTO  CONTAINMENT
110050  -3    0    0    0.0       0.0            0.0              0.0
*          FILL  TABLE  DATA  CARDS
130100   12  2   9   4   'GAL/MIN'   14.7   110.0          * LPIS
130101       0.10      5000.0    80.00     4470.0     120.00     4050.0
130102     140.00      3750.0   160.00     3250.0     180.00     2250.0
130103     190.00      1200.0   192.70        0.0    3500.00        0.0
130200   10  2   7   4   'GAL/MIN'   14.7   110.0          * HPIS
130201       0.10       605.0  1000.00      527.0    2200.00      343.0
130202    2600.00       227.0  2800.00      122.0    2874.70        0.0
130203    3500.00         0.0
130300   11  1   5   4   'LBS/SEC'   950.0  570.0          * STEAM GEN. OUTLET
130301      0.0    -1586.48501     50.0   -1586.48501    100.0  -1586.48501
130301   0.0    -1586.48501       1.0    -1586.48501       2.0      0.0
130302    500.0          0.0                        1000.0     0.0
```

TABLE A-IV (contd.)

```
130400    11  1   5    4    'LBS/SEC'    950.0  440.0           * STEAM GEN. INLET
130401       0.0       1586.48501      50.0     1586.48501     100.0    1586.48501
130401    0.0      1586.48501       1.0      1586.48501       2.0      0.0
130402      500.0         0.0                                1000.0     0.0
*  NOTE:  THE PRESSURE SETTINGS FOR THE SG SAFETY VALVES WERE INCREASED BY 12.62
*    PSIA.  THIS CHANGE IS DUE TO THE SECONDARY SIDE TEMP. BEING ADJUSTED
*    FOR HEAT OUTPUT EQUAL TO CORE BTU/HR PLUS  PUMP BTU/HR  (TORQUE X RPM)
130500    8  2  10  4  'LBS/SEC'  14.7  120.0   *  STM. GEN. SAFETY VALVES
*                                                  FOR VOLUMES 1  AND  2
130501    0.0  0.0    1077.62  0.0    1077.63  -270.5   1097.62  -270.5
130502    1097.63  -579.7   1107.62  -579.7   1107.63  -966.1   1117.62  -966.1
130503    1117.63  -1507.2   5000.0  -1507.2
130600    13   2    4     4     'LBS/SEC'        14.7        110.0      * SG AUX. FILL
130601    0.0  100.34     812.7  100.34     1136.2  69.2    1244.1  55.36
*
*          KINETICS  CONSTANTS  DATA
140000    3    0     300.0    0.0     0.8     0.0     0.0     0.0
*          SCRAM  TABLE  DATA
141001   -2     7     0.0        0.0          100.0       0.0
*          DENSITY  REACTIVITY  TABLE
142001  -18           0.0    -63.38    0.225    -38.45     0.300     -24.51
142002                0.4    -12.25    0.500     -7.46     0.600      -4.51
142003                0.67    -2.75    0.700     -2.20     0.750      -1.44
142004                0.80    -1.17    0.85      -0.49     0.900      -0.35
142005                0.95    -0.07    1.00       0.00     1.100      -0.07
142006                1.20    -0.42    1.40      -1.69     2.000      -1.69
*
*          DOPPLER  TABLE  DATA
143000   -2           32.0     0.0      5000.0      -9.8
*
*          REACTIVITY  COEFFICIENT  DATA
140010    0.4464     0.4464     0.0      0.0
140020    0.3910     0.3910     0.0      0.0
140030    0.1626     0.1626     0.0      0.0
*          HEAT  SLAB  DATA
*    1=VOLUME # AT SLAB'S LEFT SURFACE, 2=VOLUME NUMBER AT SLAB'S RIGHT SURFACE,
*    3=GEOMETRY INDEX, 4=INDICATES IF SLAB IS STACKED ON TOP OF SLAB XXX-1,
*    5=CALCULATE SLAB QUALITY OPTION, 6=HEAT TRANSFER CORRELATION AT LEFT SIDE,
*    7=HEAT TRANSFER CORRELATION AT RIGHT SIDE, 8=LEFT SURFACE AREA,
*    9=RIGHT SURFACE AREA, 10=TOTAL SLAB VOLUME,
*    11=LEFT SIDE  ((DR*(DR+DHE)**1/2)-DR.
150011    0     6     1     0     0     0     0     0.0          16578.06  148.51      0.0
150021    0     7     1     1     0     0     0     0.0          16578.06  148.51      0.0
150031    0     8     1     1     0     0     0     0.0         16578.06  148.51      0.0
*         15,530 TUBES PER STEAM GENERATOR
150041   17     1     2     0     2     0     0     37826.66  42444.64  113.72     .01922
150051   16     1     2     1     2     0     0     42355.99  47526.93  127.33     .01922
150061   15     1     2     1     2     0     0     12555.29  14088.08  37.745     .01922
150071   15     1     2     1     2     0     0     12636.82  14179.59  37.99      .01922
150081   15     1     2     1     2     0     0     12627.76  14169.39  37.96      .01922
150091   33     2     2     0     2     0     0     37826.66  42444.64  113.72     .01922
150101   32     2     2     1     2     0     0     42355.99  47526.93  127.33     .01922
150111   31     2     2     1     2     0     0     12555.29  14088.08  37.745     .01922
150121   31     2     2     1     2     0     0     12636.82  14179.59  37.99      .01922
150131   31     2     2     1     2     0     0     12627.76  14169.39  37.96      .01922
150141    3     0     3     1     0     0     0     404.83    0.0       1387.26    0.0
150151    4     0     3     0     0     0     0     731.19    0.0       2505.60    0.0
150161    5     0     3     0     1     0     0     318.97    0.0       760.90     0.0
150171   11     0     3     0     1     0     0     318.97    0.0       882.09     0.0
150181   12     3     4     1     1     0     0     342.55    351.89    86.80      0.0
```

<u>TABLE A-IV (contd.)</u>

```
150191  10    4    4    0    1    0    0    40.57     47.80     18.41     0.0
150201  10   12    5    0    3    0    0    351.49    358.59    805.10    0.0
150211  10   11    6    0    0    0    0    123.51    123.51    92.630    0.0
150221   5    5    7    0    3    0    0    102.07    102.07    132.69    0.0
150231   9    4    4    0    3    0    0    220.99    227.29    96.18     0.0
*   1=RIGHT SIDE ((DR*(DR+DHE)**1/2)-DR, 2=LEFT SIDE DHE, 3=RIGHT SIDE DHE,
*   4=LEFT SIDE CHANNEL LENGTH, 5=RIGHT SIDE CHANNEL LENGTH,
*   5=BOTTOM OF SLAB'S ELEVATION - ABOVE RIGHT VOLUME'S BOTTOM ELEVATION,
*   6=TOP OF SLAB'S ELEVATION - ABOVE RIGHT VOLUME'S BOTTOM ELEVATION.
*
150012   .01758    0.0  0.0   0.0      12.0     0.0      0.0
150022   .01758    0.0  0.0   0.0      12.0     0.0      0.0
150032   .01758    0.0  0.0   0.0      12.0     0.0      0.0
150042   .02746    0.0 .0694 16.703    3.0      0.0      16.703
150052   .02746    0.0 .0694 18.703    3.0      16.705   35.404
150062   .02746    0.0 .0694 5.544     3.0      35.408   40.952
150072   .02746    0.0 .0694 5.580     3.0      40.952   46.532
150082   .02746    0.0 .0694 5.576     3.0      46.532   52.109
150092   .02746    0.0 .0694 16.703    3.0      0.0  16.703
150102   .02746    0.0 .0694 18.703    3.0      16.705   35.404
150112   .02746    0.0 .0694 5.544     3.0      35.408   40.952
150122   .02746    0.0 .0694 5.580     3.0      40.952   46.532
150132   .02746    0.0 .0694 5.576     3.0      46.532   52.109
150142   0.0       0.0  0.0   0.0      0.0      0.0  0.0
150152   0.0       0.0  0.0   0.0      0.0      0.0  0.0
150162   0.0       0.0  0.  4.96       4.96     0.0  4.96
150172   0.0       0.0  0.0   0.0      0.0      0.0  0.0
150182   0.0       0.0  0.0   9.043    9.043    0.0      0.0
150192   0.0       0.0  0.0   1.207    1.207    15.126   0.0
150202   0.0       0.0  0.0   10.31    10.31    0.0      10.3
150212   0.0       0.0  0.0   12.54   12.54   0.0      0.75
150222   0.0       0.0  0.0   11.4     11.4     4.7      6.0
150232   0.0       0.0        0.0      12.0     12.0     3.14      15.1
*
*         CORE  SECTION  DATA
160010    1    7    9    15    0.002208    0.4464
160020    2    7    9    15    0.002208    0.3910
160030    3    7    9    15    0.002208    0.1626
*
*
*         SLAB  GEOMETRY  DATA  CARDS
170101   2    3    1    6    0.  0.015417   1.0
170102   1         2    2        0.00029167 0.0
170103   0         3    8        0.0022083  0.0
170201   2    1    4    6    0.023208    0.0028333    1.0
170301   2    2    5    6    7.125       0.015625     1.0
170302   0         6    6                0.703        0.0
170401   2    1    5    6    6.0288      0.208        0.0
170501   2    1    5    6    5.426       0.25         0.0
170601   1    1    5    6    0.0         0.75         0.0
170701   1    1    5    6    0.0         1.3         0.0
*         THERMAL  CONDUCTIVITY  DATA
*
180100 -20 500. 3.341 650. 2.671 800. 2.677 950. 2.439 1100. 2.242
180101     1250. 2.078 1400. 1.940 1550. 1.823 1700. 1.724 1850. 1.639
180102     2000. 1.568 2150. 1.507 2300. 1.457 2450. 1.415 2600. 1.382
180103 3100. 1.323 3600. 1.333 4100. 1.406 4600. 1.538 5100. 1.730
180200  2     32. .41562 5400. .41562
180300 -11 392. 6.936 752. 8.092 1112. 9.827 1472. 10.983 1832. 12.717
```

TABLE A-IV (contd.)

```
180301 2192. 14.451 2552. 17.341 2912. 20.809 3272. 25.433 3632. 31.792
180302 3992. 39.306
*
*   THE STEAM GENERATOR ACTIVE TUBES' THERMAL CONDUCTIVITY WAS DECREASED TO
*   ACCOUNT FOR SLUGE ON THE TUBE WALLS.
*  0.0003 WAS ADDED TO THE TOTAL RESISTIVITY.
*
180400  -6     100.0  4.658    200.0  4.769    400.0  5.007    600.0  5.243
180401         800.0  5.481    1000.0  5.699
180500 -4  32.  8.0  212.  9.4  572.  10.9  932.  12.4
180600 -4  32.  26.5  212.  26.  572.  25.0  932.  22.0
*
*
*         VOLUMETRIC  HEAT  CAPACITY
*
190100 16     32. 34.45 122. 38.35 212. 40.95
190101         392. 43.55 752. 46.8 2012. 51.35
190102        2732. 52.65 3092. 56.55 3452. 63.05
190103        3812. 72.8 4352. 87.7 4532. 94.25
190104        4712. 98.15 4892. 100.1 5144. 101.4
190105        8000. 101.4
190200   2    32. .000075 5400. .000075
190300   5   0.0    28.392
190301   1480.3   34.476   1675.0   85.176
190302   1787.5   34.476   3500.0   34.476
190401  -4 100. 57.18 400. 61.14 600. 63.77 800. 66.41
190500  -2  32.  53.79  500.  53.79
190600  -2  32.  53.79  500.  53.79
*
*
*         LINEAR  EXPANSION  COEFFICIENT
*
200101  -2 0. .000003718 5000. .000012653
200201  -2 0. 0. 5000. 0.
200301 -4 0. .000003094 1652. .000004706 1653. .000005389 5000. .000005389
200401  -2 0. 0. 5000. 0.
200501  -2     0.0        0.0        5000.0     0.0
200601  -2     0.0        0.0        5000.0     0.0
```

APPENDIX B

PWR SMALL COLD LEG BREAK - WESTINGHOUSE PLANT

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APPENDIX B

PWR SMALL COLD LEG BREAK - WESTINGHOUSE PLANT

1. INTRODUCTION

A Westinghouse Four-Loop PWR (Trojan Plant) was modeled using RELAP4/MOD5 for a small break loss of coolant accident (LOCA). The model represented a cold leg break with an area which was 6% of the cold leg cross-section. The break area was 0.25 ft^2. The plant configuration was based on information contained within the Trojan Plant Final Safety Analysis Report [B-1] plus personal communications with Westinghouse personnel. Some interpretation of the results is based on digital data output which was too voluminous to be included in this appendix. The model presented was used for program checkout and should not be considered a comprehensive study of the LOCA response of the actual plant.

2. SYSTEM MODEL AND ASSUMPTIONS

The Westinghouse Plant RELAP4 model consisted of 22 volumes, 34 junctions, and 33 heat slabs. More heat slabs were used for this model than would normally be used for a large break model because of the greater significance of heat transfer from system hardware during the long transient duration.

The nodalization of volumes and junctions is depicted in Figure B-1. The volumes used in the nodalization are identified in Table B-I. The three intact loops are shown lumped together on the left of Figure B-1 while the single broken loop is on the right side of the figure. The downcomer and upper annulus were combined into a single volume as were the upper head and upper plenum. A small leakage path between the downcomer (V1) and the upper plenum (V4) was included as a junction (J21). The volume between the core and the corresponding portion of the core barrel was included with the core volume (V3).

The locations of heat slabs relative to the volumes are shown for the coolant loops and the vessel in Figures B-2 and B-3. The loop and accumulator heat slabs (HS20 through 32) represent outside insulated structural walls. Those representing the steam generator tubing (HS9, 10, 11, and 12) are modeled with a volume on each side.

The vessel heat slabs consist of 8 core slabs (HS1 through 8), 3 reactor vessel slabs (HS 16, 17, and 18), three core barrel slabs (HS13, 14, and 15), and two slabs for vessel internals (HS19 and 33). Heat slabs 19 and 33 are modeled with plate geometry while the others have cylindrical geometry.

Both sides of the middle core barrel slab (HS14) transfer heat energy to the downcomer (V1) during the transient as indicated in Figure B-3 and Table B-II. This results from the design which allows a small portion of the cold leg coolant to flow downward inside the barrel in order to bypass the downcomer at the active core elevations.

Significant model options used to represent the Westinghouse Plant small break in the RELAP4/MOD5 calculations are indicated in Figure B-4. The legend explaining the option symbols is provided in Table B-III.

The liquid and vapor fluid mixtures in the volumes were homogeneously modeled except where the bubble rise model provided for partial or complete separation. The typical gradient of 0.8 and bubble rise velocity of 3.0 ft/sec (BR=1) was used for moderate boiling in single volumes (e.g., the pressurizer). A very high bubble rise velocity of 10^6 ft/sec (BR=2) was used to model the complete liquid separation in the room temperature accumulators (V17 and V18). The containment (V20) should have been treated similarly but was accidently left homogeneous. This is not considered to affect the checkout significantly. A bubble rise velocity of 40 ft/sec (BR=3) was used to model the vigorous boiling phenomena in the steam generator secondaries. The reactor vessel stacked volumes were modeled for moderate boiling using 0.0 gradient and 3.0 ft/sec bubble rise (BR=4). The steam generator primary and cold leg outlet piping as stacked components should also have been modeled with BR=4 rather than the BR=1 actually used. The difference between the nominal gradient (0.8) and the non-gradient (0.0) is not considered to have affected the check out significantly.

A bubble rise model was used in conjunction with vertical volume stacking (IAMBLO) and junction vertical slip (SRCOS) to better represent flow phenomena to be calculated in the vessel and steam generators. Enthalpy transport was used in junctions adjacent to volumes where major amounts of heat were to be added or removed from the coolant. This occurred in the core (V3) and the steam generator primaries (V6, 7, 12, and 13). The use of junction vertical slip, volume stacking, and a bubble rise model in each of a group of series connected volumes provides a single consistent mixture level in the volume stack. The volume groups so treated were the central region of the vessel (V2, 3, and 4) and the steam generator outlet sides to the minimum elevation of the pipe approaching the pump suction (V7 and 8; V13 and 14).

The downcomer (V1) could not be included in the volume stacking because the IAMBLO parameter of the lower plenum volume (V2) could accept only one input value. Stacking the lower plenum with the core was selected as the more important input. Bubble rise models were used for the inlet halves of the steam generator primaries (V6 and 12), because the mixture level would affect primary-to-secondary heat transfer during the LOCA transient.

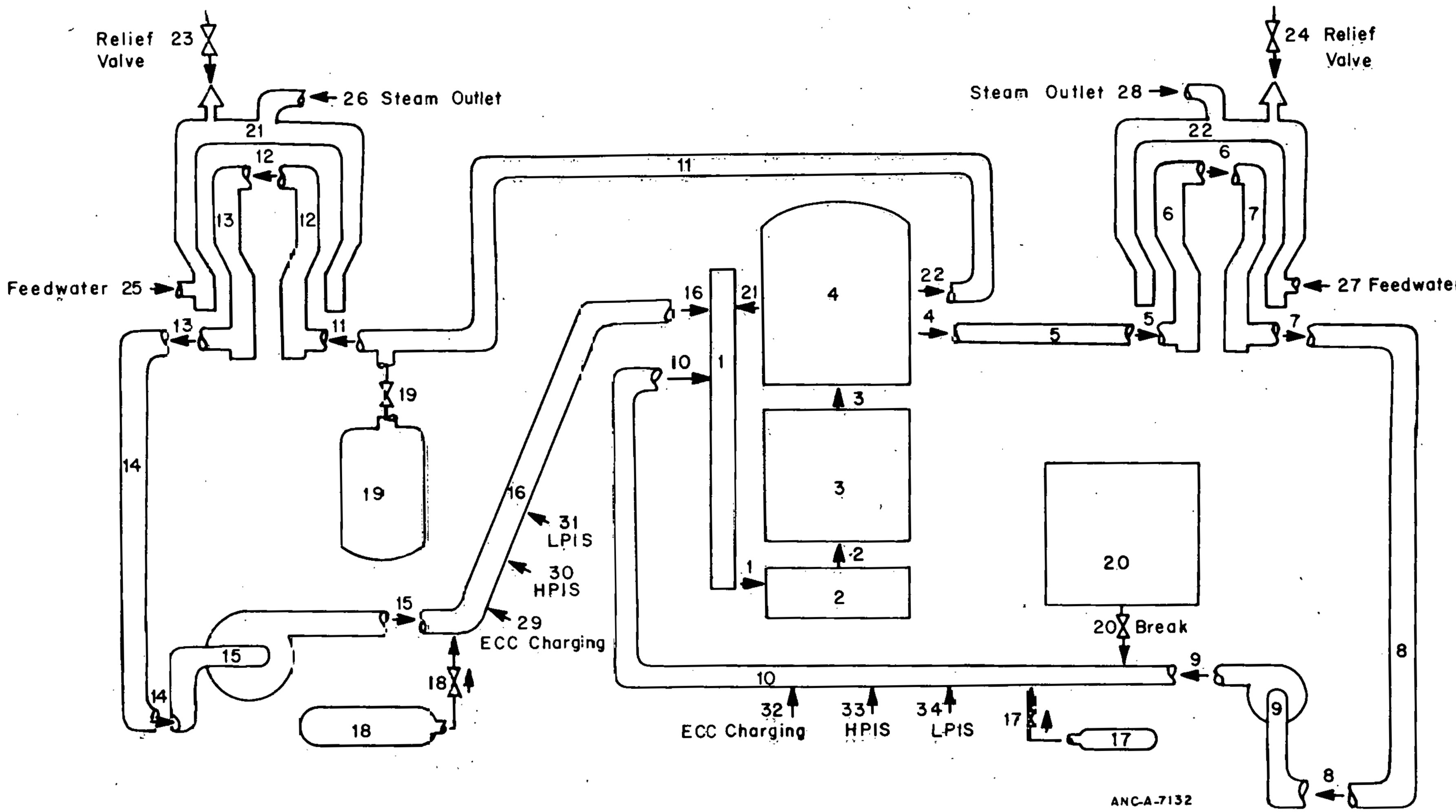

Fig. B-1 Nodalization for 6% cold leg break - Westinghouse Plant.

TABLE B-I

VOLUME IDENTIFICATION FOR 6% COLD LEG BREAK - WESTINGHOUSE PLANT

Volume No.	Description
1	Downcomer (includes Upper Annulus)
2	Lower Plenum
3	Core
4	Upper Plenum (includes Upper Head)
5	Hot Leg Pipe - Broken Loop (BL)
6	Steam Generator - Primary, Inlet Half
7	Steam Generator - Primary, Outlet Half
8	Piping - Steam Generator to Low Elevation
9	Piping and Pump - Low Elevation to Pump Outlet
10	Cold Leg Pipe - Broken Loop
11	Hot Leg Piping - Intact Loops (IL)
12	Steam Generators - Primary, Inlet Half
13	Steam Generators - Primary Outlet Half
14	Piping - Steam Generators to Low Elevation
15	Piping and Pumps - Low Elevation to Pump Outlet
16	Cold Leg Pipes - Intact Loop
17	Accumulator (BL)
18	Accumulators (IL)
19	Pressurizer
20	Containment
21	Steam Generator Secondaries (IL)
22	Steam Generator Secondary (BL)

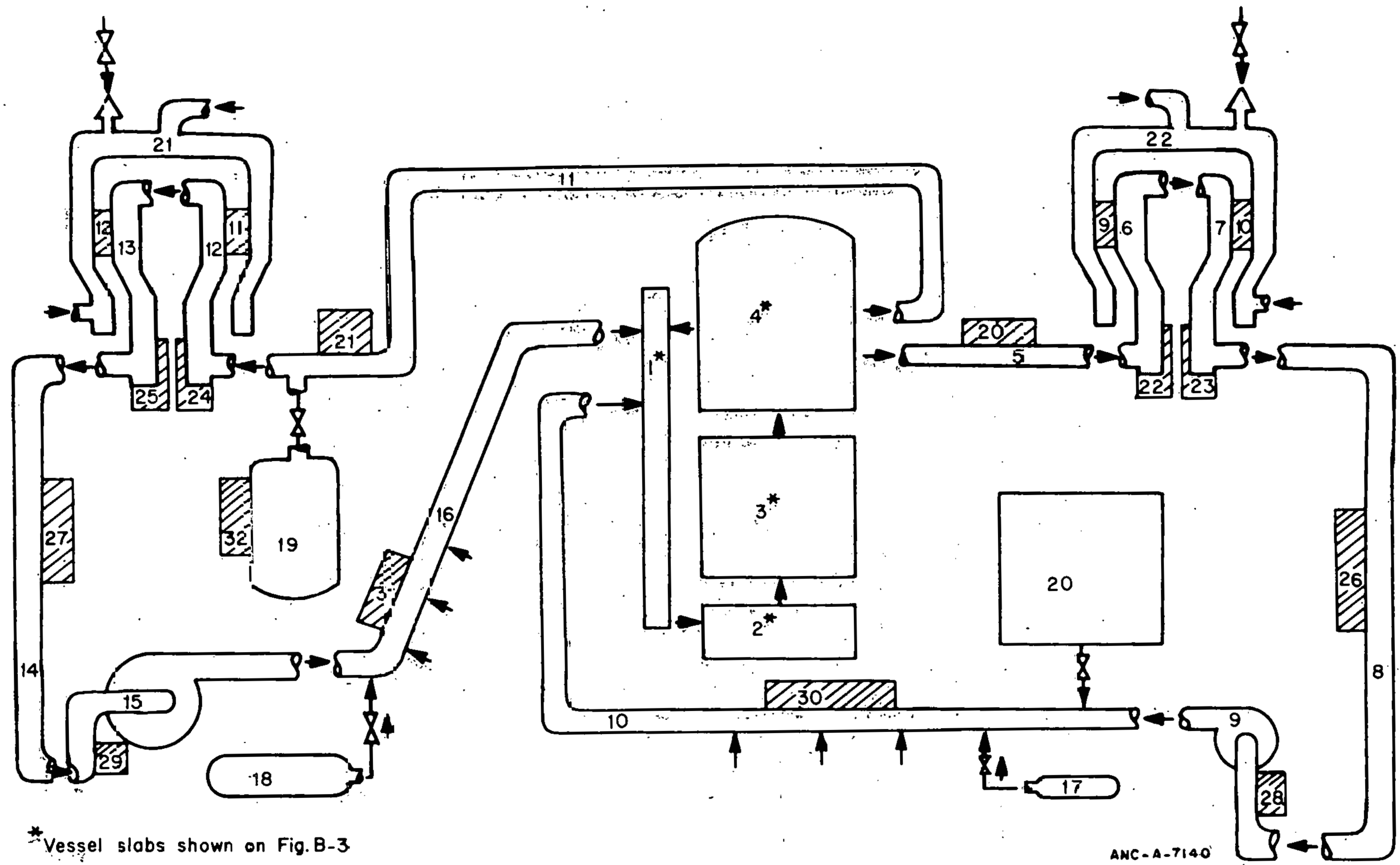

Fig. B-2 Heat slabs for 6% cold leg break - Westinghouse Plant.

TABLE B-II

HEAT SLAB IDENTIFICATION FOR 6% COLD LEG BREAK - WESTINGHOUSE PLANT

Heat Slab No.	Adjacent Volume[a] Left	Adjacent Volume[a] Right	Heat Slab Identification
1-8	0[b]	3	Core Segments
9 & 10	6 & 7	22	Steam Gen. Tubes, Broken Loop (BL)
11 & 12	12 & 13	21	Steam Gen. Tubes, Intact Loop (IL)
13	2	1	Lower Core Barrel
14	1	1	Middle Core Barrel
15	4	1	Upper Core Barrel
16	2	0	Lower Vessel
17	1	0	Middle Vessel
18	4[c]	0	Upper Vessel
19	0	4	Upper Plenum Internals (Plate)
20 & 21	5 & 11	0	Hot Leg Piping, BL and IL
22 & 23	6 & 7	0	Steam Gen. Plenum Structure, BL
24 & 25	12 & 13	0	Steam Gen. Plenum Structure, IL
26 & 27	8 & 14	0	Piping, Steam Generator to Low Elevation, BL and IL
28 & 29	9 & 15	0	Piping and Pumps, Low Elevation to Discharge, BL and IL
30 & 31	10 & 16	0	Cold Leg Piping, BL and IL
32	19[c]	0	Pressurizer Tank
33	0	2	Core Support and Lower Core Plates

[a] For cylindrical geometry, left side is inside diameter and right side is outside diameter.
Zero represents zero heat flux surface, e.g., insulated surface or center of slab.

[b] Center of rod.

[c] Center of flat plate.

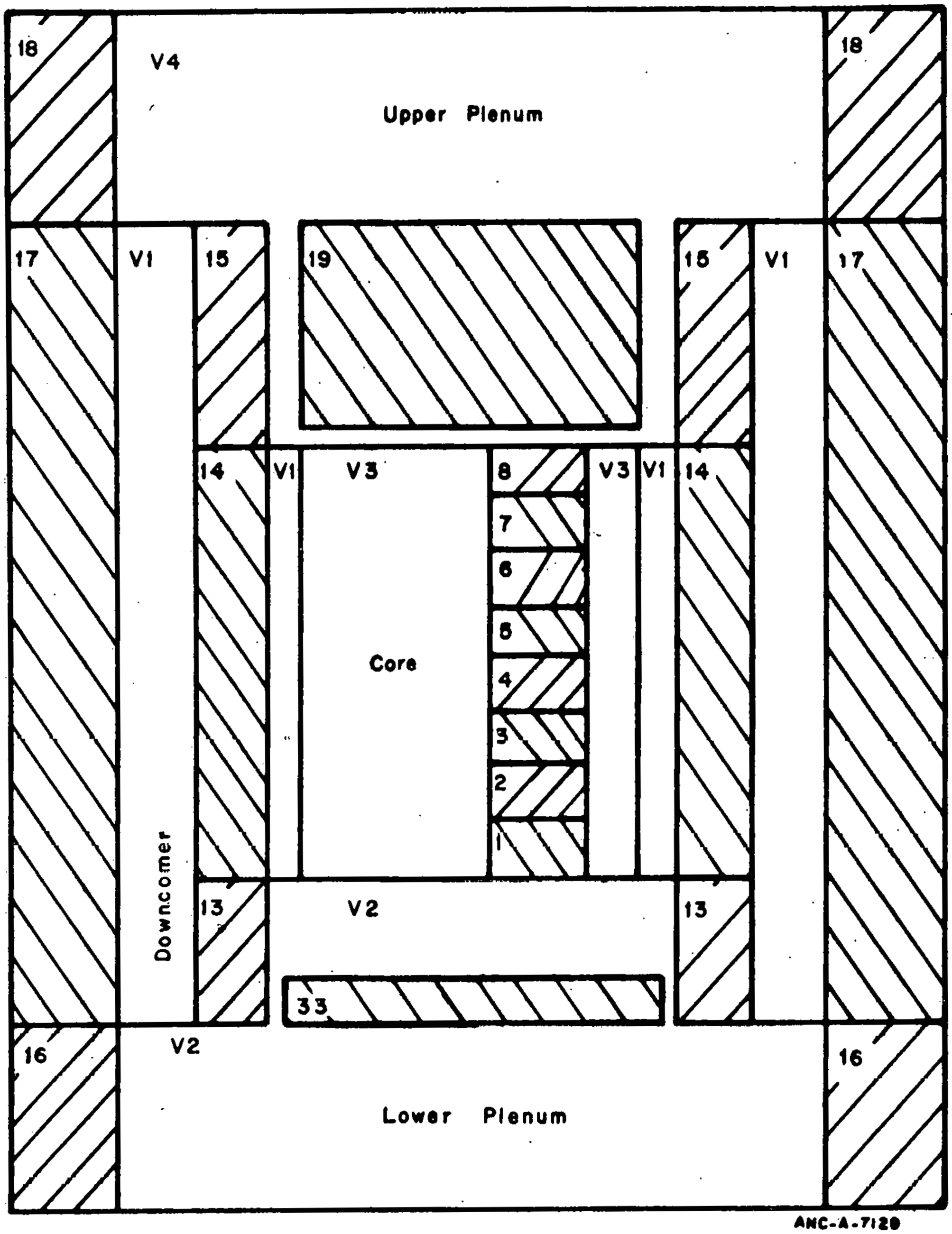

Fig. B-3 Vessel heat slabs for 6% cold leg break - Westinghouse Plant.

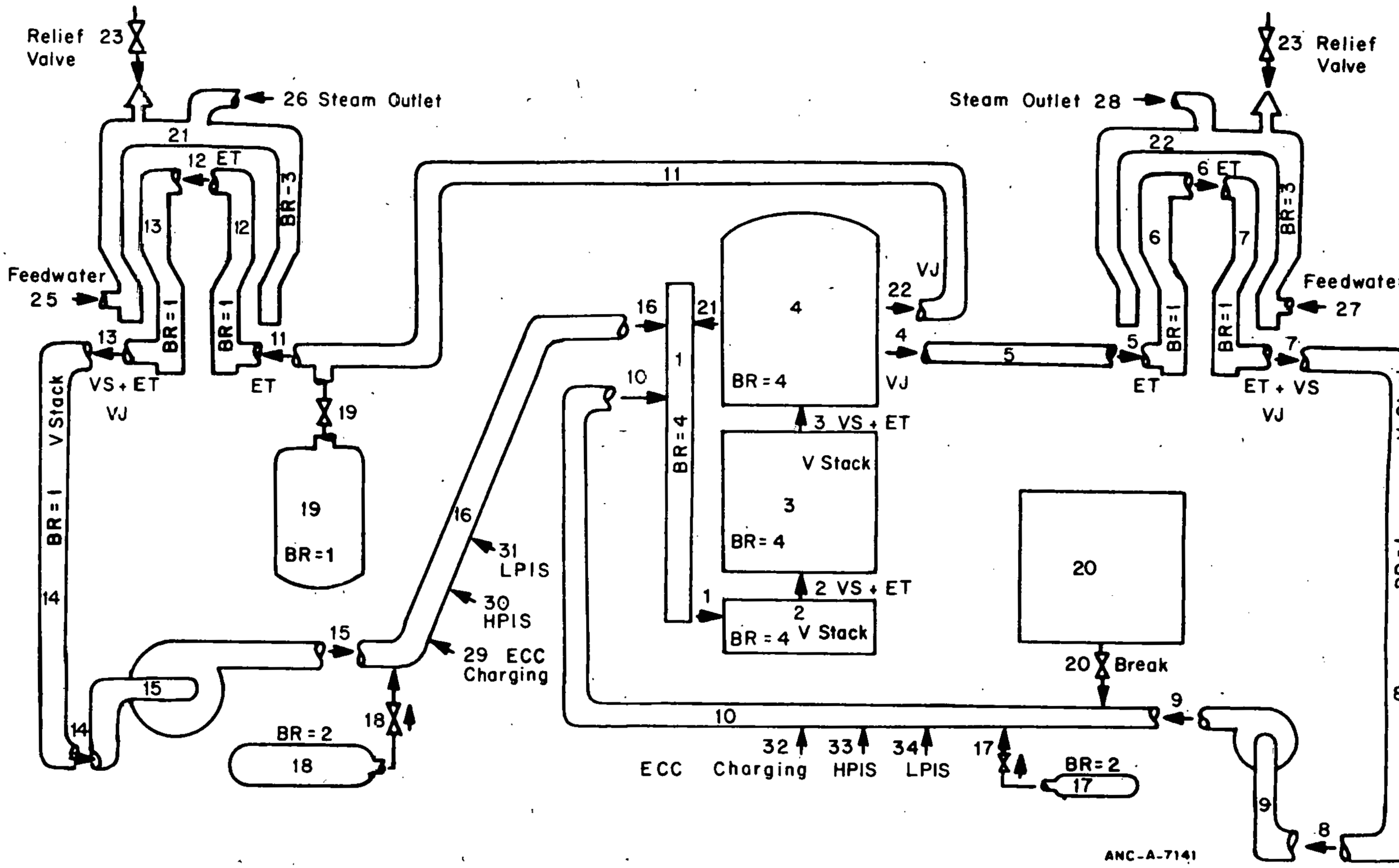

Fig. B-4 Model option used for 6% cold leg break - Westinghouse Plant.

TABLE B-III

RELAP4/MOD5 OPTIONS USED FOR 6% COLD LEG BREAK - WESTINGHOUSE PLANT

1. Bubble Rise Data Index (Volume Data Card, IBUB)

Bubble Rise (IBUB Index No.)	Bubble Rise Gradient (ALPH)	Bubble Velocity At Mixture Surface (VBUB)
1	0.8	3.0
2	0	1×10^6
3	0.8	40.0
4	0	3.0

Used to produce two phase mixture level. Otherwise volume fluid is treated as being homogeneous.

2. VSTACK, Vertical Stack and Slip Flow Index (Volume Data Card, IAMBLO)

Denotes volumes which are grouped with volumes immediately above to generate one two-phase mixture level in the volume stack. It is used with the VS option only.

3. VJ, Vertical Junction Index (Junction Data Card, JVERTL)

Shown where the junction flow area is assumed to be a vertical circular area centered at the junction elevation. Otherwise, the junction area is treated as occurring at a point for mixture level elevation purposes. It is used adjacent to volumes where the bubble rise model is used.

4. ET, Enthalpy Transport Index (Junction Data Card, IHQCOR)

Shown at junctions where enthalpy transport is used. Enthalpy transport used at junctions adjacent to volumes where significant heat is added to or removed from the coolant, i.e., core and steam generators.

5. VS, Vertical Slip Indicator (Junction Data Card, SRCOS)

Indicates junctions where vertical slip is used.

The vertical sections of piping from the low elevation to the pump suction (V9 and 15) were left homogeneous, since flow was expected to remain positive. Liquid and steam, thus, tended to move together. This also avoided splitting off the pumps as separate volumes since they could not be construed to have mixture levels. This nodalization ignored the time required to transport steam from the low pipe elevations (J8 and 14) to the pump inlets, but this simplification also is not considered to have significantly affected the check out.

The fluid in the hot and cold leg pipe volumes (V5 and 11; V10 and 16) was left homogeneous. This was done to avoid the excessive computer time that might result from use of the Horizontal Slip Model with non-stratified flow.

Vertical modeling of junctions considers that the plane normal to the direction of flow is vertical. The junctions between the vessel and the hot leg pipes (J4 and 22) were vertically modeled (JVERTL=1) to assist the upper plenum mixture level in crossing the junction elevation. The junctions at the steam generator outlets (J7 and 13) were similarly modeled as vertical. In addition, the smoothing option for "mixture level crossing of a junction from above" was input to start 90 sec after the transient began. This was used for both the vessel and the steam generator outlets.

The Henry-Fauske and the HEM models were used to calculate break flow choking. The Henry-Fauske model was used for subcooled flow, and HEM was used with a 0.9 multiplier for saturated flow with a quality greater than 0.01. The Stagnation Properties (STAGP) subroutine was used to provide stagnation properties to the choked flow model.

The initial conditions for the Westinghouse Plant 6% cold leg break LOCA analysis were all nominal steady state conditions. The break trip instantaneously opened a 0.25 ft^2 area (J20) from the single cold leg pipe (V10) to the containment (V20). The remaining trips were controlled by the ongoing RELAP4 program steps and computations.

The next major trip was the Safety Injection Signal (SIS) which was et as a high pressure trip of 4 psig in the containment (18.7 psia in 20). This trip would cause:

(1) Immediate power shutoff to the primary coolant pumps (V9 and 15) plus initiation of reactor scram

(2) A one-second delay after SIS plus a one-second linear closure ramp on the steam generator secondary feedwater and steam outlet valves (J25, 26, 27, and 28)

(3) A 24.25 sec delay after SIS prior to activating the charging pumps for ECC (J29 and 32)

(4) A 28.75 sec delay after SIS prior to activating the HPIS pumps for ECC (J30 and 33)

(5) A 37.75 sec delay after SIS prior to activating the LPIS pumps for ECC (J31 and 34). To be consistent with not losing site and preferred power, the ECC pump delays should have been set at 12.25 sec delay after SIS. It should be noted, however, that LPIS flow could not start until the system pressure dropped below 200 psi due to the cutoff pressure modeled in the Fill Table.

A trip was set to shut off flow from each accumulator (J17 and 18) when the mixture level reached 0.01 ft. This prevented accumulator air from reaching these junctions. Air flow at either of the junctions would have caused the calculation to terminate.

An extra trip was provided, as a contingency, for shutting off flow from the pressurizer at J19. It was set for a high elapsed time and was not to be used unless minor flows in and out of the pressurizer, after it emptied, caused an unacceptable number of small time steps with the attendant increase in computer time. Accordingly, it was not used.

3. RESULTS

The Westinghouse Plant small cold leg break model was run with the RELAP4/MOD5 code to a LOCA elapsed-time of 900 sec. This required approximately 50 min of CPU time for the Berkeley CDC 7600 computer installation. A chronology of the transient is listed in Table B-IV. Output data were obtained in the form of data traces which are included as Figures B-5 through B-15 in Section 5 of this appendix. The input data is similarly included as Table B-V in Section 6 of this appendix. An interpretation of the transient output data is as follows:

(1) The end of this small break blowdown problem run was somewhat arbitrarily determined. Fuel surface temperatures peaked 10 sec into the LOCA transient at temperatures less than 30°F above their initial values and fell thereafter (see Figure B-5). The core was momentarily uncovered to a maximum exposed depth of 1.8 ft at 120 sec, but remained covered or very nearly so afterwards (Figure B-6). It was necessary to calculate LOCA conditions for 900 sec, however, to complete the pressure blowdown (Figure B-7). Even at 900 sec, the core contained only 77% of its initial mass. The lower density was due to the presence of bubbles from continued boiling. Fuel surface temperatures were nearly stabilized just below 300°F due to the power residual (2.2% of the nominal power). Both fuel residual power and surface temperatures were slowly decaying, but the high cost of further calculation at that point did not warrant problem continuation. The last 200 sec of the blowdown (700 to 900 sec) had used over half the CPU time, apparently due to water packing related phenomena in the cold legs (V10 and 16).

(2) Many of the major events in the blowdown are reflected in the upper plenum pressure changes (Figure B-7) and in the break flow (Figure B-8).

TABLE B-IV

MAJOR EVENTS SUMMARY
FOR 6% COLD LEG BREAK - WESTINGHOUSE PLANT

Time (sec)	Event
0.01	(J20) break opened to 6% of cold leg area
0.5-1.5	Pressure plateau; break volumetric flow approximated that of vapor formation
5	End of (V4) subcooled blowdown
8.4	Containment (V20) pressure reached 18.7 psia major trip
	Pump power shutoff
	Scram started (completed at 11.0 sec)
7.5-9.5	Vessel pressure increased (Fig. B-7)
9.4-10.4	Steam generator secondary feedwater and steam valves (J25, 26, 27, 28) closed
10	Upper Plenum (V4) mixture level began falling (Fig. B-13)
15	Pressurizer emptied of liquid
23	Intact loop steam generator inlet side (V12) mixture level began falling
28	Broken loop steam generator inlet side (V6) mixture level began falling
28	Steam generator secondaries (V21 and 22) began venting (>1,100 psig)
32.65	Charging pump flows started on auxiliary power (J29 @ 81 gpm and J32 @ 27 gpm initial flow)
36	Intact loop steam generator outlet (V13) mixture level began falling
36	Broken Loop Vessel inlet nozzle flow (J10) reversed due to break flow

TABLE B-IV (contd.)

Time (sec)	Event
37.15	HPIS pump flows started on auxiliary power (J30 @ 60 gpm and J33 @ 20 gpm initial flow)
39	Broken loop steam generator outlet (V7) mixture level began falling
40-120	System pressure plateau sustained at 1,180 psia by charging and HPIS pumps (Fig. B-7)
90	First core flow reversal
92	Broken loop (V8) mixture level between steam generator and pump suction began falling
93	Broken loop pump inlet uncovered (two-phase at J8)
106	Core (V3) mixture level began falling (Fig. B-6)
	Intact loop (V14) mixture level between steam generator and pump section began falling
107	Intact loop pump inlet uncovered (two-phase at J14)
118	Two-phase flow began in broken loop (V10) cold leg and at break (J20) (Fig. B-11)
120	Core mixture level minimum with 1.8 ft of 12 ft core uncovered (Fig. B-6)
127	Core recovered by mixture (later short duration uncoverings limited to less than 0.2 ft of core) (Fig. B-6)
145	Two-phase flow began in intact loop cold leg (V16)
152	Downcomer (V1) mixture level began falling as intact loop cold leg (J16) flow reversed (dropped to nozzle elevation) (Fig. B-14)
200	Steam generator secondaries (V21 and 22) venting ended (>1,100 psig)

TABLE B-IV (contd.)

Time (sec)	Event
210-310	Core mass boiled off from 72% to 46% of initial value as pressure fell
266	Accumulator flows (J17 and 18) started
267	Intact loop cold leg flow (J16) to vessel became strongly positive (Fig. B-15)
278	Vessel mixture level raised to nozzle elevation in upper plenum (V4) (Fig. B-13)
280	Two-phase flow ended at break (J20) (Fig. B-11)
286	Downcomer (V1) volume refilled to top (Fig. B-14)
310-345	Core (V3) mass increased from 46 to 67% of initial
345-420	Core mass decreased from 67% to minimum of 36%
375	LPIS flows (J31 and 34) started; flow increased as system pressure fell below 200 psi
380	Accumulator flows (J17 and 18) ended
422	Downcomer (V1) mixture level began falling (2nd time, mixture level dropped half way to nozzle elevation and immediately recovered) (Fig. B-14)
430	LPIS rate of flow (J31, 600 lb/sec and J34, 200 lb/sec) increase leveled off
440	Downcomer (V1) volume refilled to top (2nd time) (Fig. B-14)
704	Pressure and flow perturbation in broken loop caused by steam collapse in pump (V9)
820-900	Pressure and flow perturbations in both loops (Figs. B-8 and 15)

TABLE B-IV (contd.)

Time (Sec)	Event
900	End of problem run Mass of coolant in core (V3) was 77% of initial value Residual power was 2.2%

The pressure increased during the periods from 1 to 2 sec and from 8 to 9.5 sec. This corresponded to changes in core heat transfer modes to nucleate boiling which caused spikes in steam generation rates. The pressure plateau existing from about 40 to 120 sec reflected the ECC flows from the ECC charging and HPIS pumps which started between 30 to 40 sec System Injection Signal at 8.4 sec plus start delay times).

As can be seen from Figure B-7, from 118 to 280 sec, the system depressurized due to higher volumetric flow at the break, caused by the two-phase state of the break flow. The digital output data (not included herein) showed that the volumetric flow rate doubled with two-phase flow although the mass flow rate (Figure B-8) was cut to less than one-third of what it had been prior to 118 sec.

The start of accumulator liquid injection into the cold leg pipes at 266 sec caused the end of two-phase flow at the break. Also, the mass of liquid injected was large enough to increase the rate of depressurization by condensing significant volumes of steam (270 to 320 sec) as indicated by the (V10) average water temperature and quality near the break (Figures B-9 and 11).

From 320 to 380 sec, the accumulator flows were adequate to cause another pressure plateau. The mass flow rate at the break was high (Figure B-8) due to the temporarily lower liquid temperature (Figure B-9).

The 200 psi threshhold for LPIS flow was reached and the flow started just before the accumulator flow ended. The LPIS flow was a considerably smaller flow but built up during the period between 378 sec and 430 sec. It was insufficient to maintain the pressure plateau beyond 380 sec or to keep the cold leg (V10) temperature depressed (Figures B-7 and 9).

From 400 to 700 sec, the system pressure decreased gradually (Figure B-7). The significant break flow rate (Figure B-8) primarily reflected the density of the water which was indicated by the relatively low temperature (Figure B-9). The disturbances at 704 and 830 sec were due to steam in the pumps collapsing violently. These flow and pressure disturbances are assumed to result from the cold water being drawn into the pumps with attendant water hammer and water packing. Although water packing has been largely overcome in the code, this was an example of its now infrequent occurrence.

(3) The steam which reached the break after 118 sec came from the upper plenum (V4) venting. The low elevation for the broken loop pump suction (J8) uncovered at 92 sec (Figure B-10). The steam reached the break at 118 sec due to flow time delay (Figure B-11) to complete the vent path. As the steam vent path was being completed, there was a flow around the broken loop as shown by the flow (J6) from the upper plenum to the cold leg at 104 sec (Figure B-12). This flow surge caused the mixture level in the reactor vessel to continue downward from the upper plenum (Figure B-13) to a partially uncovered core location (Figure B-6).

(4) The mixture level in the downcomer dropped twice during the blowdown (Figure B-14). The first drop reached the level of the cold leg nozzles. Both drops in the downcomer mixture level were caused by flow reversals and/or negligible flow in the cold leg of the intact loop (Figure B-15).

4. CONCLUSIONS

The problem ran reasonably smooth out to 700 sec where water packing temporarily increased the number of time steps. A second water packing incident increased the required number of time steps between 820 and 900 sec. Although water packing has been largely overcome in the code, this was an example of its now infrequent occurrence.

Total CPU time was about 50 min on a Control Data Corporation (CDC) 7600, which met the acceptance criteria outlined in Volume III, Section 7.2

Although the core refilled to only 77% of its initial mass of coolant due to continued boiling, the core mixture level remained essentially covered except for a short period at 120 sec. The two very short drops in mixture level beyond 800 sec (see Figure B-6) are discounted as part of the water packing perturbations. Since other parameters had stabilized by 900 sec, little benefit was seen in continuing the calculation beyond that time.

5. OUTPUT DATA

The output data traces for the Westinghouse Plant 6% cold leg break are included within this section as Figures B-5 through B-15.

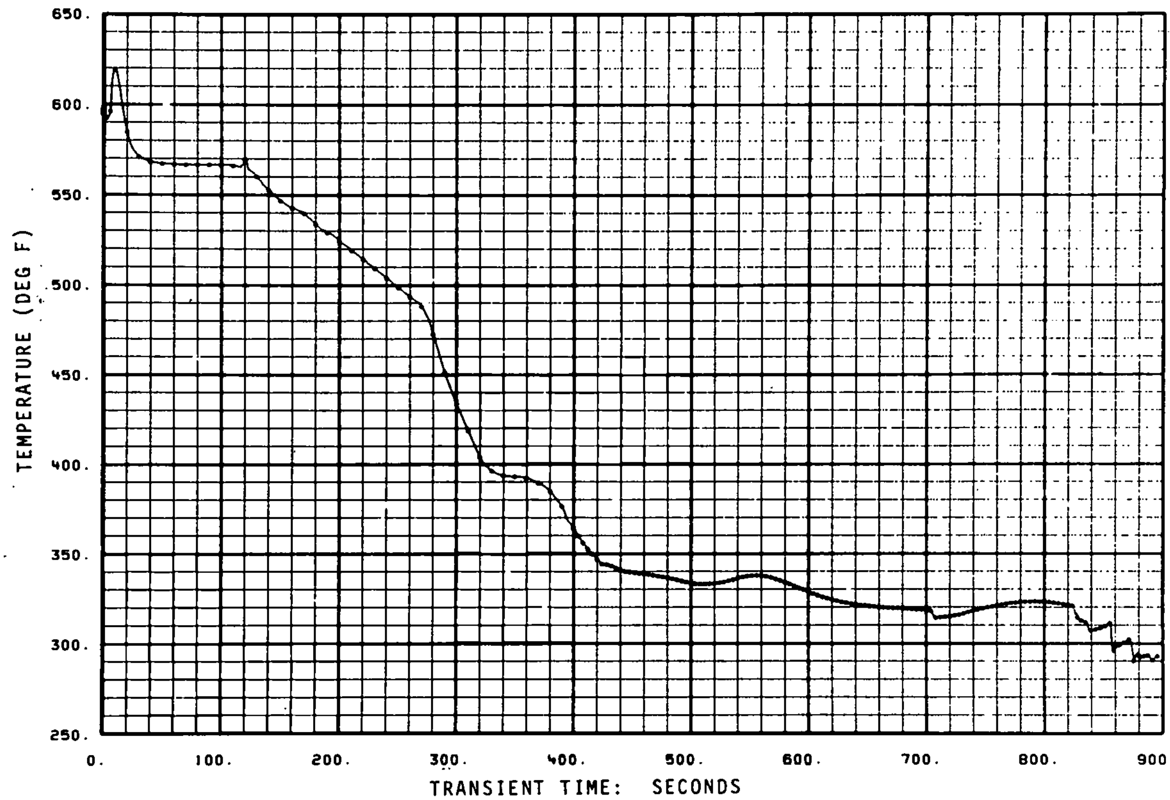

Fig. B-5 Core cladding surface temperature, top heat slab (1.5 ft) - Westinghouse Plant (6% break).

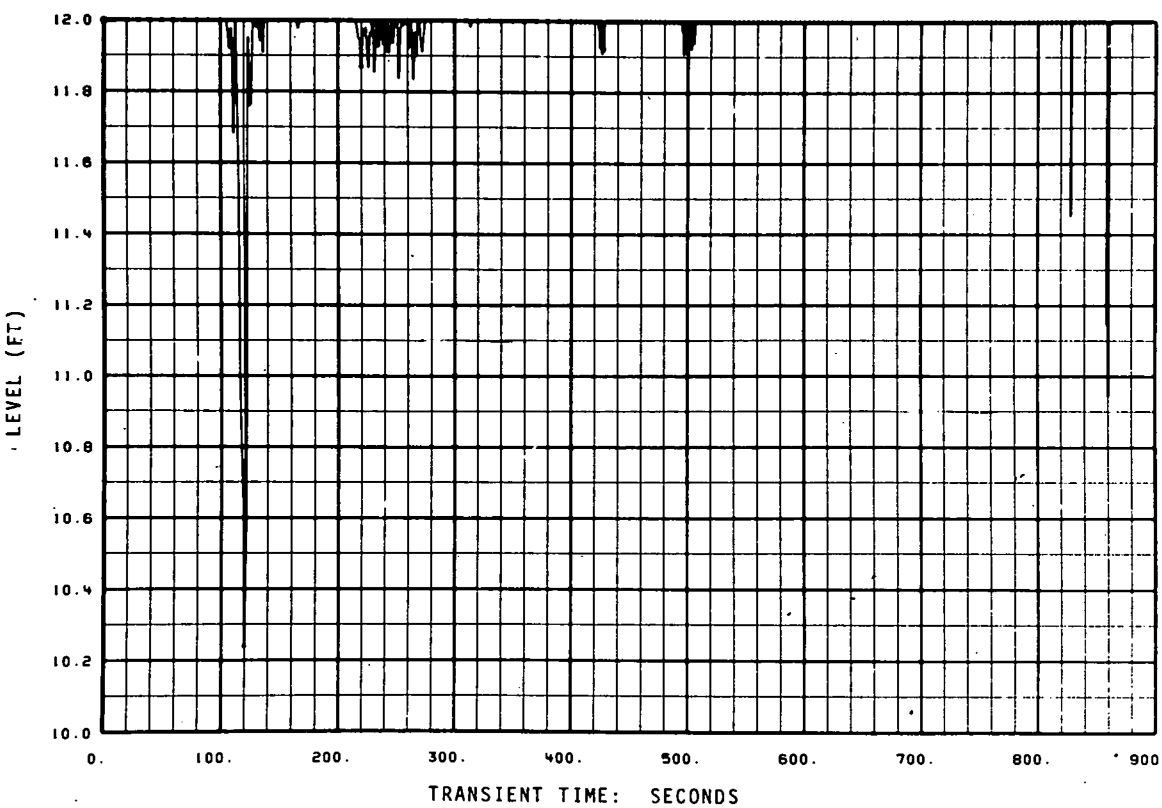

Fig. B-6 Core mixture level - Westinghouse Plant (6% cold leg break).

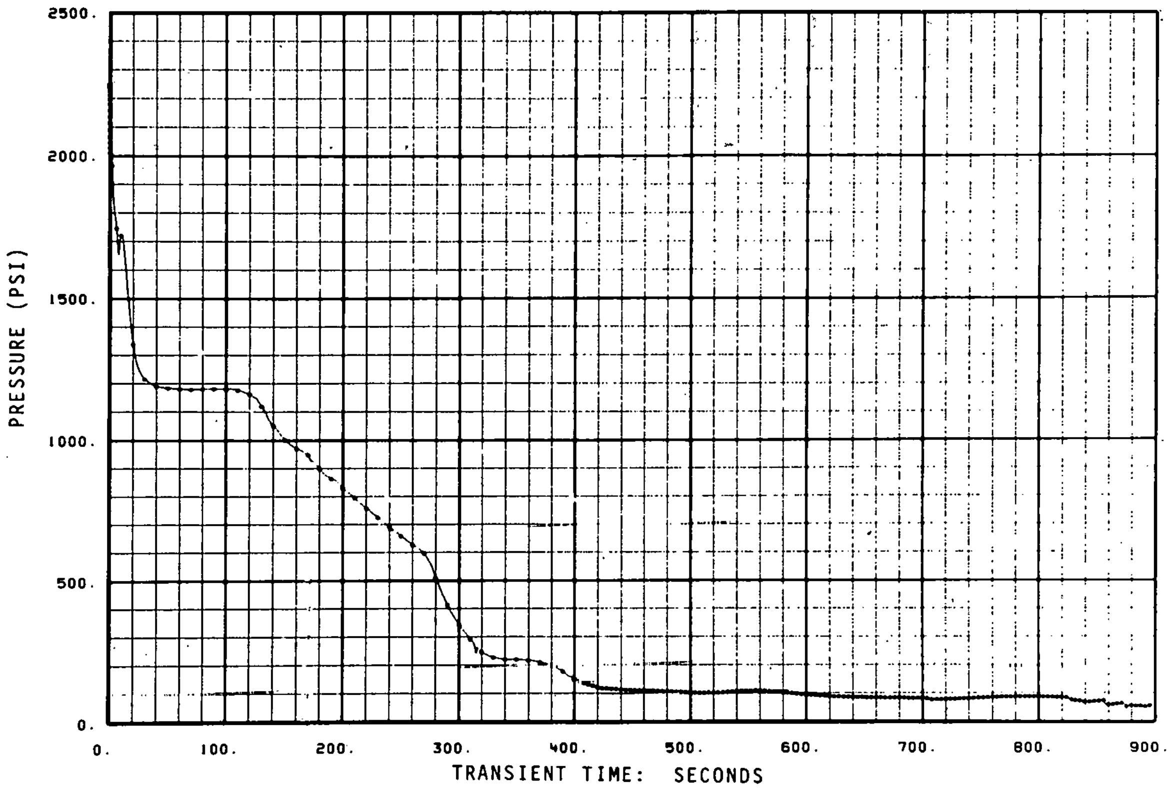

Fig. B-7 Upper plenum pressure - Westinghouse Plant (6% cold leg break).

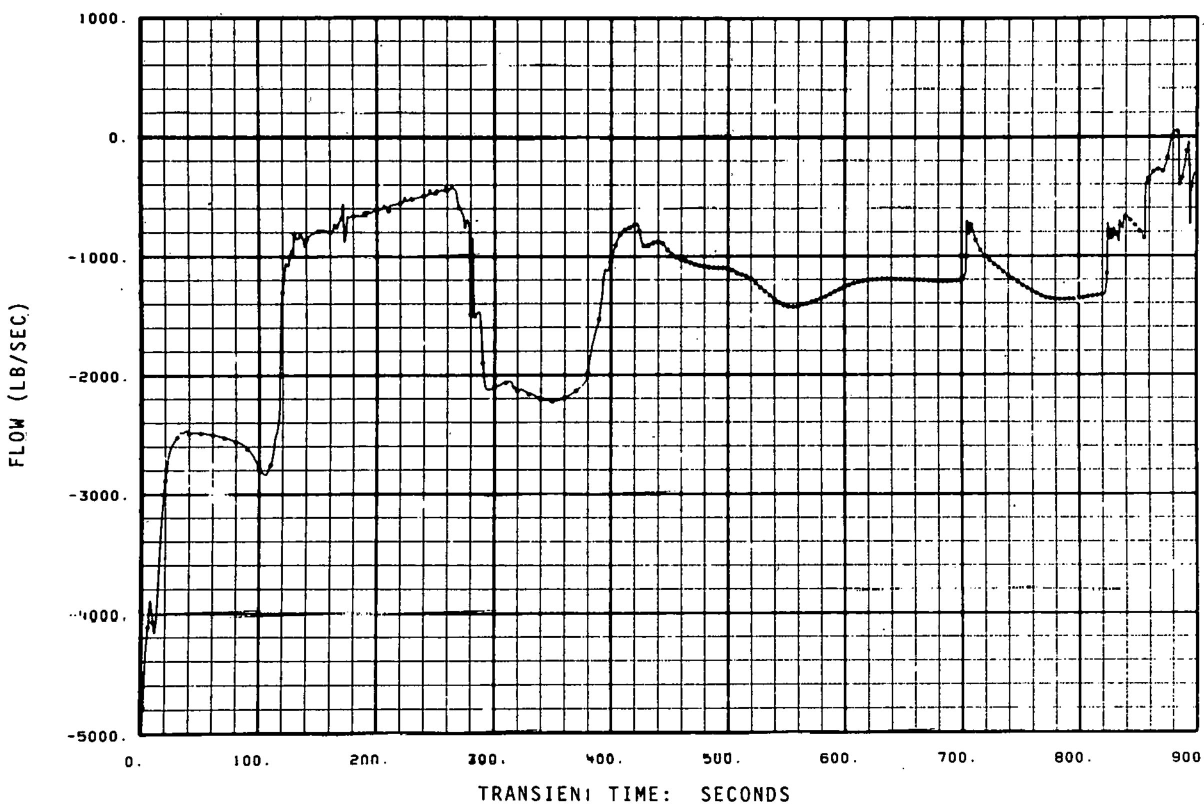

Fig. B-8 Break flow - Westinghouse Plant (6% cold leg break).

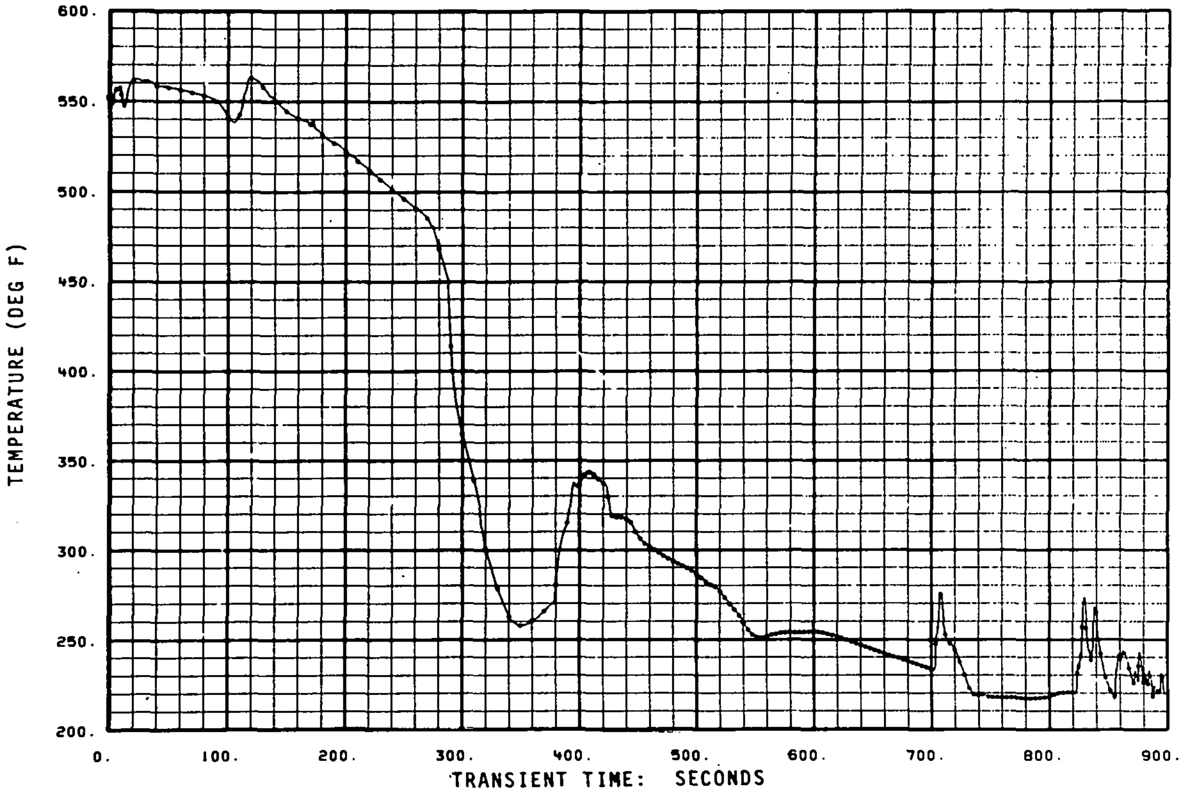

Fig. B-9 Temperature, broken loop cold leg (break donor volume) - Westinghouse Plant (6% cold leg break).

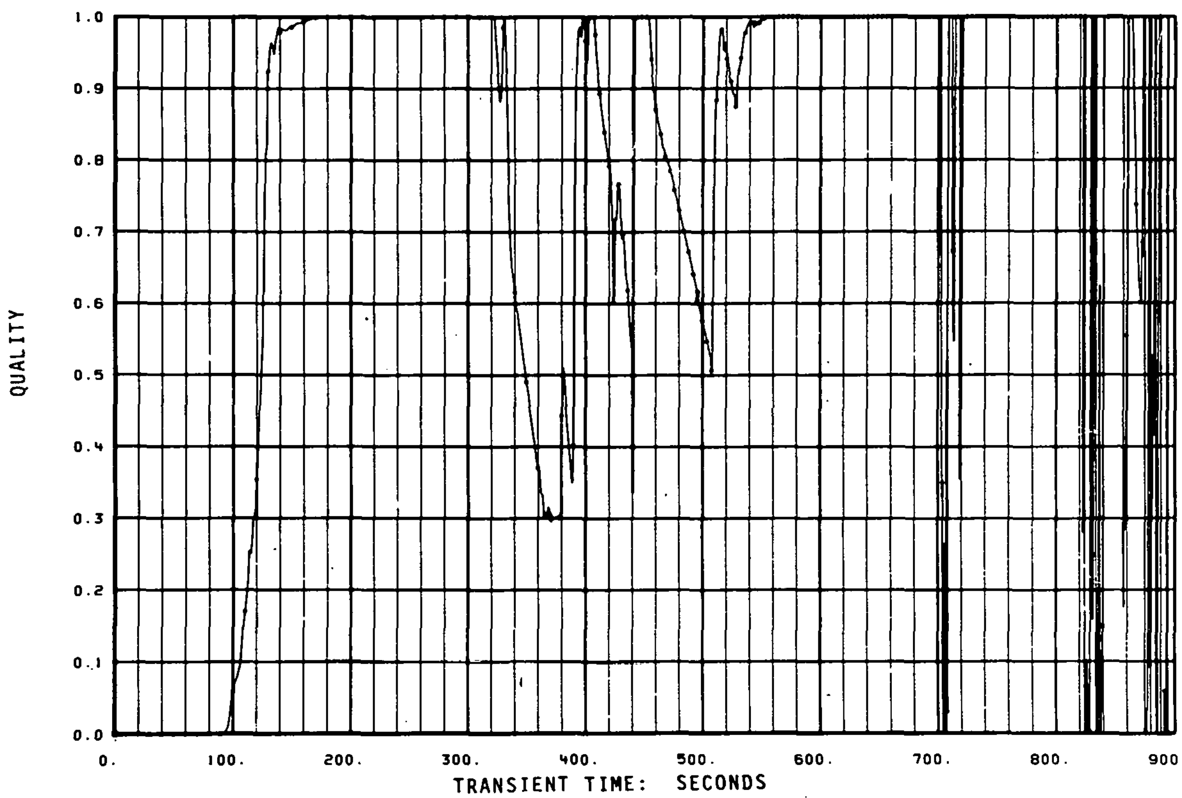

Fig. B-10 Quality at broken loop pump suction (low elevation) - Westinghouse Plant (6% cold leg break).

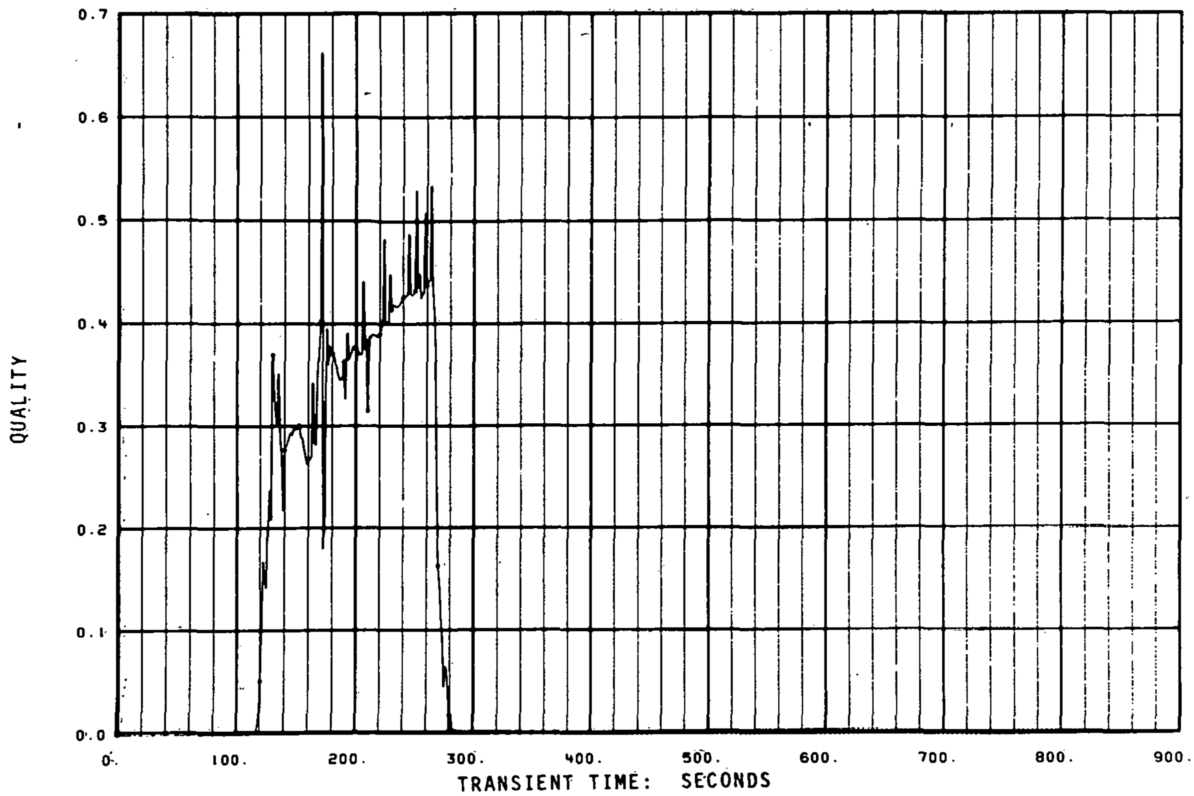

Fig. B-11 Quality, broken loop cold leg (break donor volume) - Westinghouse Plant (6% cold leg break).

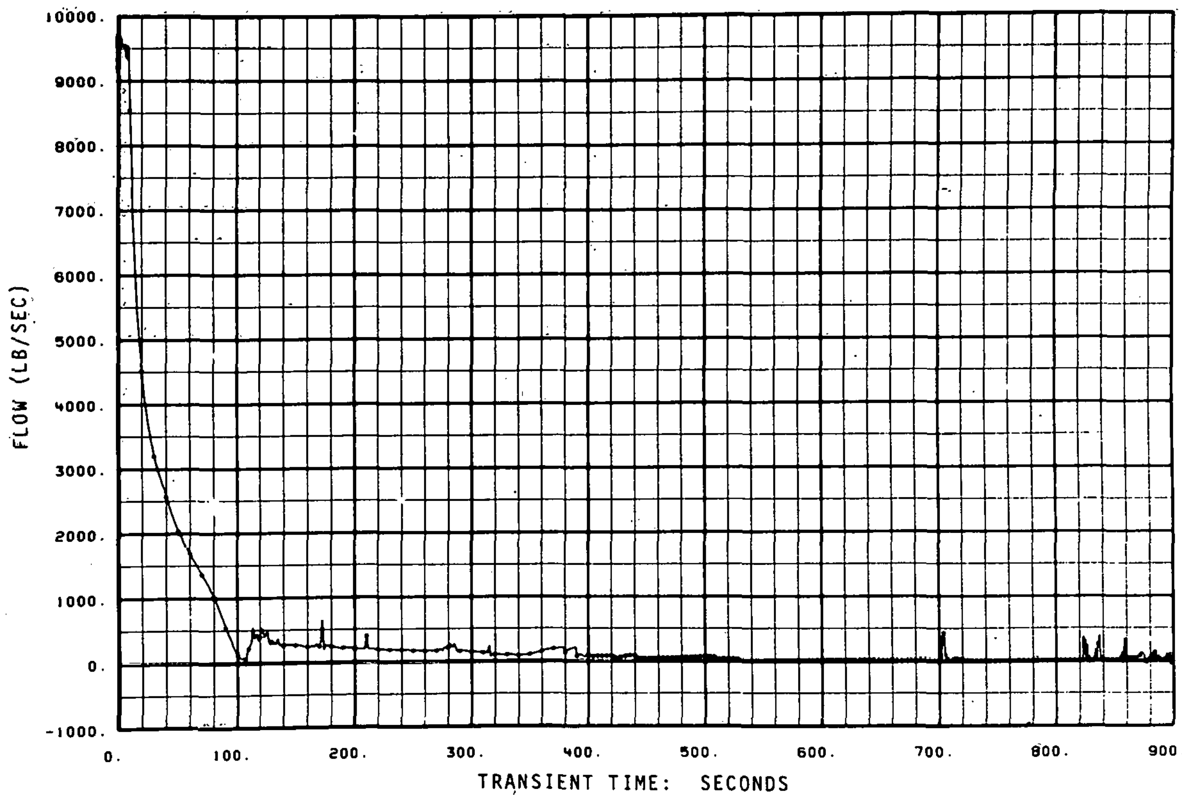

Fig. B-12 Flow, vessel to broken loop hot leg - Westinghouse Plant (6% cold leg break).

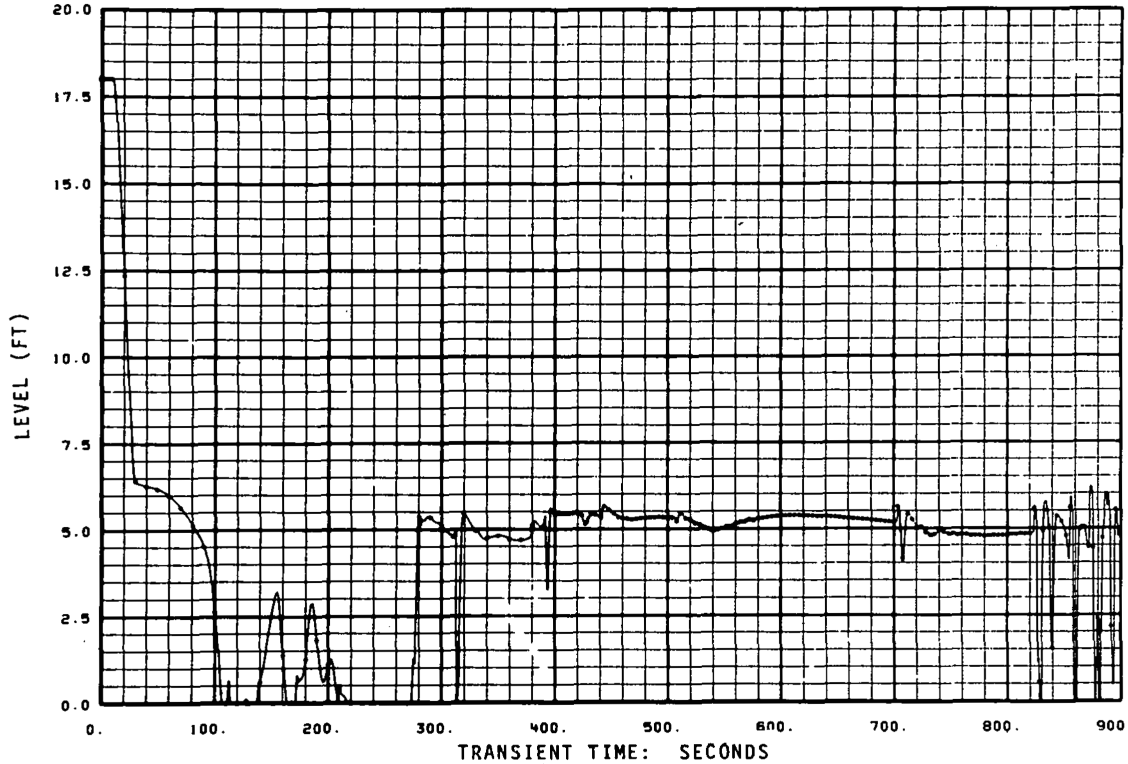

Fig. B-13 Upper plenum mixture level - Westinghouse Plant (6% cold leg break).

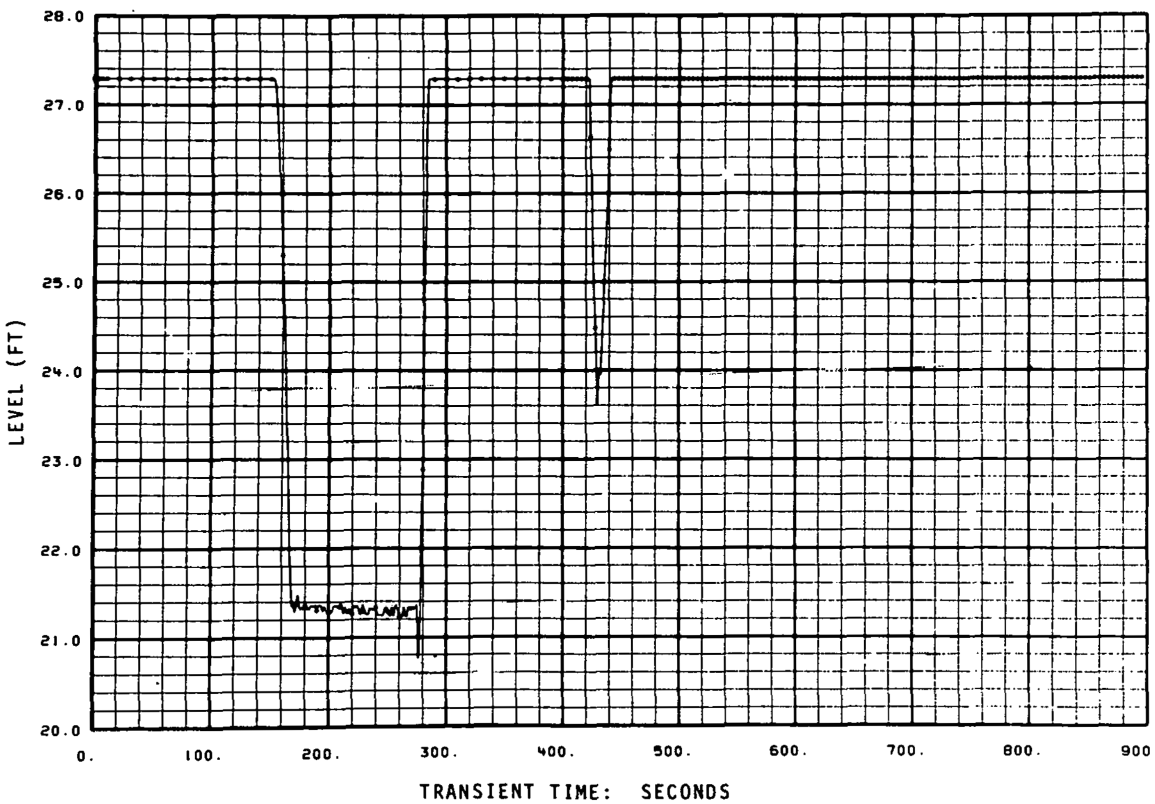

Fig. B-14 Downcomer mixture level - Westinghouse Plant (6% cold leg break).

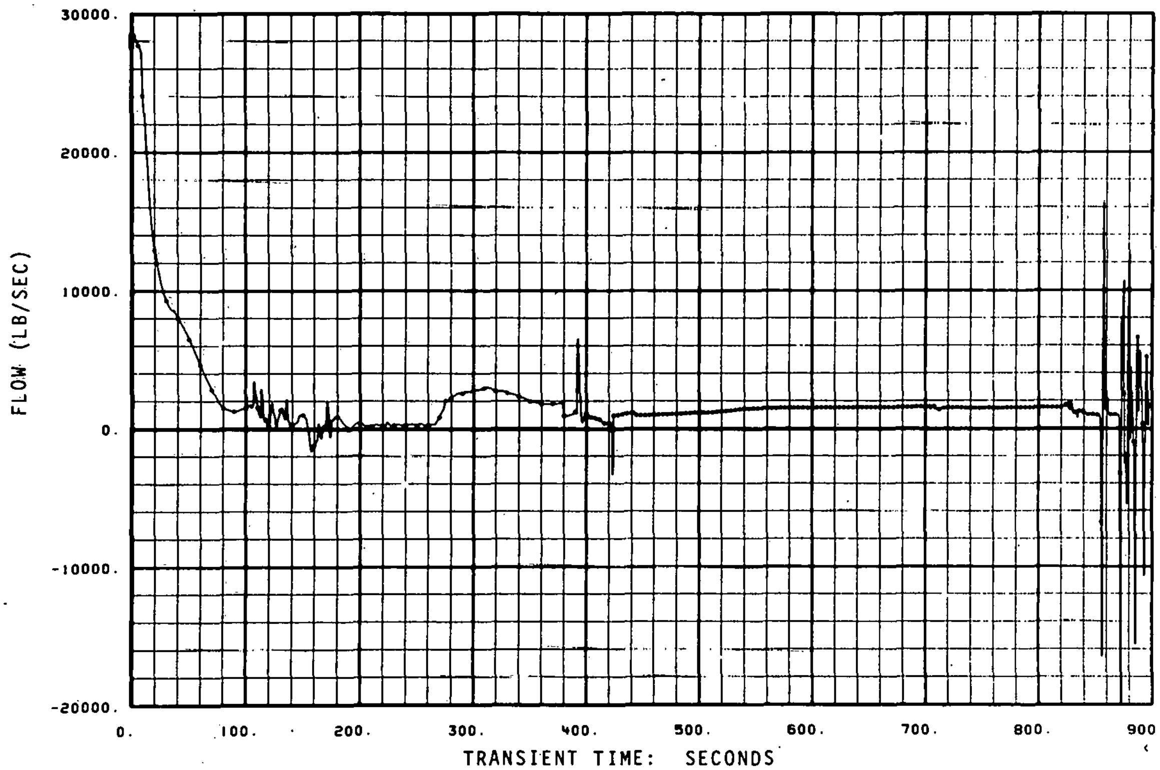

Fig. B-15 Flow, intact loop cold leg to vessel - Westinghouse Plant (6% cold leg break).

6. INPUT LISTING

An input listing for this run is given in Table B-V, which follows.

TABLE B-V

INPUT LISTING

```
=TROJAN 4 LOOP 6 PERCENT COLD LEG BREAK     (LOW SCRAM, 10% HIGH ACCUMUL FEED)
*********THIS IS CHECK OUT CASE FOR RELAP4/MOD5(1).
****IT CHECKS OUT CODE FEATURES FOR A CASE SIMILAR TO THE PHYSICAL
****TROJAN CASE FOR ON-SITE POWER LOSS SIMULTANEOUS WITH A 6%
****COMMUNICATING COLD-LEG BREAK.   REPLACEMENT CARDS NEEDED TO BETTER
****REPRESENT THE PHYSICAL CASE FOLLOW FOR RECORD ONLY AND ARE NOT USED
****BECAUSE:  (1)THEY ARE PLACED AHEAD OF THE CHECK OUT CARDS AND
****(2)THE FIRST COLUMN DIGIT HAS BEEN REPLACED BY A COMMENT CARD FLAG(*).
*********EXCEPT AS NOTED, THE "*" REPLACES A "0" IN THE FOLLOWING DISABLED CARDS
*40080    8 -5 17  0     1.01     0      *CLOSE ACCUML, 1-FT XTRA WATER LEFT-BL,V17
*40090    9 -5 18  0     1.01     0      *CLOSE ACCUML, 1-FT XTRA WATER LEFT-OL,V18
*50061     4 0        2226.31       597.600    -1.        537.8        39.867   39.867
*50071     4 0        2213.34       564.821    -1.        537.8        39.867   39.867
*50081     4 0        2207.         552.2      -1.        84.          16.924   16.924
*50121     4 0        2226.31       597.600    -1.        1613.4       39.867   39.867
*50131     4 0        2213.34       564.821    -1.        1613.4       39.867   39.867
*50141     4 0        2207.         552.2      -1.        252.         16.924   16.924
*50172       0        88.808        10.4       0.146      0   *BOTTOM 1-FT EXTRA/UNUSED
*50182       0        266.424       10.4       0.146      0   *BOTTOM 1-FT EXTRA/UNUSED
*50201     2 0        14.7          100.       0.6        1980000.   250.     0.    *BR
*80042     1 -1  0  3   0      0       0     0 1.       0                *VJ+VS
*80052     1 -1  3  3   0      0       0     2 0        0                *VJ+ET
*80062     1 -1  2  3   0      0       0     3 0        0                *VJ+ET
*80082     1 -1  0  3   0      0       0     0 0        0                *VJ
*80102     1 -1  0  3   0      0       0     0 0        0                *VJ
*80112     1 -1  3  3   0      0       0     2 0        0                *VJ+ET
*80122     1 -1  2  3   0      0       0     3 0        0                *VJ+ET
*80142     1 -1  0  3   0      0       0     0 0        0                *VJ
*80162     1 -1  0  3   0      0       0     0 0        0                *VJ
*80222     1 -1  0  3   0      0       0     0 1.       0                *VJ+VS
*********THE "*" REPLACES A "1" IN THE FOLLOWING 4 CARDS.
*41001    -14      11      0.0  0.0     0.78  -0.0889     1.0  -0.1778     1.22  -0.3201
*41002    1.44  -0.5334     1.62  -0.8890      1.83  -1.5824      1.96  -2.2047
*41003    2.02  -3.2715     2.15  -5.0673      2.25  -7.8232      2.37  -8.5080
*41004    2.60  -8.8900     1000.  -8.8900
*********END OF DISABLED CARD SET.
*     PROBLEM DIMENSION DATA
*        CARD 010001 W1  TAPE CONTROL:  -2 STORE RESTART & PLOT.
010001  -2  9  5  11  22  4  0  34  2  5  1  6  33  14  7  8  0  0
*     PROBLEM CONSTANTS DATA
010002  3410.98  1.0
*     EDIT VARIABLE DATA
020000    AP 4   JW 20    ML 4    ML 3    ML 6    ML 7    ML  8    ML 12    ML 13
030003 50          ***CALLS WATER PACKING PRINTOUT.  CHOKE SMOOTH BY DEFAULT.
030004    50  90.    *ML/JUNCT CROSS-FROM-ABOVE SMOOTHING.   EDITS, START TIME.
*     TIME STEP DATA
030010   2  25   5  0     0.002       0.00005      0.5     3200.***CPU TIME LIMIT
030020   1   5   2  0     0.1         0.0005       2.      *SAME TIME STEPS, MORE EDITS
030030   2  10   2  0     0.1         0.0005       10.     *SAME TIME STEPS, MORE EDITS
030040  10  10   2  0     0.125       0.001       400.
030050  10  10  2   0   0.05  0.0005        1200.
*     TRIP CONTROL DATA
040010   1  1  0  0    900.       0      *END OF PROBLEM, SEC
040020   2  1  0  0    .010002   0      *BREAK/LINE  &  ST GEN RELIEF VALVE AVABLE.
040030   3  4 20  0    18.7      24.25  *ECC DELAY (SEC) - CHARGING PUMP     TRP-V20
040040   4  4 20  0    18.7      28.75  *ECC DELAY (SEC) - HPIS (SI)         TRP-V20
040050   5  4 20  0    18.7      37.75  *ECC DELAY (SEC) - LPIS (RHR)        TRP-V20
040060   6  4 20  0    18.7      1.     *ST. GEN. SECONDARY VALVE CLOSE      TRP-V20
040070   7  1  0  0     0         0      *ST GEN SEC & RELIEF VALVES AVAILABLE
040080   8 -5 17  0     0.01      0      *CLOSE ACCUML, 10% XTRA WATER FED-BL,V17
040090   9 -5 18  0     0.01      0      *CLOSE ACCUML, 10% XTRA WATER FED-OL,V18
040100  10  1  0  0 1200.     0          *PRESSURIZER SHUT-OFF(XTRA-NOT NORNAL USED)
040110  11  4  20  0  18.7  0.           * PUMPS SHUT-OFF AND SCRAM
*     VOLUME DATA
050011     4 0        2276.3        552.5      -1.        902.5        27.291   27.291
050012       0        33.42         1.623      -21.375    0
050021     4 0        2278.8        552.5      -1.        1046.        10.333   10.333*NC
```

TABLE B-V (contd.)

050022	0	101.23	0.5		-27.625	3	*IAMBLO-CORE		
050031	4 0	2264.1	586.399		-1.	881.4	12.	12.	
050032	0	53.64	0.061		-17.292	4	*IAMBLO-UP		
050041	4 0	2249.02	616.8		-1.	1725.	18.008	18.008	
050042	0	100.	1.406		-5.292	0			*NC
050051	0 0	2244.0	616.8		-1.	79.	5.32	5.32	*NC
050052	0	4.587	2.417		-1.208	0			*NC
050061	1 0	2226.31	597.600		-1.	537.8	39.867	39.867	
050062	0	10.679	0.094		1.6	0			
050071	1 0	2213.34	564.821		-1.	537.8	39.867	39.867	
050072	0	10.679	0.094		1.6	0			
050081	1 0	2207.	552.2		-1.	84.	16.924	16.924	
050082	0	5.242	2.583		-11.604	7	*IAMBLO-ST/GEN		
050091	0 0	2244.5	552.5		-1.	98.	12.75	12.75	*NC
050092	0	5.242	6.027		-11.604	0			*NC
050101	0 0	2284.7	552.5		-1.	85.	2.292	2.292	
050102	0	4.125	2.292		-1.146	0			
050111	0 0	2244.0	616.8		-1.	237.	5.32	5.32	*NC
050112	0	13.761	2.417		-1.208	0			*NC
050121	1 0	2226.31	597.600		-1.	1613.4	39.867	39.867	
050122	0	32.037	0.094		1.6	0			
050131	1 0	2213.34	564.821		-1.	1613.4	39.867	39.867	
050132	0	32.037	0.094		1.6	0			
050141	1 0	2207.	552.2		-1.	252.	16.924	16.924	
050142	0	15.726	2.583		-11.604	13	*IAMBLO-ST/GEN		
050151	0 0	2244.5	552.5		-1.	294.	12.75	12.75	*NC
050152	0	15.726	6.027		-11.604	0			*NC
050161	0 0	2284.7	552.5		-1.	255.	2.292	2.292	
050162	0	12.375	2.292		-1.146	0			
050171	2 0	609.92	125.		0.	1499.3	16.9	11.	*NC
050172	0	88.808	10.4		1.146	0			
050181	2 0	609.92	125.		0.	4497.9	16.9	11.	*NC
050182	0	266.424	10.4		1.146	0			
050191	1 0	0.	652.05838		0.00023	1846.	51.	30.6	
050192	0	38.5	7.		0.078	0			
050201	0 0	14.7	100.		0.6	1980000.	250.	0.	
050202	0	1000.	100.		-50.	0			*NC
050211	3 0	0.	516.6		0.006	10995.	62.	42.	
050212	0	30.	0.1		6.8	0			*NC
050221	3 0	0.	516.6		0.006	3665.	62.	42.	
050222	0	10.	0.1		6.8	0			*NC
*									
* BUBBLE DATA									
060011		0.8	3.0						
060021	0. 1.E6								
060031		0.8	40.						
060041		0.	3.0						
* JUNCTION DATA									
080011	1 2 0 0	36791.67	33.42		-21.375	0	0.649	0.501	
080012	0 -1 2 3	0	0	0	0 1.	0			
080021	2 3 0 0	36791.67	31.805		-17.292	0	0	0	
080022	0 -1 3 3	0	0	0	2 1.	0			
080031	3 4 0 0	36791.67	50.9		-5.292	0	0	0	
080032	0 -1 3 3	0	0	0	1 1.	0			
080041	4 5 0 0	9215.28	4.587		0.	3.8181	0.429	0.910	
080042	1 -1 0 3	0	0	0	0 0	0	*VJ		
080051	5 6 0 0	9215.28	4.587		2.9	0	0	0	
080052	0 -1 3 3	0	0	0	2 0	0	*ET		
080061	6 7 0 0	9215.28	10.679		41.467	0	0.09	0.09	
080062	0 -1 2 3	0	0	0	3 0	0	*ET		
080071	7 8 0 0	9215.28	5.242		2.9	0	0	0	
080072	1 -1 3 3	0	0	0	1 1.	0	*VJ+ET+VS		
080081	8 9 -1 0	9215.28	2.621		-10.312	3.243	0.03954	0.03954	
080082	0 -1 0 3	0	0	0	0 0	0			
080091	9 10 1 0	9215.28	2.621		0.	3.081	0.0	0.0	
080092	0 -1 0 3	0	0	0	0 0	0			

TABLE B-V (contd.)

```
080101  10  1  0  0   9215.28   4.125     0.         2.9016    0.7684     0.3945
080102   0 -1  0  3   0         0         0  0 0     0
080111  11 12  0  0  27645.84   13.761    2.9        0         0          0
080112   0 -1  3  3   0         0         0  2 0     0                *ET
080121  12 13  0  0  27645.84   32.037    41.467     0         0.09       0.09
080122   0 -1  2  3   0         0         0  3 0     0                *ET
080131  13 14  0  0  27645.84   15.726    2.9        0         0          0
080132   1 -1  3  3   0         0         0  1 1.    0                *VJ+ET+VS
080141  14 15 -2  0  27645.84   7.863     -10.312    1.081     0.03954    0.03954
080142   0 -1  0  3   0         0         0  0 0     0
080151  15 16  2  0  27645.84   7.863     0.         1.027     0.0        0.0
080152   0 -1  0  3   0         0         0  0 0     0
080161  16  1  0  0  27645.84   12.375    0.         0.9672    0.7684     0.3945
080162   0 -1  0  3   0         0         0  0 0     0
080171  17 10  0  2       0.    0.418     1.146      336.45    9.0        9.095*EX
080172   0 -1  0  3   0         0         0  0 0     0
080181  18 16  0  3       0.    1.253     1.146      112.15    9.0        9.095*EX
080102   0 -1  0  3   0         0         0  0 0     0
080191  19 11  0  5       0.    0.7213    0.078      89.64     2.9        -3.03
080192   0 -1  0  3   0         0         0  0 0     0
080201  20 10  0  1       0.    0.25      0.         694.      1.0        0.45
080202   0 5   0  0   0         0        11  0 0     0
080211   4  1  0  0     -69.44  0.02612   5.916      15.       1.45       1.45
080212   0 -1  0  3   0         0         0  0 0     0
080221   4 11  0  0  27645.83   13.761    0.         1.2727    0.429      0.910
080222   1 -1  0  3   0         0         0  0 0     0                *VJ
080231   0 21  6  0       0.    0.75      68.8       0         0          0
080232   0 -1  3 -2   0         0         0  0 0     0
080241   0 22  6  0       0.    0.25      68.8       0         0          0
080242   0 -1  3 -2   0         0         0  0 0     0
080251   0 21  5  4   3161.67   0.75      6.9        0         0          0
080252   0 -1  3  3   0         0         0  0 0     0
080261   0 21  4  4  -3161.67   0.75      68.8       0         0          0
080262   0 -1  3 -2   0         0         0  0 0     0
080271   0 22  5  4   1053.89   0.25      6.9        0         0          0
080272   0 -1  3  3   0         0         0  0 0     0
080281   0 22  4  4  -1053.89   0.25      68.8       0         0          0
080282   0 -1  3 -2   0         0         0  0 0     0
080291   0 16  1  0       0.    1.5       0.078      0         0          0
080292   0 -1  3  3   0         0         0  0 0     0
080301   0 16  2  0       0.    1.5       1.146      0         0          0
080302   0 -1  3  3   0         0         0  0 0     0
080311   0 16  3  0       0.    1.5       1.146      0         0          0
080312   0 -1  3  3   0         0         0  0 0     0
080321   0 10  1  0       0.    0.5       0.078      0         0          0
080322   0 -1  3  3   0         0         0  0 0     0
080331   0 10  2  0       0.    0.5       1.146      0         0          0
080332   0 -1  3  3   0         0         0  0 0     0
080341   0 10  3  0       0.    0.5       1.146      0         0          0
080342   0 -1  3  3   0         0         0  0 0     0
******ALL ECC PUMPS OPERATING, 3 PAIRS EACH,    1.5 & 0.5    (OL & BL)
*
082000   1          *STAGNATION PROPERTIES .GT. 0.3-MACH 2PH & ALL SUBCOOLED
082003   1.   0.9   0.9   0.01        *HENRY-FAUSKE--HEM,  JCHOKE=5, ICHOKE=ANY
*    PUMP CURVE INPUT INDICATOR DATA.
100000   0  0  0  0
*    PUMP DESCRIPTION DATA, WESTINGHOUSE PUMP SET - INTERNAL DATA
090011   2 11 0 1 0  1185.    1.       88500.    277.      31900.     82000.
090012                                           46.67     0  0  0
090021   2 11 0 1 0  1185.    1.      265500.    277.      95700.     246000.
090022                                           46.67     0  0  0
```

TABLE B-V (contd.)

```
*     PUMP HEAD MULTIPLIER DATA         M3(A)
091001  11 0.  0.   .1   0.   .15  .05  .24  .8   .3   .96  .4   .98  .6   .97
091002      .8  .9   .9   .8   .96  .5   1.0  0.
*     PUMP TORQUE MULTIPLIER DATA*
*     PUMP TORQUE MULTIPLIER DATA*******N(A)
*****PUMP TORQUE MULTIPLIER DATA---DUMMY INPUT.  USED AS ALL ZERO'S UNLESS

*          A TORQUE-DIFFERENCE HOMOLOGOUS CURVE IS ALSO INPUT.
*          I.E.   NO TWO-PHASE TORQUE DEGRADATION THIS CASE DESPITE N(A) INPUT.
092001    7   0. 0.    .1 0.    .15 .05   .24 .56   .80 .56   .96 .45   1. 0.
*     PUMP STOP DATA
095011 0. 0. 0.
095021 0. 0. 0.
*     VALVE DATA CARDS
110010    -2 0 0   0    0    0    0       *BREAK/CONTAINMENT
110020    28 0 0 1.E-8  4.    0    0        *ACCUMLATOR CHECK VALVES, TYPE 22-BL,V17
110030    29 0 0 1.E-8  4.    0    0        *ACCUMLATOR CHECK VALVES, TYPE 22-OL,V18
110040     6 1 0   0    0    0    0       *ST GEN SEC FLOW VALVES
110050    10 0 0   0    0    0    0       *PRESSURIZER VALVE (NORMALLY OPEN & UNUSED)
*      LEAK TABLE DATA    (ST GEN SEC VALVES CLOSE RAMP ONLY)
120101    3  6    0      0. 1.0    1.0 0.  1000. 0. *ST GEN SEC VALVES CLOSE RAMP
*      FILL TABLE DATA
130100     3  2  8  4     GAL/MIN    2000.  100.         *CHRG
130101                                       0.       550.       1075.     409.5
130102                      1694.   318.5    2230.    220.5      2470.     113.75
130103                      2527.   45.5     2575.    0.         3000.     0.  *CHRGE
130200     4  2  8  4     GAL/MIN    1200.  100.         *SI (HPIS)
130201                                       0.       650.       613.      500.
130202                      939.    400.     1137.    320.       1292.     240.
130203                      1377.   160.     1495.    0.         3000.     0.  *SI
130300     5  2  8  4     GAL/MIN     180.  100.         *RHR (LPIS)
130301                                       0.       4500.      73.5      3600.
130302                      123.5   2700.    158.1    1800.      171.1     1350.
130303                      182.3   900.     200.     0.         3000.     0.  *RHR
*         SECONDARY SIDE STEAM FLOW---STEADY STATE FILL(+ LEAK CLOSE RAMP)
130400     7 1 2 4   LBS/SEC    1000.  440.        *P & T DUMMY FOR NEGATIVE FILL
130401                             0. -4215.56     1000. -4215.56
130500     7 1 2 4   LBS/SEC    1000.  440.
130501                             0.  4215.56     1000.  4215.56
130600     2  2  4  3     LBS/SEC     533.3    1.0   *ST/GEN RV (P&X DUM FOR NEG FIL
130601                                           0.       0.        1114.7     0.
130602                                        1164.7 -120.5     1414.7 -146.3
*     KINETICS CONSTANTS DATA
140000     3  0         300.        0.0         .8    0  0  0     *LAST 3 ADDED TVS
*     REACTIVITY COEFFICIENT DATA
140010                0.0735     0.0735        0        0.
140020                0.1515     0.1515        0        0.
140030                0.1919     0.1919        0        0.
140040                0.1953     0.1953        0        0.
140050                0.1688     0.1688        0        0.
140060                0.1219     0.1219        0        0.
140070                0.0682     0.0682        0        0.
140080                0.0289     0.0289        0        0.
*     SCRAM TABLE DATA
141001    -14     11     0.0  0.0     0.78  -0.0826     1.0  -0.1652     1.22  -0.2974
141002    1.44   -0.4956     1.62  -0.8260     1.83  -1.4703     1.96  -2.0485
141003    2.02   -3.0397     2.15  -4.7082     2.25  -7.2688     2.37  -7.9048
141004    2.60   -8.2600    1000.  -8.2600
*     DENSITY REACTIVITY TABLE DATA
142001    -13  0. -52.22  .0729 -42.68   .146 -34.3    .292 -20.97   .437 -11.66
142002    .583 -5.41    .729 -1.80 .875 -.28  1. 0.    1.02 0.    1.166 -.28
142003    1.312 -.55    1.458 -.14
*     DOPPLER TABLE DATA
143000    -4            70.        1.72       500.       1.07       3000.      -2.68
143001                 10000.     -13.18
```

TABLE B-V (contd.)

```
*      HEAT SLAB DATA
*      CORE HEAT SLABS
150011   0  3    1 0 2 0 0    0 6525. 57.375  0 .044529  0 0    0 0  0     1.5
150021   0  3    1 1 2 0 0    0 6525. 57.375  0 .044529  0 0    0 0  1.5   3.0
150031   0  3    1 1 2 0 0    0 6525. 57.375  0 .044529  0 0    0 0  3.0   4.5
150041   0  3    1 1 2 0 0    0 6525. 57.375  0 .044529  0 0    0 0  4.5   6.0
150051   0  3    1 1 2 0 0    0 6525. 57.375  0 .044529  0 0    0 0  6.0   7.5
150061   0  3    1 1 2 0 0    0 6525. 57.375  0 .044529  0 0    0 0  7.5   9.0
150071   0  3    1 1 2 0 0    0 6525. 57.375  0 .044529  0 0    0 0  9.0  10.5
150081   0  3    1 1 2 0 0    0 6525. 57.375  0 .044529  0 0    0 0 10.5   0
*      STEAM GENERATOR TUBE SLABS  BL/OL
150091  6 22 2 0 3 0 0 20746. 23422. 92.04 .06455 0    0 0    34.667 2.   0 34.66
150101  7 22 2 0 3 0 0 20746. 23422. 92.04 .06455 0    0 0    34.667 2.   0 34.66
150111 12 21 2 0 3 0 0 62238. 70266. 276.1 .06455 0    0 0    34.667 2.   0 34.66
150121 13 21 2 0 3 0 0 62238. 70266. 276.1 .06455 0    0 0    34.667 2.   0 34.66
*      REACTOR VESSEL HEAT SLABS
150131  2  1 3 0 3 0 0   157.6   162.4  30.     0 0   0 0  4.1 4.1    0     4.08 *LP/DC
150141  1  1 4 0 3 0 0   465.    508.   467.   .1 0   0 0 12.  12.   4.1   16.08*CR/DC
150151  4  1 3 0 3 0 0   432.8   446.    82.4   0 0   0 0 11.21 11.21 16.1 0  *UP/DC
150161  2  0 7 0 1 0 0   288.      0.   137.    0 0   0 0  6.25 0    0      6.25*LP/VS
150171  1  0 6 0 0 0 0 1232.       0.   936.    0 0   0 0 27.29 0    0      0   *DC/VS
150181  4  0 5 0 1 0 0   295.      0.   170.  1.5 0   0 0  6.8  0  11.208 0    *UH/VS
150191  0  4  8 0 2 0 0      0.  4439.  219.8  0 0     0 0  0 11.21 0    11.21*IN-U
*      LOOP HEAT SLABS
150201  5   0  9 0 0 0 0   129.      0.    29.2  0 0     0 0   0 0     0    0     *HL-BL
150211 11   0  9 0 0 0 0   387.      0.    87.6  0 0     0 0   0 0     0    0     *HL-OL
150221  6   0 10 0 1 0 0   103.      0.    37.6  0 0     0 0   0 0     0  5.2 *QGPI-BL
150231  7   0 10 0 1 0 0   103.      0.    37.6  0 0     0 0   0 0     0  5.2 *QGPO-BL
150241 12   0 10 0 1 0 0   206.      0.   112.8  0 0     0 0   0 0     0  5.2 *QGPI-OL
150251 13   0 10 0 1 0 0   206.      0.   112.8  0 0     0 0   0 0     0  5.2 *QGPO-OL
150261  8   0 11 0 1 0 0   129.8     0.    31.1  0 0     0 0   0 0     0   .0  *PIPE-BL
150271 14   0 11 0 1 0 0   389.4     0.    93.3  0 0     0 0   0 0     0    0  *PIPE-OL
150281  9   0 11 0 0 0 0    64.9     0.    15.55 2.583 0 0 0 0 0     0  5.79*PIPE-BL
150291 15   0 11 0 0 0 0   194.7     0.    46.65 2.583 0 0 0 0 0     0  5.79*PIPE-OL
150301 10   0 12 0 0 0 0   151.2     0.    32.5  0 0     0 0   0 0     0    0   *CL,P-BL
150311 16   0 12 0 0 0 0   453.6     0.    97.5  0 0     0 0   0 0     0    0   *CL,P-OL
150321 19   0 13 0 1 0 0  1122.      0.   796.   0 0     0 0   0 0     0    0 *QPRESIZR
150331  0   2 14 0 2 0 0     0     252.   126.   0 0     0 0   0 0  6.25 7.71   *CS-LP
*     CORE SECTION DATA
160010      1  1  8 16           .002025                  .0735
160020      2  1  8 16           .002025                  .1515
160030      3  1  8 16           .002025                  .1919
160040      4  1  8 16           .002025                  .1953
160050      5  1  8 16           .002025                  .1688
160060      6  1  8 16           .002025                  .1219
160070      7  1  8 16           .002025                  .0682
160080      8  1  8 16           .002025                  .0289
*AXIAL POWER REF:  FSAR FIG 4.3-14 CURVE 8,  AMMEND 13, MAY 74
*      HEAT SLAB GEOMETRY DATA
*      CORE GEOMETRY
170101    2    3   1   6   0          0.015166     1.        *FUEL                    *NC
170102         1       2   2          0.0003925    0         *GAP                     *NC
170103         0       3   8          0.002025     0         *CLAD                    *NC
*      STEAM GENERATOR TUBE GEOMETRY
170201    2    1   7   6   0.032292 0.0041667      0         *ST. GEN. TUBES
*      VESSEL HEAT SLAB GEOMETRY
170301    2    1   5   9   6.167    0.1875         0         *CB AT UP                304 NC
170401    2    1   5  13   6.167    0.2817         0         *CB AT NEUT. SHIELD PAD  304
170501    2    2   4   4   6.985    0.013021       0         *VES AT UH               AUS
170502       0     6   9            0.5417         0         *                        MILD
170601    2    2   4   4   7.20834  0.013021       0         *VES AT UA + DC          AUS NC
170602       0     6  10            0.708334       0         *                        MILD
170701    2    2   4   4   7.20834  0.013021       0         *VES AT LP               AUS NC
170702       0     6   8            0.44791        0         *                        MILD
170801    1    1   5   6   0        0.0377         0         *SUP ASSY+CYL UH/UP ASM-304 SS
```

TABLE B-V (contd.)

```
*     LOOP HEAT SLAB GEOMETRY
170901   2   2   4   5  1.208     0.04167    0        *HL PIPE                   AUS NC
170902     0     4   5            0.1667     0        *                          AUS NC
171001   2   2   4   4  3.15      0.013021   0        *ST. GEN. PLENUMS          AUS SS
171002     0     6   6            0.33334    0        *            EST. ONLY     MILD
171101   2   2   4   5  1.292     0.04167    0        *PIPE GEN/PUMP             AUS NC
171102     0     4   5            0.1792     0        *                          AUS NC
171201   2   2   4   5  1.146     0.04167    0        *COLD LEG PIPE             AUS NC
171202     0     4   5            0.1562     0        *                          AUS NC
171301   2   2   5   4  3.5       0.013021   0        *PRESSURIZER               304 SS
171302     0     6   6            0.3333     0        *            EST. ONLY     MILD
171401   1   2   5   8  0         0.08333    0        *CORE SUPP & LO PLATE/LP304 SS
171402     0     5  12            0.41667    0         *SAME                     304 SS
*    THERMAL CONDUCTIVITY DATA
180100 -20  500.    3.341  650.    2.971  800.   2.677  950.    2.439  1100.  2.242
180101      1250.   2.078  1400.   1.940  1550.  1.823  1700.   1.724  1850.  1.639
180102      2000.   1.568  2150.   1.507  2300.  1.457  2450.   1.415  2600.  1.382
180103      3100.   1.323  3600.   1.333  4100.  1.406  4600.   1.538  5100.  1.730
180200    2-         32.         .41562     5400.      .41562
180300 -11 392. 6.936 752. 8.092 1112. 9.827 1472. 10.983 1832. 12.717
180301 2192. 14.451 2552. 17.341 2912. 20.809 3272. 25.433 3632. 31.792
180302 3992. 39.306
180401 -2 200. 8.3 1000. 11.8
180501 -2 200. 9.52 1000. 13.12
180601    -5  32. 30.   212. 29.5   392. 28.3   572. 26.6   572. 24.7
180601    -5  32. 30.   212. 29.5   392. 28.3   572. 26.6   672. 24.7
*          HIGH TEMP CONDUCTIVITY OF MATL NO. 6
180701    -4  100. 8.5  300. 9.58  600. 11.15  1100. 13.65
180701    -9       70. 5.426    200. 5.621    400. 5.988    600. 6.327    800. 6.641
180702          1000. 6.957   1200. 7.268    1400. 7.558    1600. 7.825
*     VOLUMETRIC HEAT CAPACITY DATA
190100   16                   32. 34.45          122. 38.35           212. 40.95
190101                       392. 43.55          752. 46.8           2012. 51.35
190102                      2732. 52.65     3092. 56.55  3452. 63.05
190103                      3812. 72.8          4352. 89.7           4532. 94.25
190104                      4712. 98.15         4892. 100.1          5144. 101.4
190105                      8000. 101.4
190200     2           32.        .000075    5400.       .000075
190300    5   0.0    28.392
190301    1480.3    34.476    1675.0    85.176
190302    1787.5    34.476    3500.0    34.476
190401 -9 200. 57.114 300. 59.118 400. 61.122 500. 63.126 600. 64.629
190402 700. 66.13 800. 67.134 1000. 69.138 2000. 80.16
190501 -9 200. 57.114 300. 59.118 400. 61.122 500. 63.126 600. 64.629
190502 700. 66.13 800. 67.134 1000. 69.138 2000. 80.16
190601    -5  167. 60.83  437. 62.3  527. 65.25  617. 67.21  707. 70.15
190701    -4  100. 57.18  400. 61.14  600. 63.77  800. 66.41
*     LINEAR EXPANSION COEFFICIENT DATA
200101 -2 0. 3.718E-6  5000.  1.2653E-5
200201 -2 0. 0. 5000. 0.
200301   -4  0.   3.094E-6  1652.  4.706E-6  1653.  5.389E-6  5000. 5.389E-6
200401   -2  0  0  5000.  0
200501   -2  0  0  5000.  0
200601   -2  0  0  5000.  0
200701   -2  0  0  5000.  0
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REFERENCE

B-1 Final Safety Analysis Report, Docket No. 50-344 (through Amendment 22) Trojan Nuclear Plant, Portland General Electric Co. (August 1975).

APPENDIX C

PWR INTERMEDIATE SIZED COLD LEG BREAK - COMBUSTION ENGINEERING PLANT

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APPENDIX C

PWR INTERMEDIATE SIZED COLD LEG BREAK - COMBUSTION ENGINEERING PLANT

1. INTRODUCTION

This RELAP4/MOD5 calculation applied the Evaluation Model (EM) feature of the code to an intermediate sized (25% of cross section) cold leg break of a 2560 MW pressurized water reactor. The Combustion Engineering (CE), Calvert Cliffs Station was used for illustration purposes. The accident was postulated to be a 1.00 ft^2 area break located in the cold leg pump discharge line. A fully communicating break was assumed, i.e., the flow path through the broken pipe was considered to be unaffected by the presence of the break. The following sections describe the plant model and code features used in this problem and provide a commentary on the significant features of the transient following the break. Some interpretation of the results is based on digital data and plots which were too voluminous to be included in this appendix. The model presented was used for program checkout and should not be considered a comprehensive study of the LOCA response of the actual plant.

2. SYSTEM MODEL AND ASSUMPTIONS

A diagram of the volume and junction nodalization used in the calculation is shown in Figure C-1. Table C-I provides a description of the volume nodes and fill junctions of Figure C-1. The vessel and steam generator heat slab placement described in Table C-II is shown in Figure C-2. A total of 39 volumes, 56 junctions, and 16 heat slabs were used. The reactor core was modeled as three stacked heat slabs of equal height.

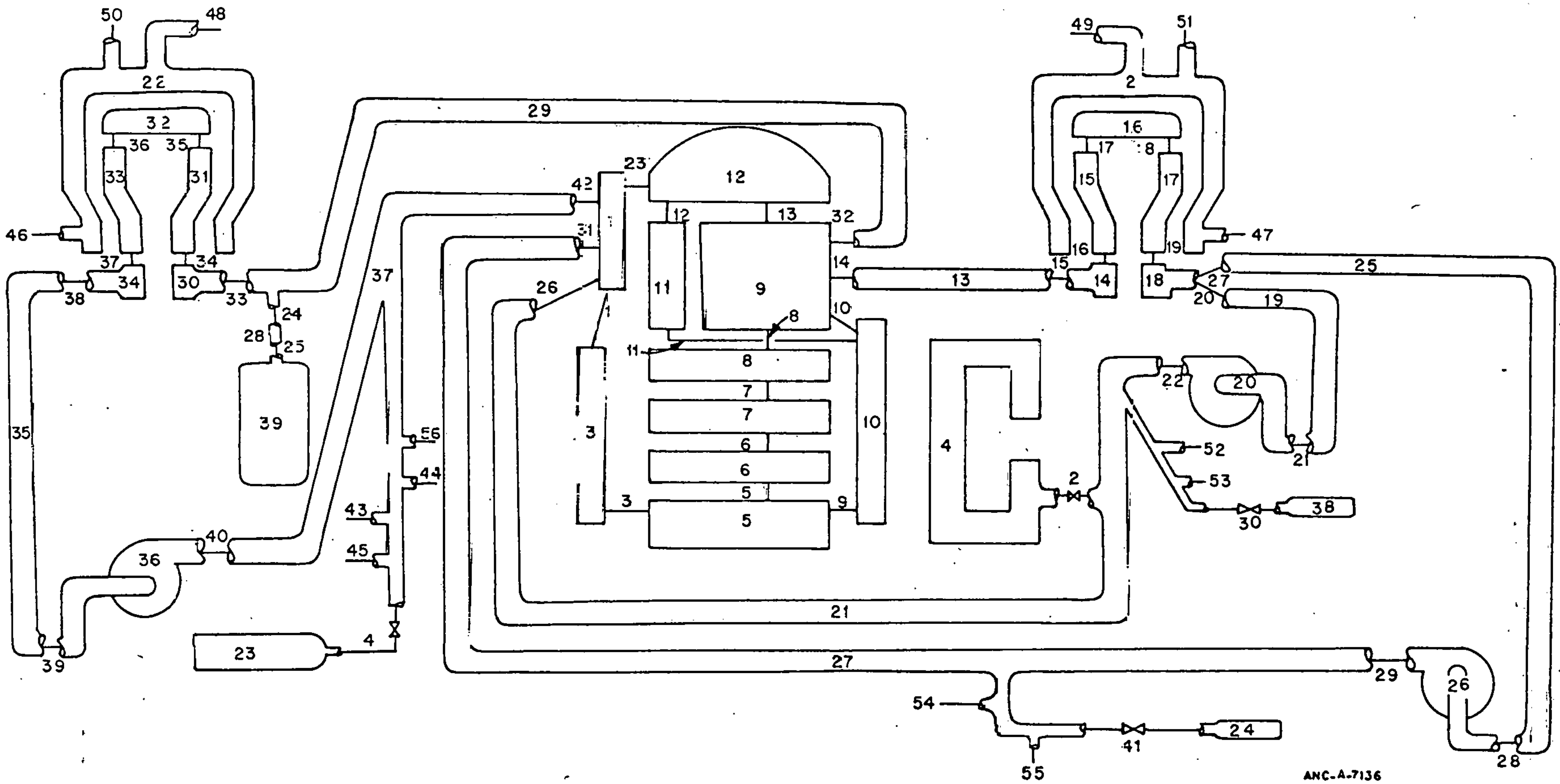

Fig. C-1 Nodalization for 25% cold leg break - Combustion Engineering Plant.

TABLE C-I

VOLUME AND FILL JUNCTION IDENTIFICATION FOR PWR 25% COLD LEG BREAK - CE PWR PLANT

Volume No.	Description
1	Upper Annulus
2	Steam Generator (Secondary Side)
3	Downcomer
4	Containment
5	Lower Plenum
6,7,8	Lower, Middle, and Upper 1/3 of Core
9	Upper Plenum
10	Core Bypass thru Guide Tubes
11	Upper Plenum Bypass thru CEA Shrouds
12	Upper Head
13	Hot Leg
14	Steam Generator Inlet Plenum
15,16,17	Steam Generator (Primary Side)
18	Steam Generator Outlet Plenum
19	Pump Suction Leg to Minimum Elevation
20	Suction Leg from Minimum Elevation and Pump
21	Cold Leg
22	Steam Generator (Secondary Side)
23,24	Accumulators
25	Pump Suction Leg to Minimum Elevation
26	Suction Leg from Minimum Elevation and Pump
27	Cold Leg
28	Pressurizer Surge Line
29	Hot Leg
30	Steam Generator Inlet Plenum
31,32,33	Steam Generator Tubes (Primary Side)
34	Steam Generator Outlet Plenum
35	Pump Suction Legs to Minimum Elevation
36	Suction Legs from Minimum Elevation and Pumps
37	Cold Legs
38	Accumulator
39	Pressurizer

Junction No.	Description
43	Low Pressure Safety Injection
44,45	High Pressure Safety Injection
46,47	Steam Generator Feed Water
48,49	Steam Outlet
50,51	Steam Relief Valves (Negative Fill)
52	Low Pressure Safety Injection
53	High Pressure Safety Injection
54	Low Pressure Safety injection
55	High Pressure Safety Injection
56	Low Pressure Safety Injection

TABLE C-II

HEAT SLAB IDENTIFICATION FOR
INTERMEDIATE SIZED COLD LEG BREAK - CE PWR PLANT

Heat Slab No.	Adjacent Volume[a] Left	Adjacent Volume[a] Right	Heat Slab Identification
1	0[b]	6	Lower 1/3 Core
2	0	7	Middle 1/3 Core
3	0	8	Upper 1/3 Core
4	15	2	Steam Gen. Tubes (Inlet 1/3)
5	16	2	Steam Gen. Tubes (Middle 1/3)
6	17	2	Steam Gen. Tubes (Outlet 1/3)
7	31	22	Steam Gen. Tubes (Inlet 1/3)
8	32	22	Steam Gen. Tubes (Middle 1/3)
9	33	22	Steam Gen. Tubes (Outlet 1/3)
10	5	0	Lower Plenum Head
11	12	0	Upper Plenum Head
12	3	0	Reactor Vessel
13	1	0	Upper Annulus
14	10	3	Lower Core Barrel
15	10	1	Middle Core Barrel
16	9	1	Upper Core Barrel

[a] For cylindrical geometry, left is the inside and right is the outside surface diameter.

[b] Zeros represent surface of 0 Heat Flux, e.g., insulated surface or the point, line, or plane at the center of slabs.

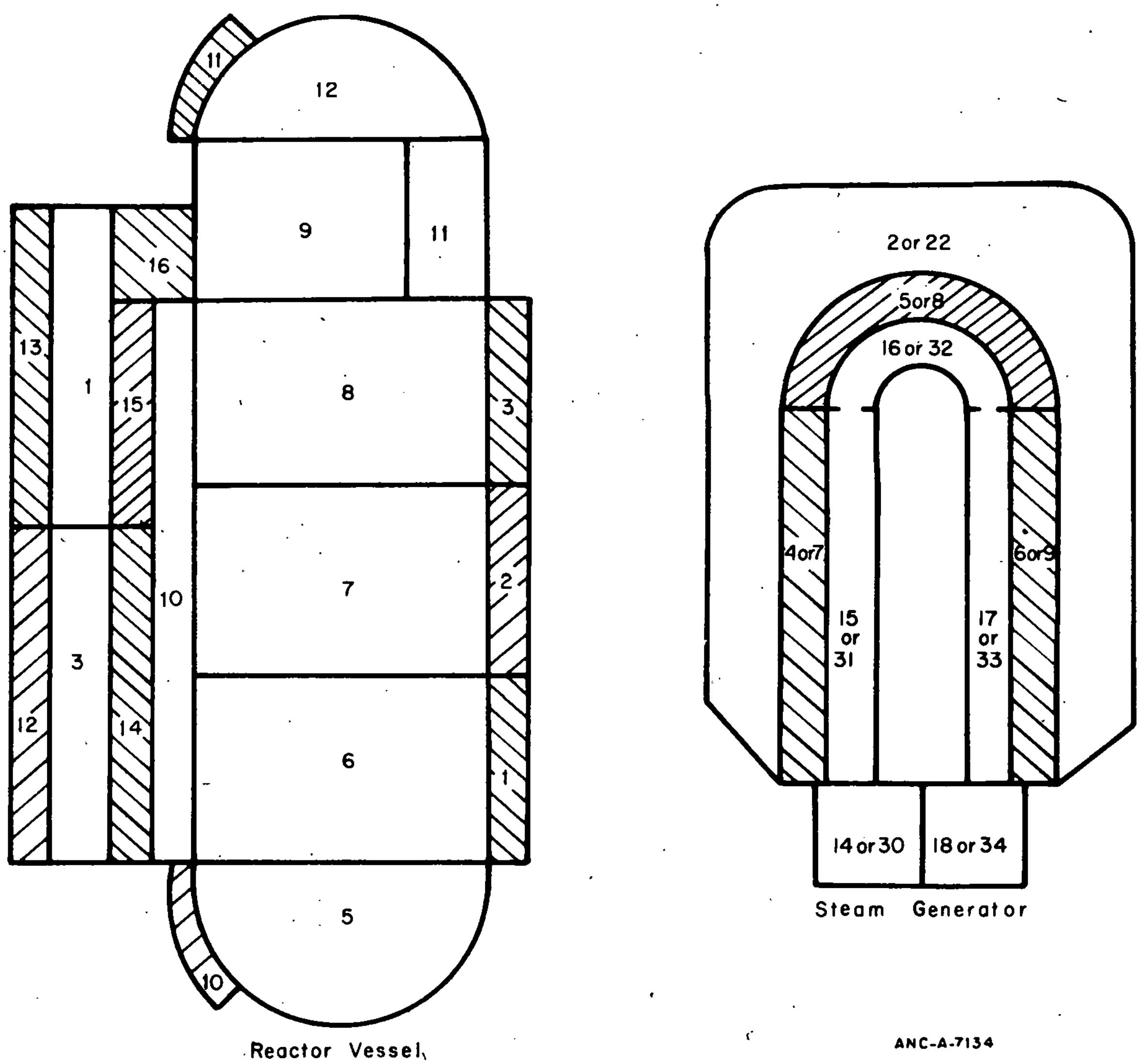

Fig. C-2 Heat slab placement - Combustion Engineering Plant (25% cold leg break).

Models used were as specified for evaluation-type (EM) calculations. ITCV=22-29 type check valves were used at accumulator outlets. Vertical slip, with default model parameters, was used in the two downcomer junctions (J1 and 3). Bubble rise was used for certain volumes as follows:

(1) Upper plenum, upper plenum bypass, upper head, lower plenum, and pressurizer (V9, 11, 12, 5, and 39) gradient 0.8, rise 3 ft/sec

(2) Steam generator secondary sides (V2 and 22) gradient 0.8, rise 80 ft/sec

(3) Accumulators and containment (V4, 23, 24, and 38) gradient 0, rise 10^6 ft/sec.

3. RESULTS

The relatively long transient time (98 sec) to lower plenum refill combined with a rather detailed nodalization, yielded a run that required 48 minutes of CPU time on the CDC 7600 computer at Brookhaven National Laboratory. A run fully complying with evaluation model standards would have required some 5 to 10 min additional CPU time to the point of lower plenum refill, with a 6 or 7 sec transient-time extension.

The output data traces are shown as Figures C-3 through C-22 in Section 5 of this appendix. The significant features of the transient illustrated by these data are:

(1) 12 to 14 sec: Saturation was reached in cold legs and the large volume of steam slowed cold leg flows. Break flow was in transition to saturation (Figure C-9).

(2) 46 to 50 sec: Flow reversal occurred at top of core. Introduction of liquid into previously steam-filled volume caused flashing. This resulted in increased core flow in the negative direction with temperature quenching (Figures C-8, C-18, C-19, and C-20).

(3) 75 sec: Accumulators were turned on (Figure C-6). Condensation in cold legs caused strong negative downcomer flow (Figures C-3 and C-5) with slight quenching effect on clad temperatures.

(4) 79 sec: Condensation-caused flows abated. A positive flow spike in downcomer (Figure C-3) caused premature end-of-bypass (EOB) signal. Eighty-five percent of the liquid remaining at 79 sec was removed from the lower plenum by the operation of the EM model which allows no credit for accumulator flow into the lower plenum through the downcomer (Figure C-12).

(5) 87 sec: True EOB occurred (Figure C-3).

(6) 98 sec: Lower plenum was refilled to satisfy completion requirements (Figure C-12).

The behavior of the end-of-bypass logic deserves further explanation. The EOB logic was set to trip after accumulator flow start. The small break size and the relatively low pressure at which the accumulators started, resulted in an absence of a strongly negative flow while bypass was occurring (Figure C-3). A one-second delay from the time the accumulators activated to the time the direction of the downcomer flow began to be monitored for end-of-bypass was introduced to correct this problem. A flow spike at 79 sec also tripped the EOB logic 8 sec prematurely, resulting in a lesser amount of fluid removal from the vessel and cold leg volumes than would have been removed had the logic been tripped at the true EOB. The true magnitude of the spike at 79 sec did not show well on the junction flow plots due to its short duration.

Increasing the velocity required for an EOB trip did not circumvent the problem. In view of the fact that the EM logic was shown to operate as designed and refill was accomplished, the checkout runs were terminated at this point. Hand-calculated ECC injection rates and accumulator loss up to 87 sec, yielded the result that refill should have been delayed approximately 6 to 7 sec, given EOB triggering at the proper time. This would have increased CPU time some 5 to 8 min.

The model problem was first attempted using two cold leg volumes for each intact cold leg and four for the broken leg. This resulted in severe pressure oscillations when these volumes water packed with sub-cooled ECC fluid. Reducing the nodalization to only one cold leg volume per loop (V21, 27, and 37), reduced CPU time by a factor of approximately three during later portions of the transient.

Other results of interest are shown on the data plot Figures C-3 through C-22 contained in Section 5 of this appendix.

4. CONCLUSIONS

The EM logic appears to function properly. However, for this run it was necessary to install a one-second delay from the time when the accumulators were activated to the time at which the direction of the downcomer flow began to be monitored for end-of-bypass. This delay feature was subsequently entered as a permanent code feature. A flow spike at 79 sec also tripped the EOB logic prematurely, resulting in a lesser amount of fluid removal from the vessel and cold leg volumes. These would have been emptied had the logic been tripped at the true EOB. ECC bypass requires special attention when using the EM option, since spurious flow spikes may significantly affect calculated results.

Subsequent model review has suggested that the core bypass nodalization (specifically Volume 10 and Junctions 9 and 11) could be improved. In this model the dominant flow was assumed to be the flow up the guide tubes into the upper plenum bypass (the CEA shrouds). This may have lead to improper representation of the hydraulics of the emptying of the region between the core shroud and core barrel. This region is a large reservoir having its volume included within Volume 10. The small area of Junction 9 is not representative of the actual connection of the core-shroud volume to the lower plenum. This may have significantly affected the blowdown behavior of the lower plenum. The effect of this upon core flows is not readily apparent, but could also have been significant.

The completion criteria listed in Volume III, Section 2 for the MOD5 checkout runs were satisfied.

5. OUTPUT DATA

The output data traces for the Combustion Engineering 25% cold leg break (Evaluation Model) are included as Figures C-3 through C-22 in this section.

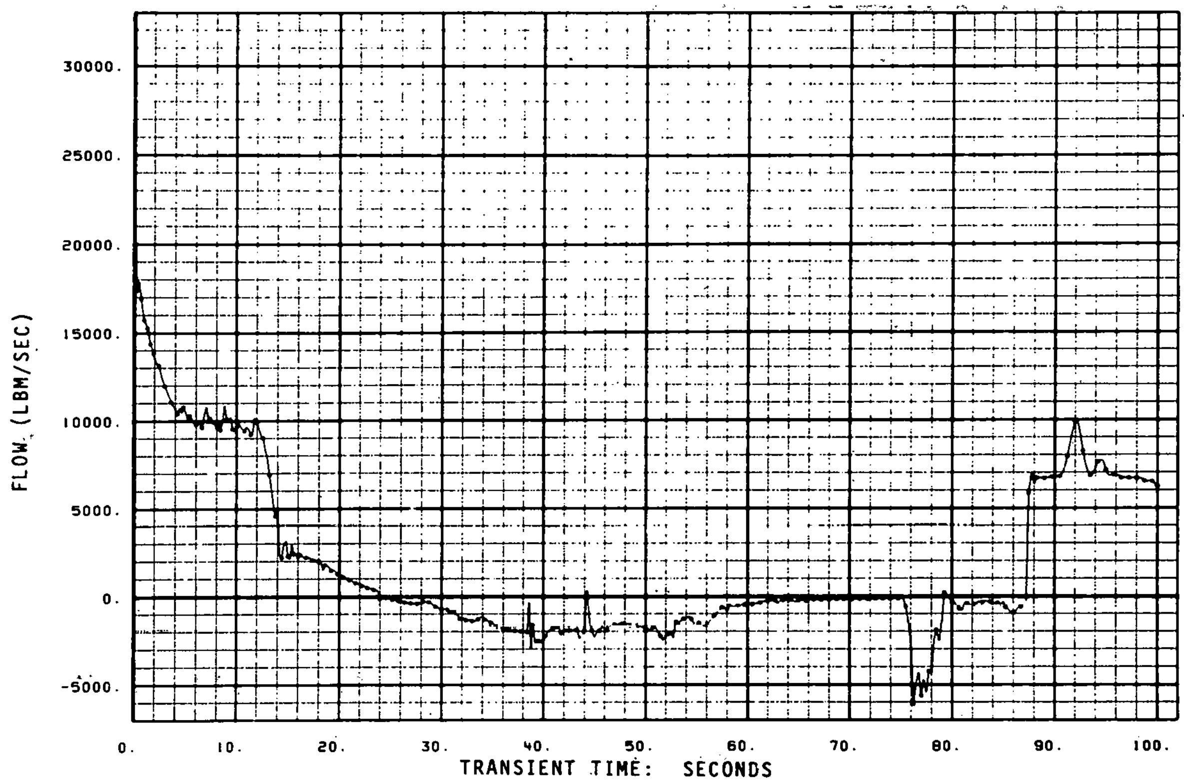

Fig. C-3 Annulus downcomer flow - Combustion Engineering Plant (25% cold leg break).

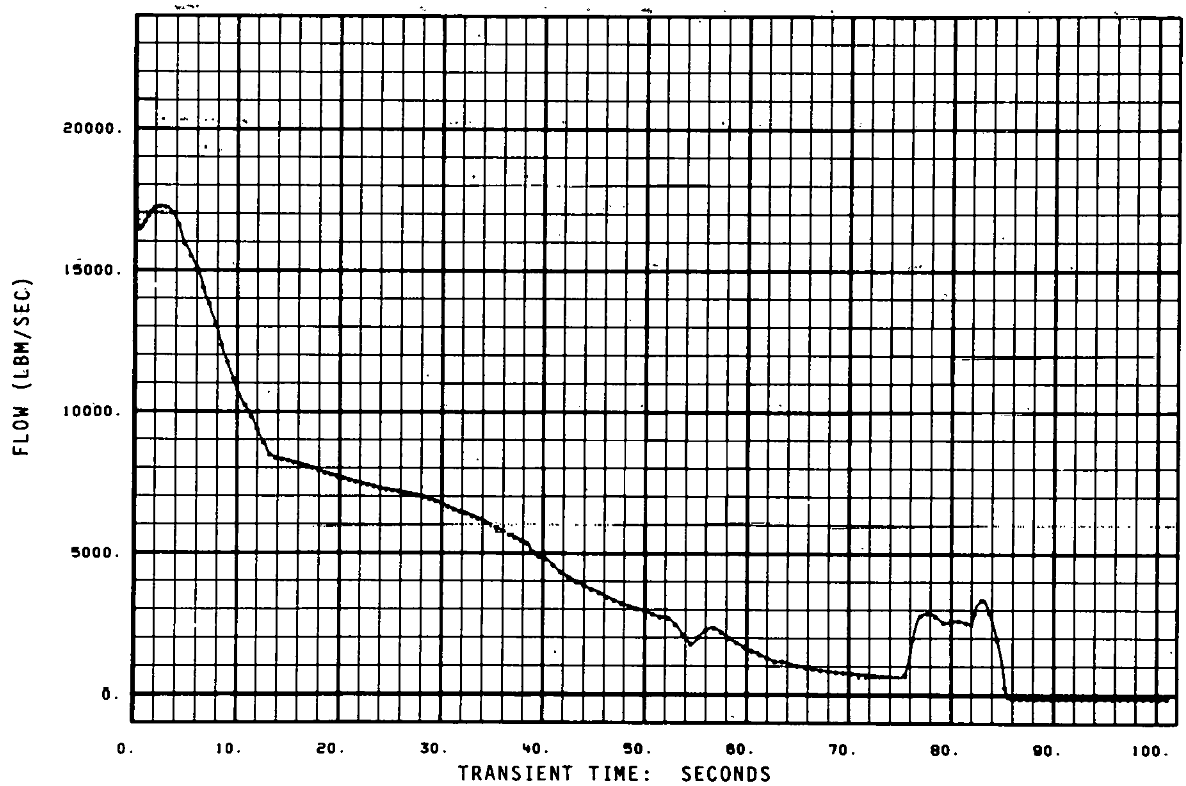

Fig. C-4 Break flow - Combustion Engineering Plant (25% cold leg break).

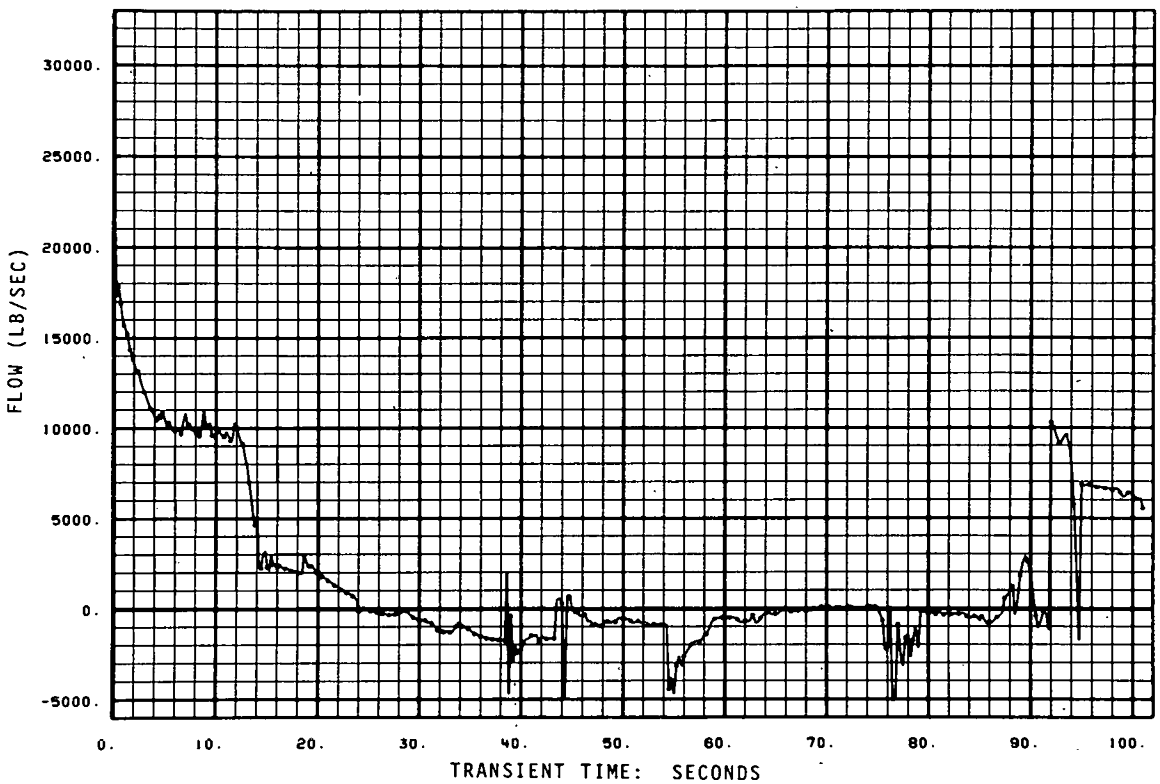

Fig. C-5 Downcomer - lower plenum flow - Combustion Engineering Plant break).

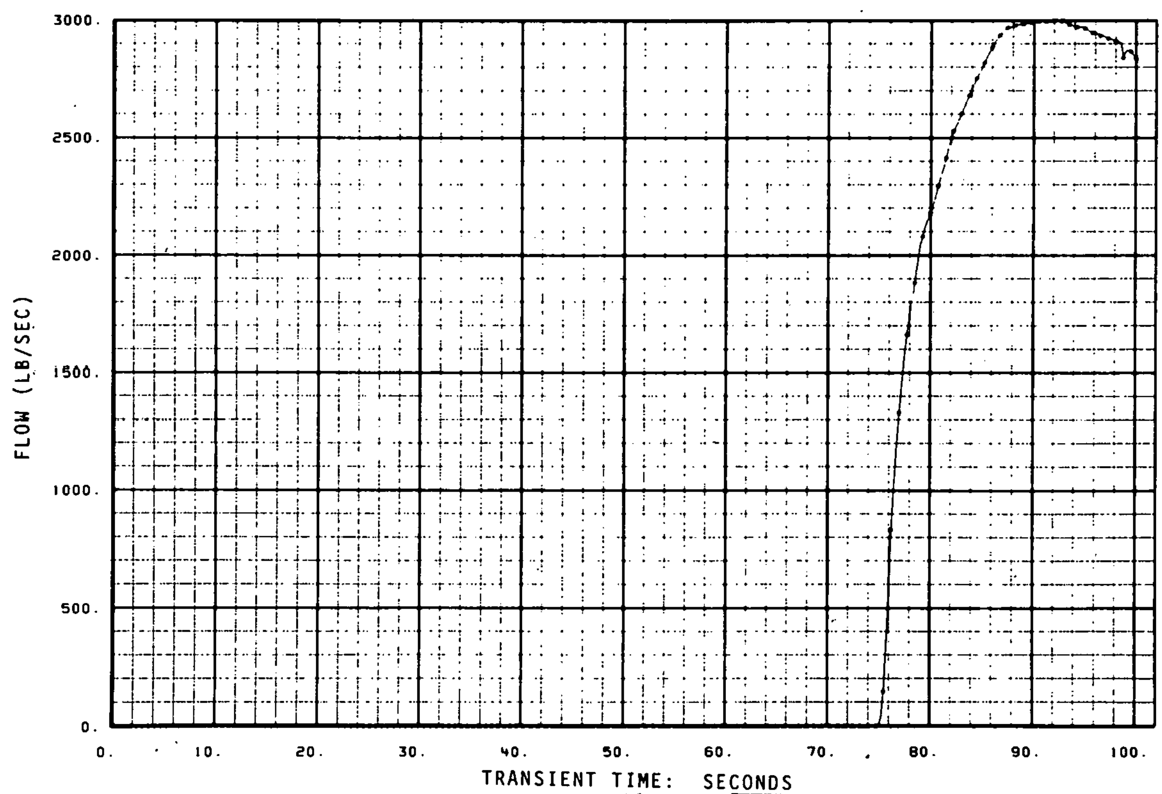

Fig. C-6 Accumulator flow - Combustion Engineering Plant (25% cold leg break).

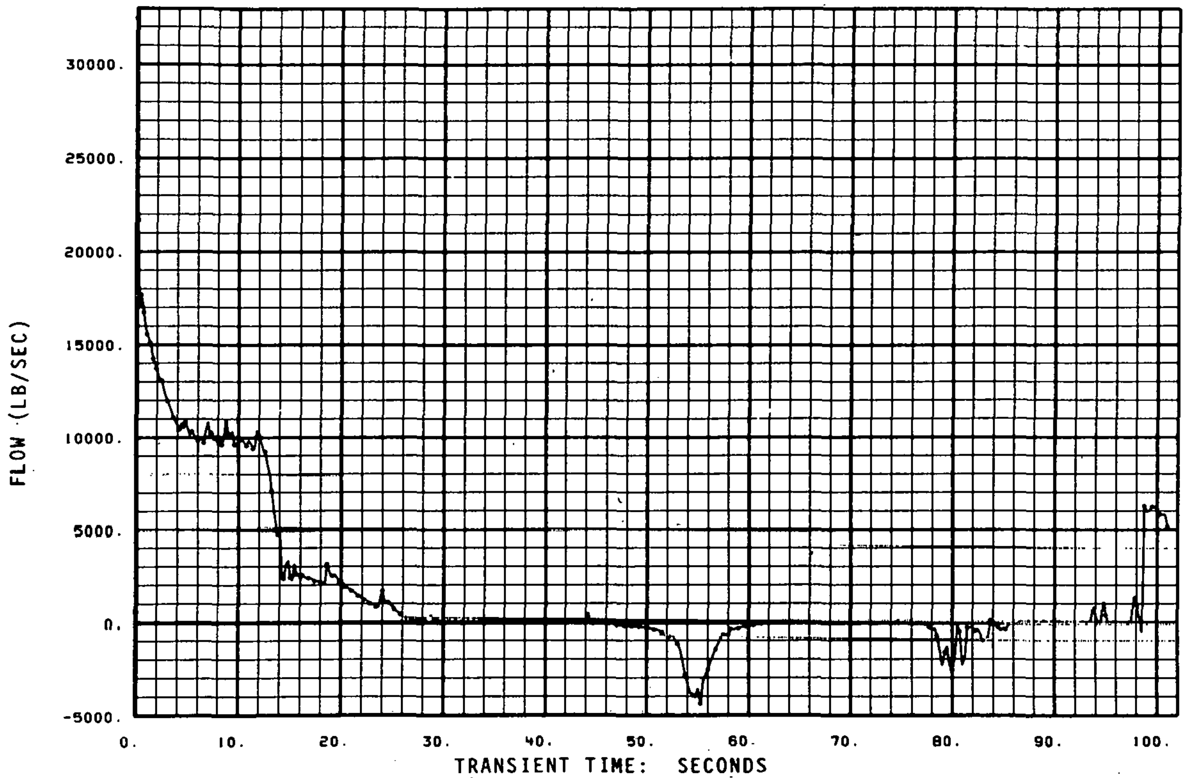

Fig. C-7 Core inlet flow - Combustion Engineering Plant (25% cold leg break).

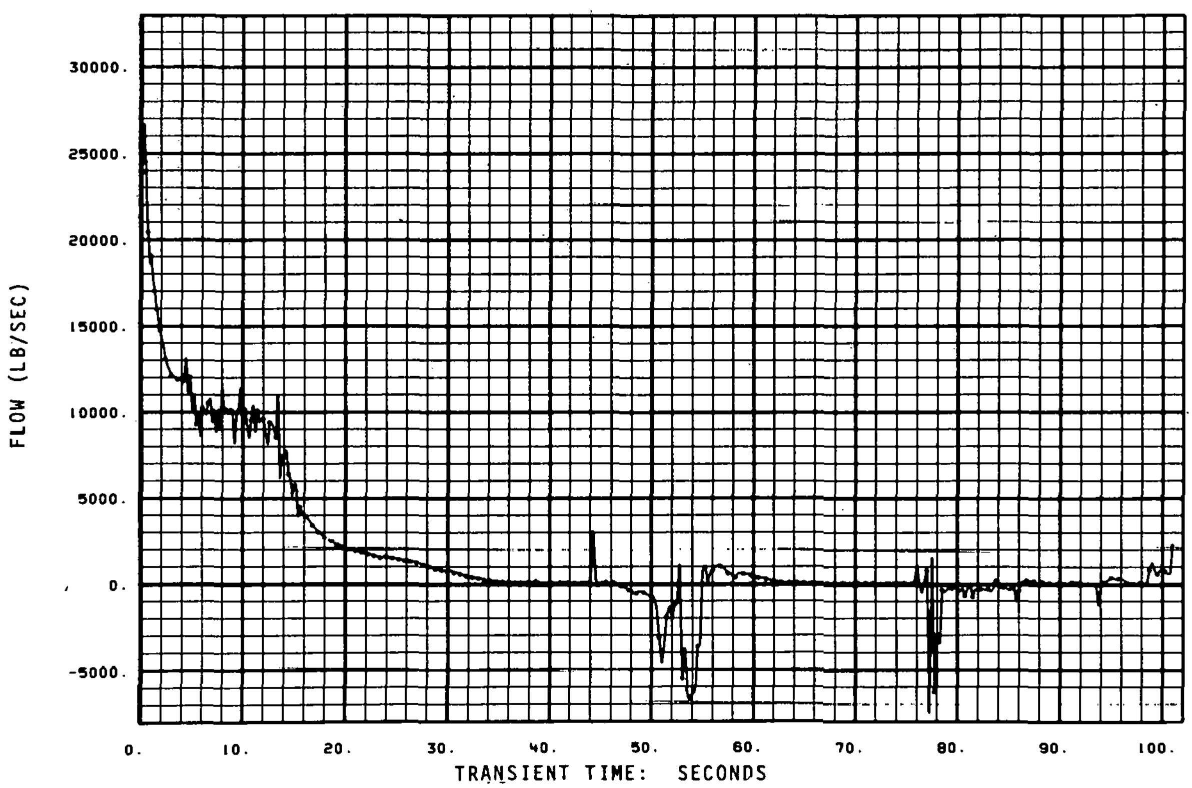

Fig. C-8 Core outlet flow - Combustion Engineering Plant (25% cold leg break).

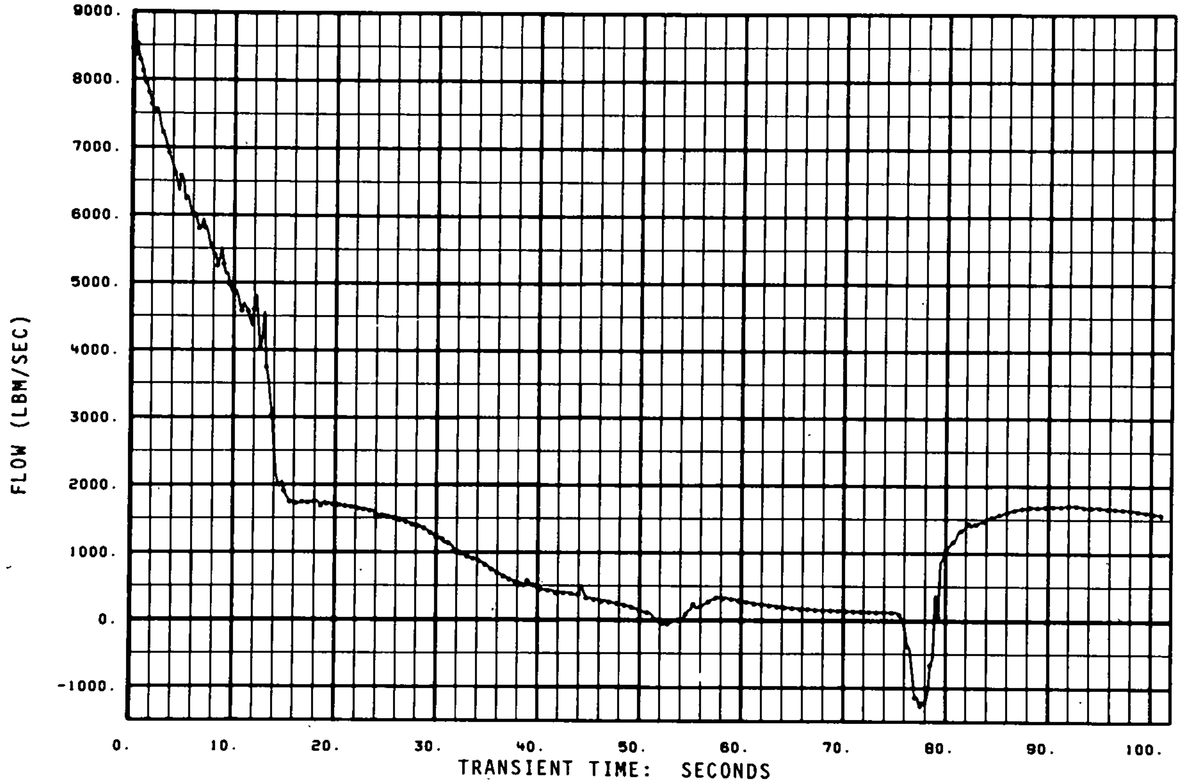

Fig. C-9 Cold leg - Upper annulus flow - Combustion Engineering Plant (25% cold leg break).

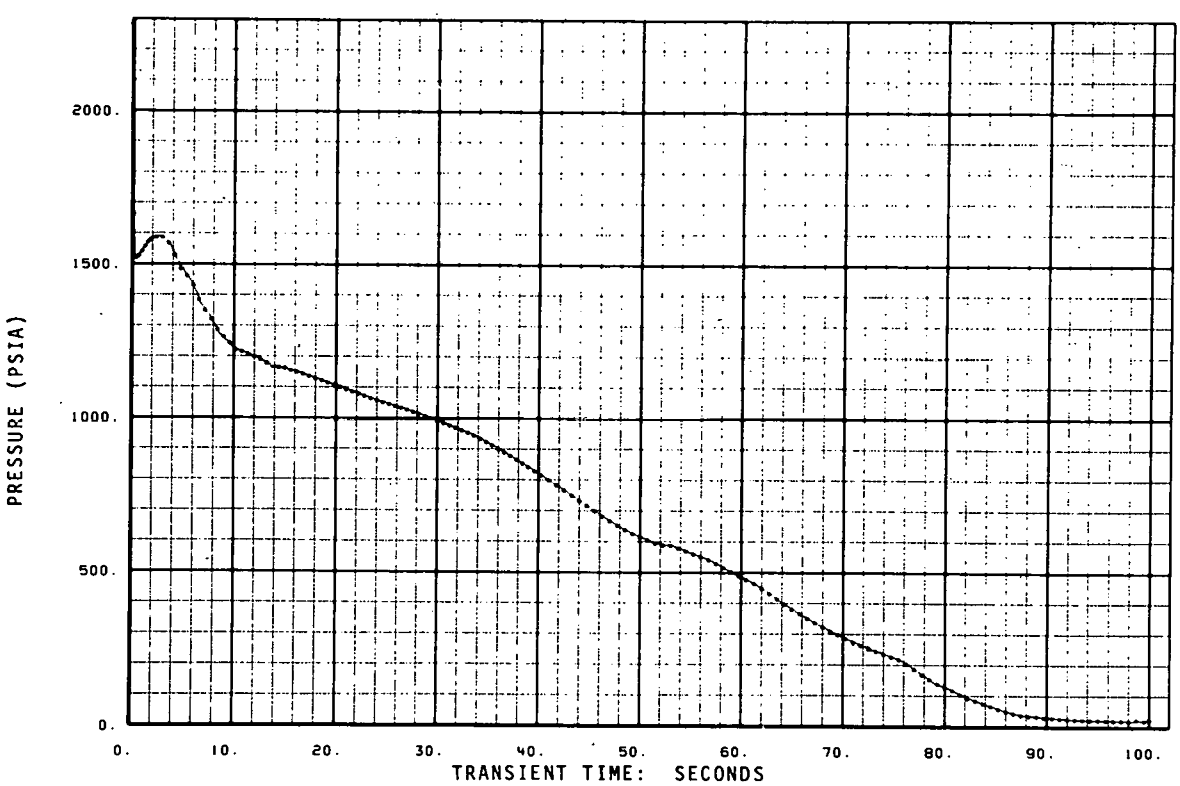

Fig. C-10 Lower plenum pressure - Combustion Engineering Plant (25% cold leg break).

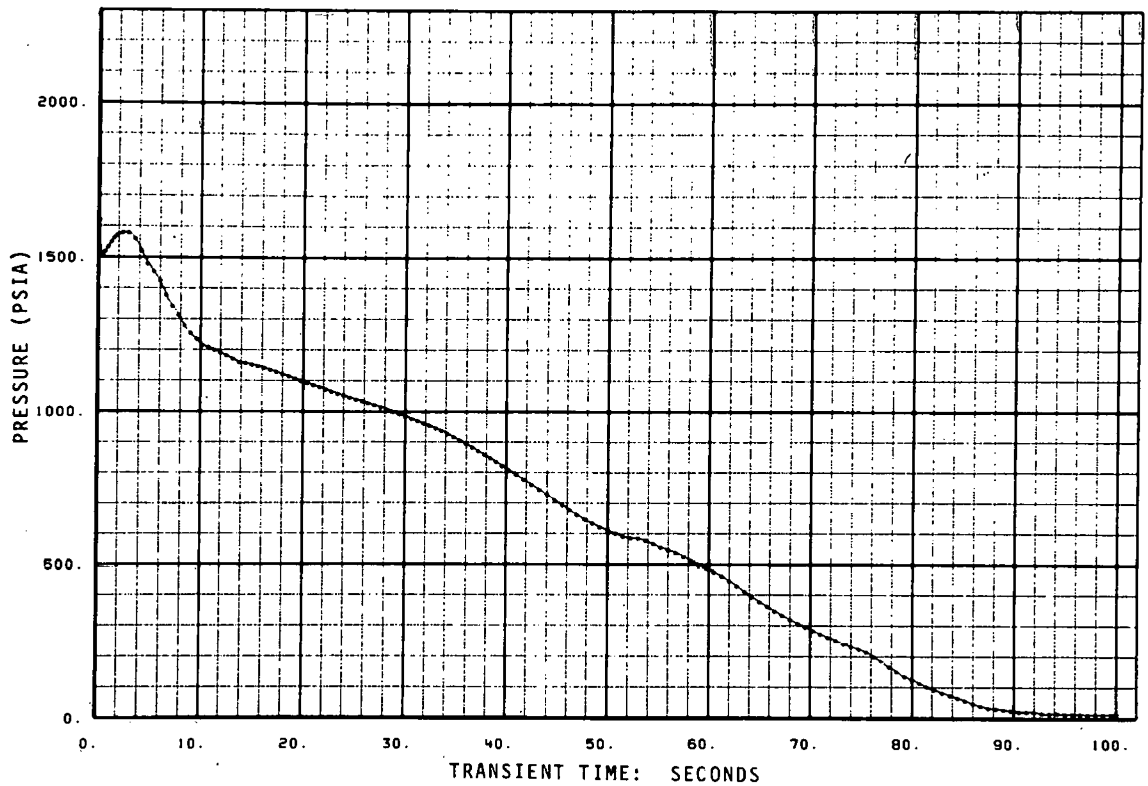

Fig. C-11 Break volume pressure - Combustion Engineering Plant (25% cold leg break).

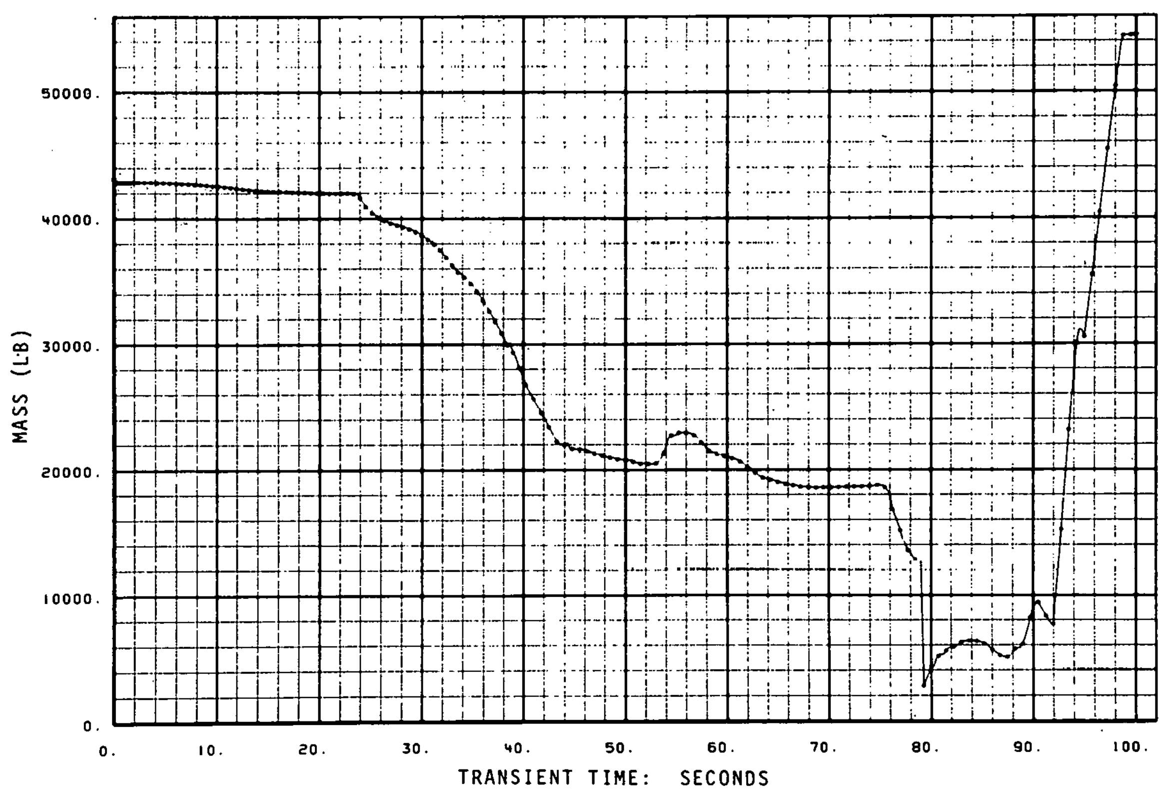

Fig. C-12 Lower plenum total mass - Combustion Engineering Plant (25% cold leg break).

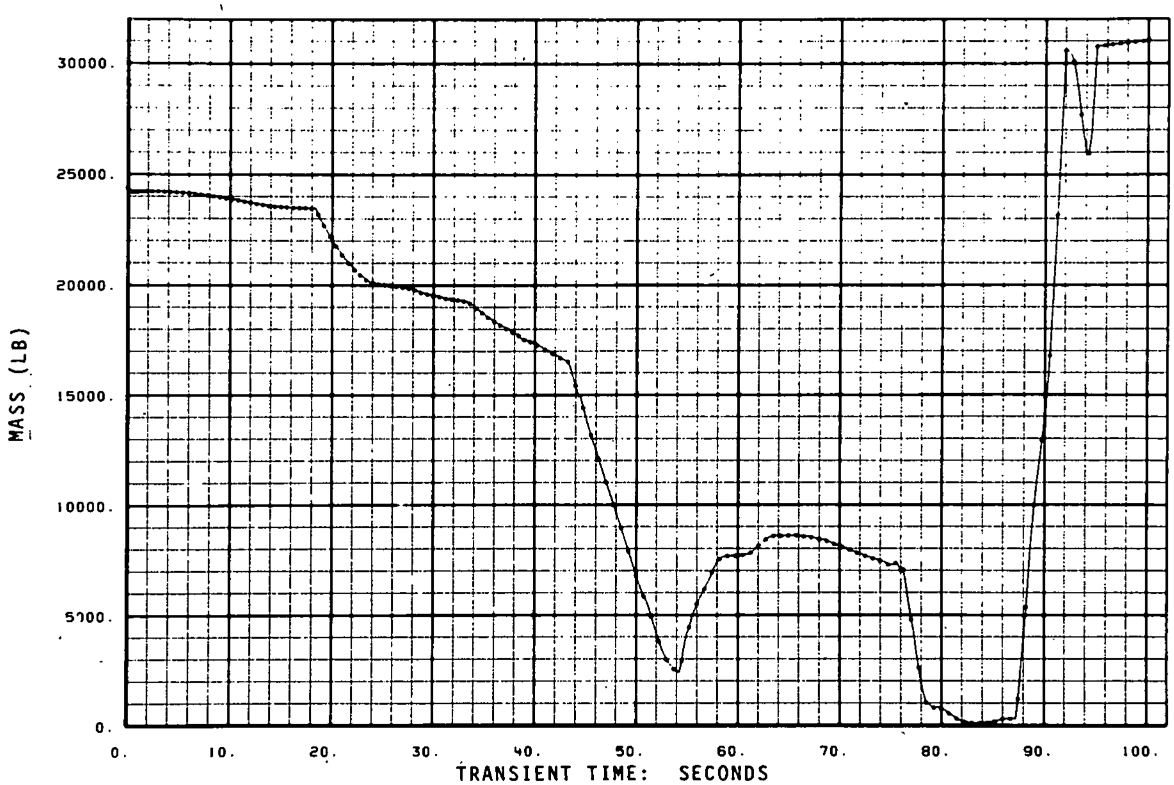

Fig. C-13 Downcomer total mass - Combustion Engineering Plant (25% cold leg break).

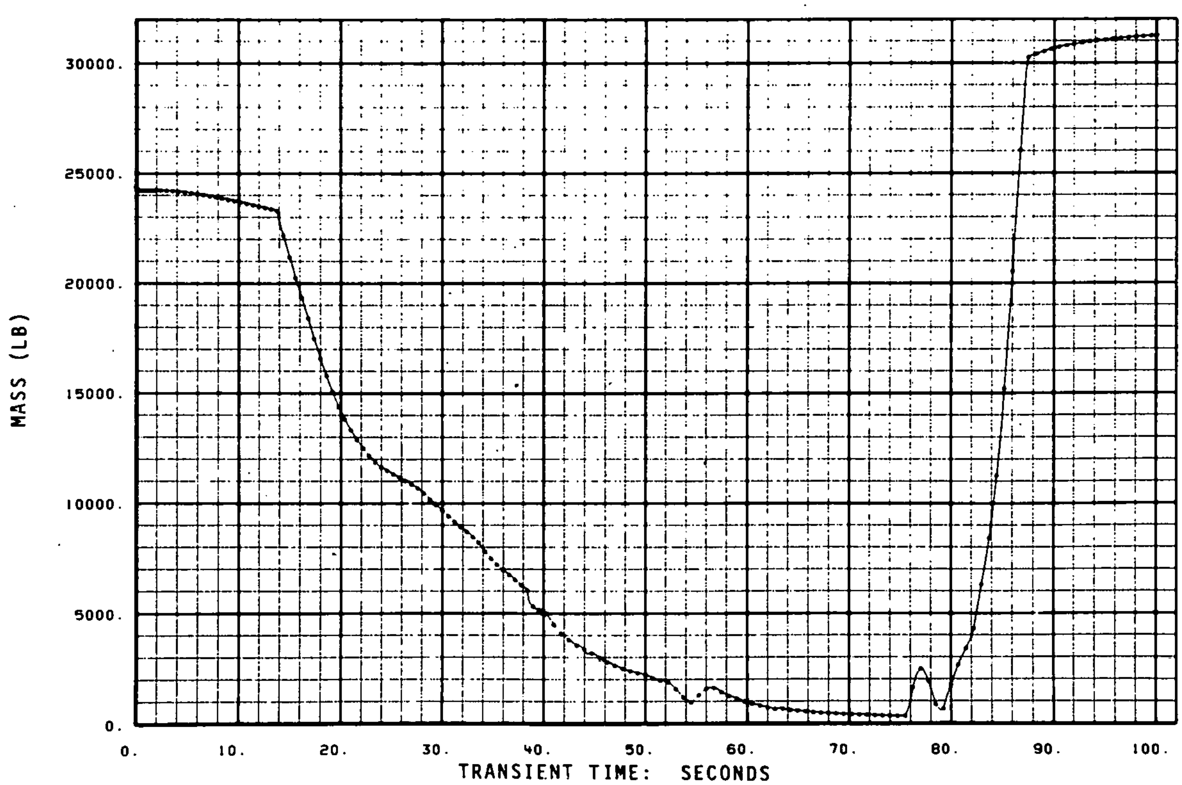

Fig. C-14 Upper annulus total mass - Combustion Engineering Plant (25% cold leg break).

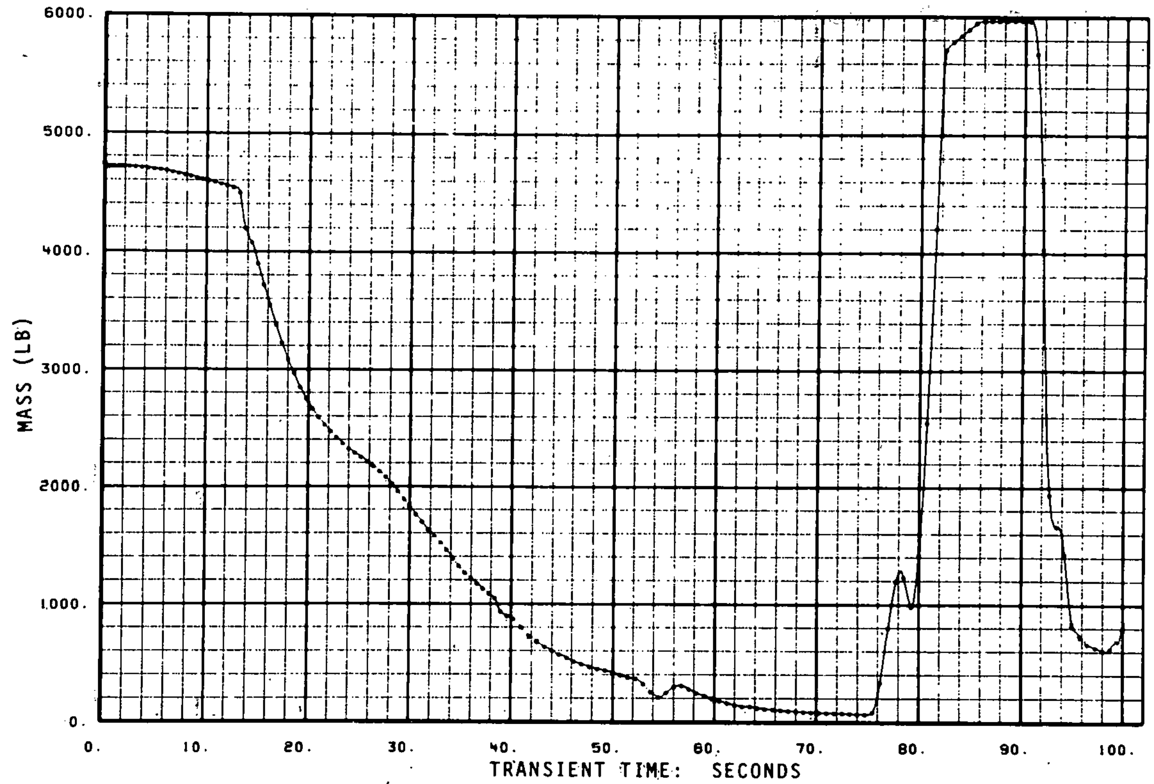

Fig. C-15 Broken cold leg total mass - Combustion Engineering Plant (25% cold leg break).

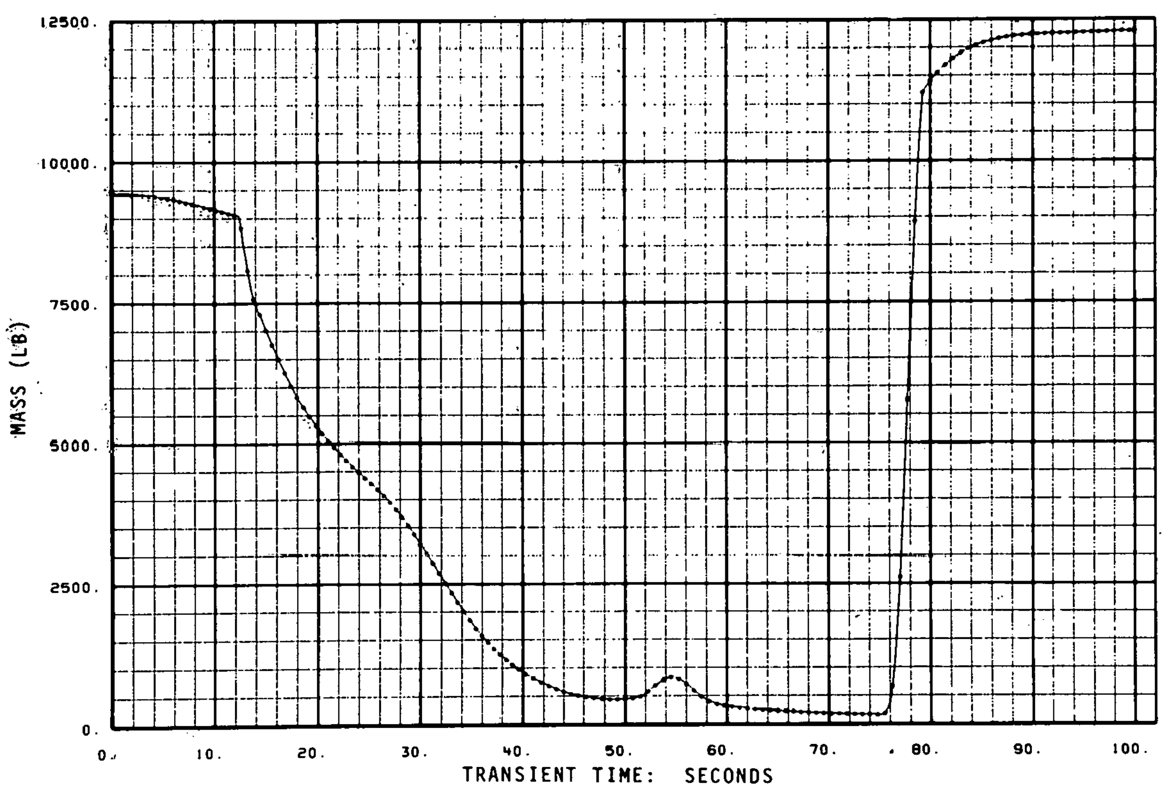

Fig. C-16 Intact cold leg total mass (V37) - Combustion Engineering Plant (25% cold leg break).

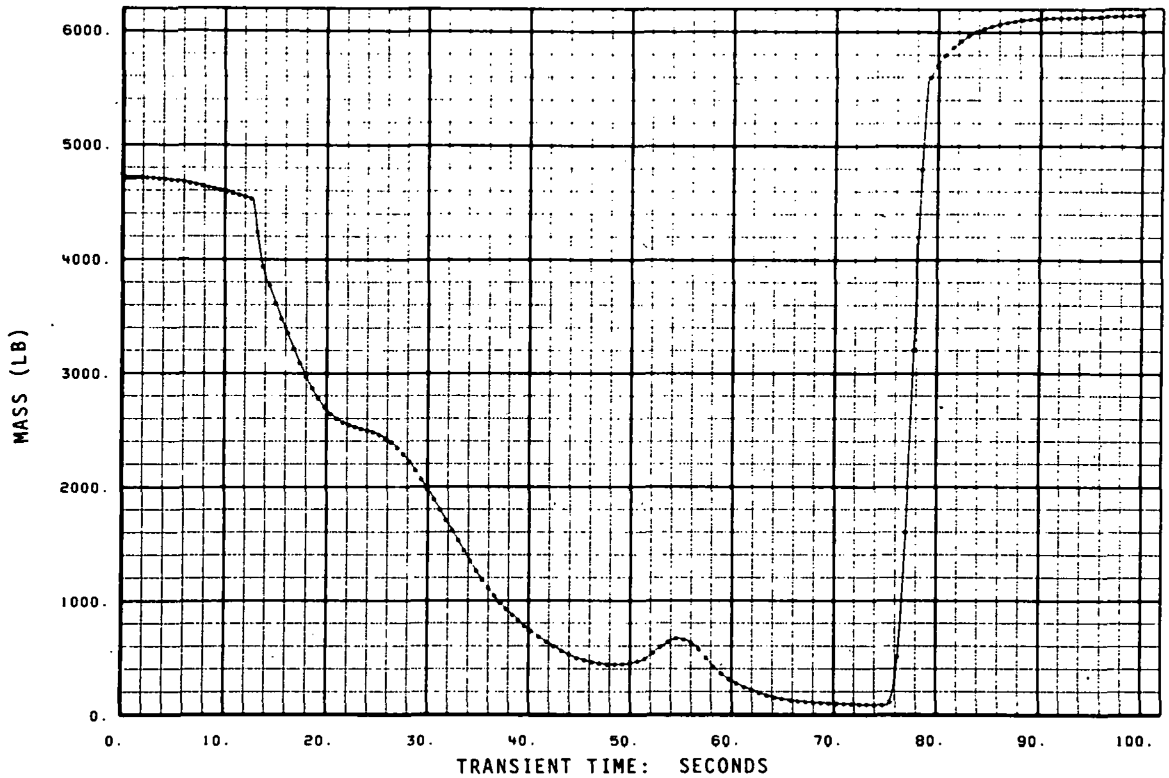

Fig. C-17 Intact cold leg total mass (V27) - Combustion Engineering Plant (25% cold leg break).

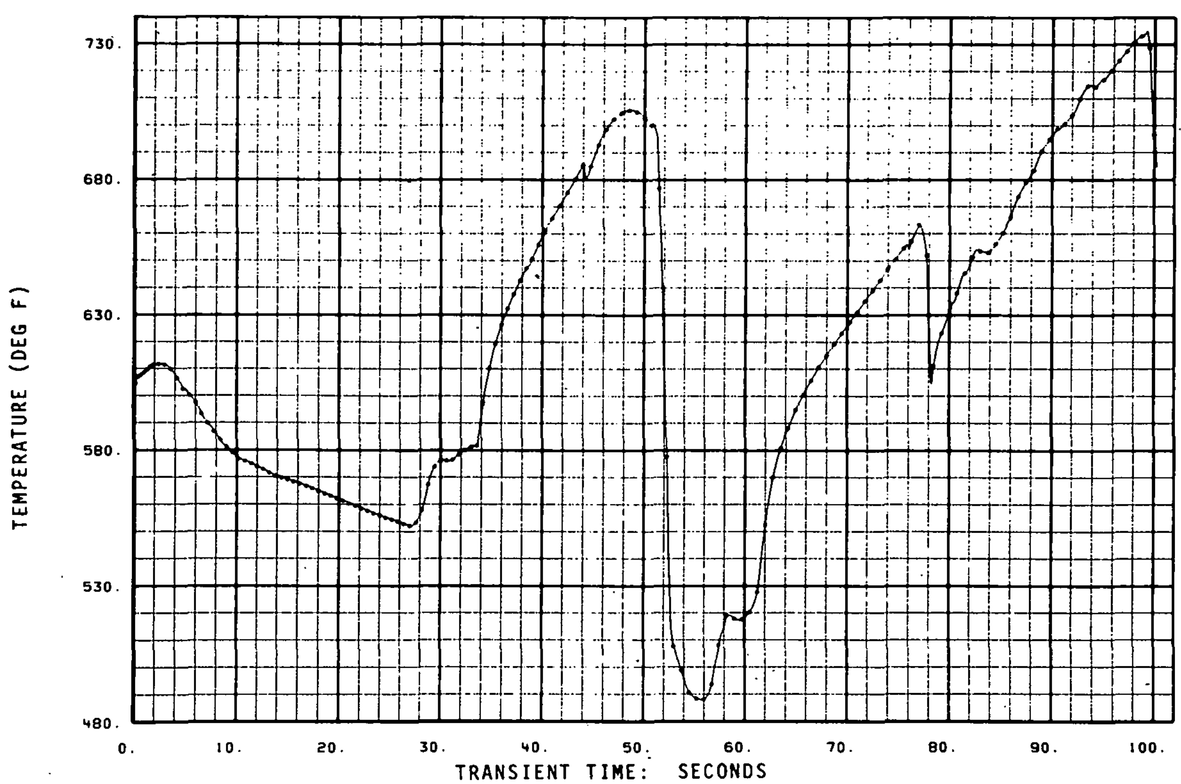

Fig. C-18 Core temperature, lower third - Combustion Engineering Plant (25% cold leg break).

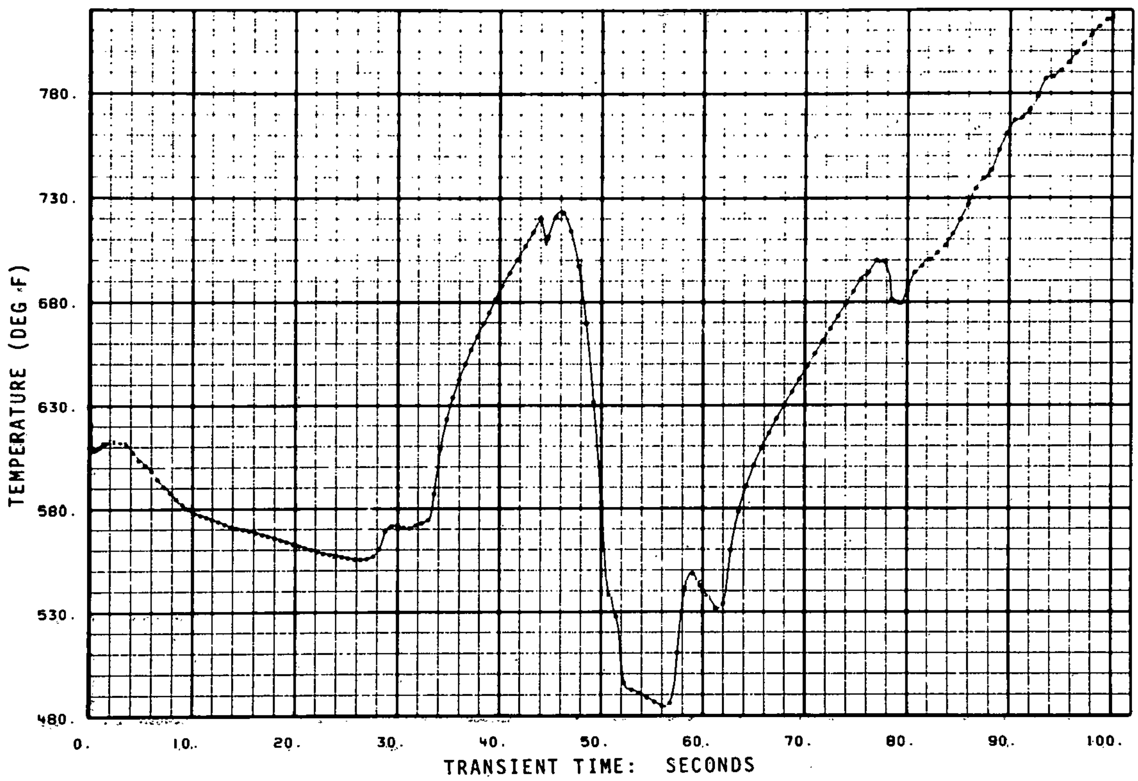

Fig. C-19 Core temperature, middle third - Combustion Engineering Plant (25% cold leg break).

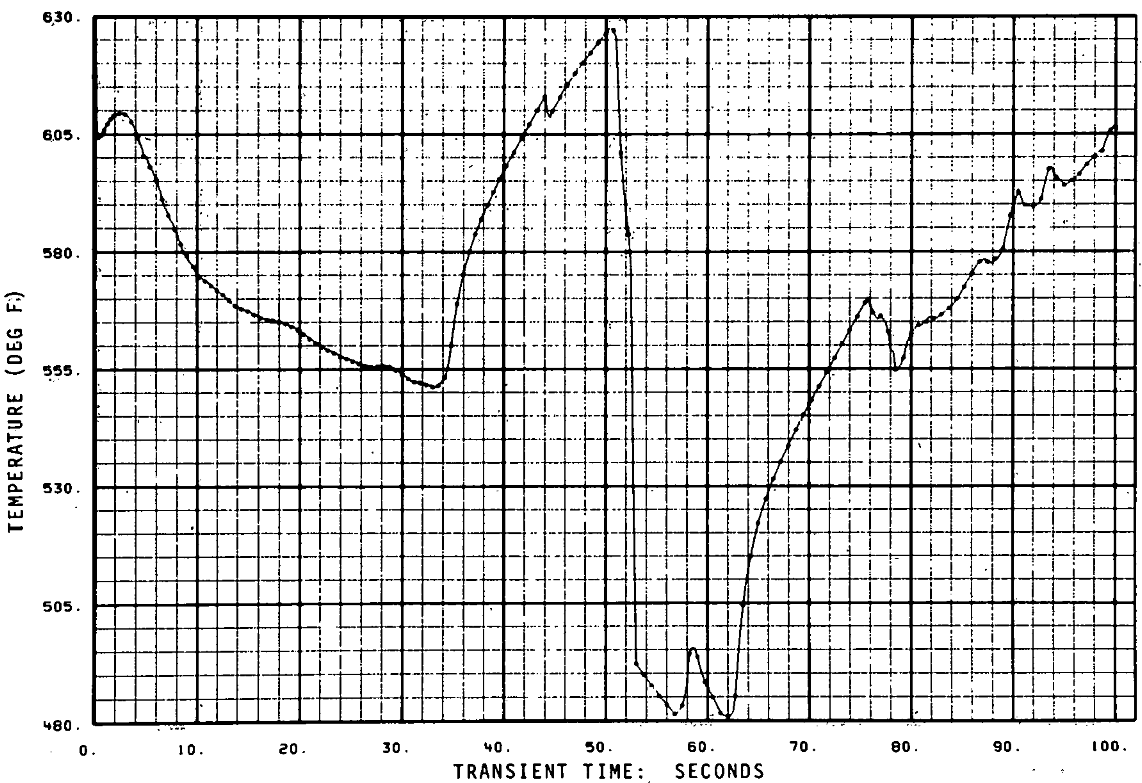

Fig. C-20 Core temperature, upper third - Combustion Engineering Plant (25% cold leg break).

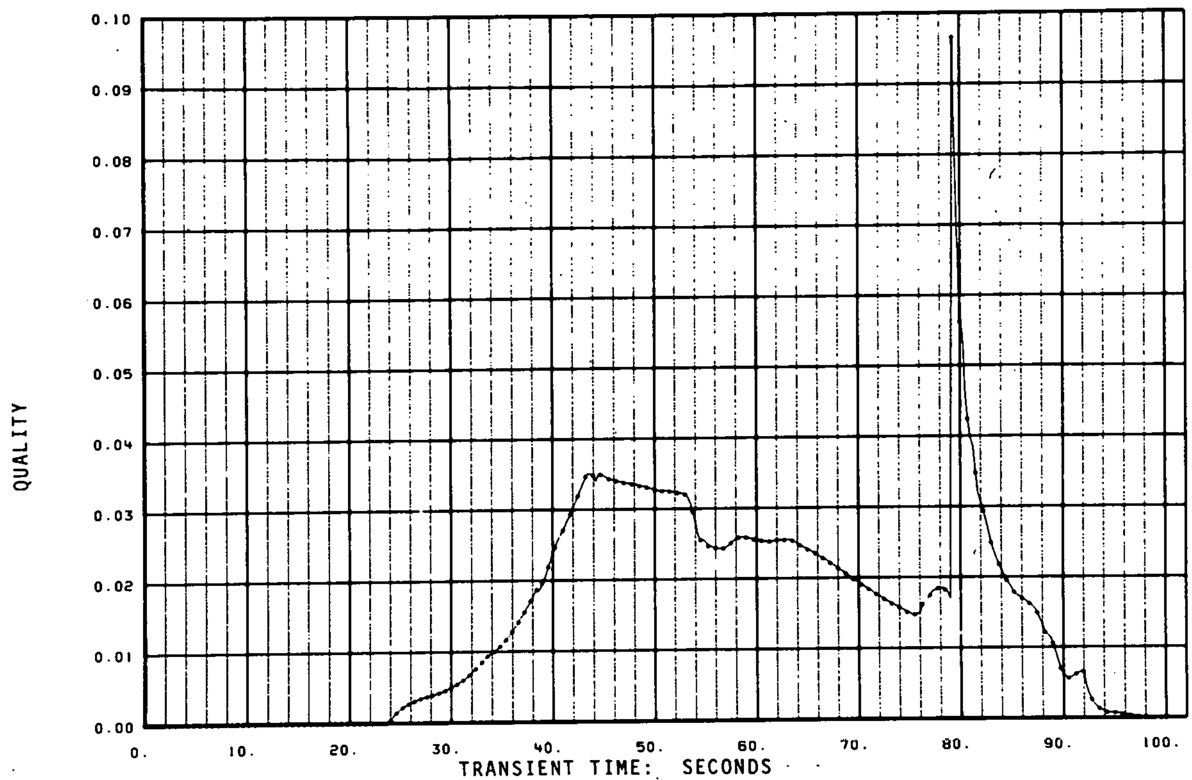

Fig. C-21 Lower plenum average quality - Combustion Engineering Plant (25% cold leg break).

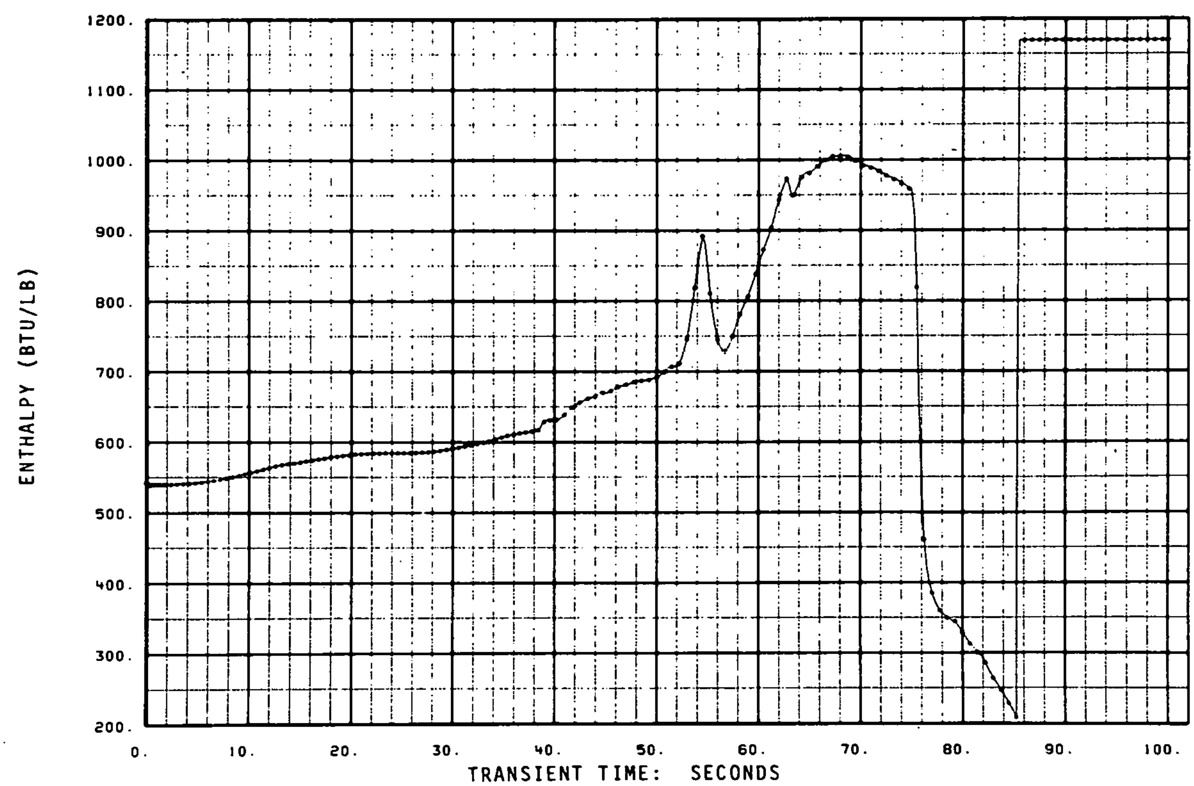

Fig. C-22 Break junction enthalpy - Combustion Engineering Plant (25% cold leg break).

6. INPUT LISTING

An input listing for this run is given in Table C-III which follows.

TABLE C-III

INPUT LISTING

```
=  CALVERT CLIFFS -  25% COLD LEG BREAK
* PROBLEM DATA CARD
010001 -2 9 6 9 39 3 0 56 3 6 0 5 16 6 6 3 0 1
*  PROBLEM CONSTANT AND METHOD CARD
010002  2560. 1.
*  EDIT VARIABLES
020000 JW 6 AP 7 AT 7 CR 2 WR 2 SE 2 CL 5 WL 5 AT 16
030004    50   1.0   * MIXTURE LEVEL CROSSING FIX
*         TIME CARDS
030010 4  5 2 0 .005 .0005 .01  1500.
030020 100 1 1 0 .0005 .00001 .05
030030 50 5 1 0 .002 .00005 .5
030040 10 20 1 0 .01 .0001 2.0
030050 10 10 1 0 .02 .0001 40.
030060 50 8 1 0 .005 .0001 150.
040010  1  1  0  0 120.0   0.    *END OF PROBLEM
040020  2  1  0  0 .010002 0.    *INITIATE BREAK
040030 3  1  0 0 0. 0.            * STEAM GENERATOR TRIP
040040  4  4 4   0  18.7      11.  *LPIS DELAY
040050  5  4 4   0  18.7      6.   *HPIS DELAY
040060 6 -4 21 0 218.4 0.
040070 7 -5 38 0 .01 0.    * ACCUMULATOR SHUT-OFF
040080 8 -5 24 0 .01 0.    * ACCUMULATOR SHUT-OFF
040090 9 -5 23 0 .01 0.    * ACCUMULATOR SHUT-OFF
* VOLUME DATA CARDS
050011 0 0 2279.985 546.4 -1. 517.43 14.92 14.92 0 39.88 1.9 18.056       0
050021 3 0 0. 526.43 .00395  8006.  101.29 35.06 0  79.04 0.     34.76  0
050031 0 0 2284.78 546.4 -1. 517.43 14.92 14.92 0 39.88 1.9 3.136         0
050041 2 0 14.7   100.   0.6 2.E+6  181.7   0.   0 11009. 0.       0.     0
050051 1 0 2284.25 546.5 -1. 915.73 10.07 10.07 0 90.97 0.  0.0           0
050061 0 0 2278.61 558.2 -1. 202.97 3.798 3.798 0 53.457 .04445  10.07  0
050071 0 0 2276.31 581.9 -1. 202.97 3.798 3.798 0 53.457 .04445  13.868 0
050081 0 0 2274.03 598.6 -1. 202.97 3.798 3.798 0 53.457 .04445  17.666 0
050091 1 0 2269.27 600.9 -1. 989.41 10.64 10.64 0 92.99   0.     21.464 0
050101 0 0 2277.18 545.3 -1. 172.31 16.02 16.02 0 13.125 0.       6.667 0
050111 1 0 2269.70 544.9 -1. 253.40 13.50 13.50 0 18.77    .402   21.464 0
050121 1 0 2267.31 545.5 -1. 557.39 6.622 6.622 0 84.198 0.      32.07  0
050131 0 0 2263.50 600.9 -1. 207.24 6.42   6.42  0 9.6211 0.      25.29  0
050141 0 0 2259.07 600.9 -1. 346.88 8.215 8.215 0 34.797 0.      26.545 0
050151 0 0 2251.15 584.2 -1. 329.75 16.0   16.0  0 20.609 .0555   34.76  0
050161 0 0 2241.66 563.4 -1. 329.75  6.0    6.0  0 20.609 .0555   50.76  0
050171 0 0 2239.25 550.3 -1. 329.75 16.0   16.0  0 20.609 .0555   34.76  0
050181 0 0 2240.41 546.1 -1. 346.88 8.215 8.215 0 42.15   0.      26.545 0
050191 0 0 2231.55 546.1 -1. 112.93 7.255 7.255 0  4.909 2.5      19.29  0
050201 0 0 2259.11 546.4 -1. 142.38  9.00   9.00 0  4.909 9.21     19.29  0
050211 0 0 2286.00 546.4 -1. 100.68  2.50   2.50 0  4.909 2.5      25.79  0
050221 3 0 0. 526.43 .00395  8006.  101.29 35.06 0  79.04 0.      34.76  0
050231 2 0   218.4 120.     0. 4217.4  32.56 18.57 0  64.4   3.93   27.04  0
050241 2 0   218.4 120.     0. 2108.7  32.56 18.57 0  32.2   3.93   27.04  0
050251 0 0 2231.56 546.4 -1. 112.93  7.255 7.255 0 4.909 2.5      19.29  0
050261 0 0 2259.14 546.4 -1. 142.38  9.00   9.00 0  4.909 2.5      19.29  0
050271 0 0 2286.70 546.4 -1. 100.68  2.50   2.50 0  4.909 2.5      25.79  0
050281 0 0 2264.07 635.7 -1.   26.88  7.25   7.25 0  .559   0.      28.79  0
050291 0 0 2263.50 600.9 -1. 207.24  6.42   6.42 0  9.621 0.       25.29  0
050301 0 0 2259.07 600.9 -1. 346.88  8.215 8.215 0 34.797 0.      26.545 0
050311 0 0 2251.15 584.2 -1. 329.75  16.0   16.0 0  20.609 .0555  34.76  0
050321 0 0 2241.66 563.4 -1. 329.75   6.0    6.0 0  20.609 .0555  50.76  0
050331 0 0 2239.26 550.3 -1. 329.75  16.0   16.0 0  20.609 .0555  34.76  0
050341 0 0 2240.42 546.1 -1. 346.28  8.215 8.215 0 42.15   0.     26.545 0
050351 0 0 2231.57 546.1 -1. 122.93  7.255 7.255 0  9.818 2.50   19.29  0
```

TABLE C-III (contd.)

```
050361 0 0 2259.14 546.4 -1. 284.76  9.0     9.0  0  9.818 2.50    19.29  0
050371 0 0 2286.70 546.4 -1. 201.36  2.5     2.5  0  9.818 2.50    25.79  0
050381 2 0  218.4 120.     0. 2108.7  32.56 18.57 0  32.2  3.93    27.04  0
050391 1 0    0.  653.00  0. 1500.   27.4  14.62 0  50.27 0.      36.04  0
*       BUBBLE RISE DATA
060011    0.8    3.0
060021   0.0 1.E+6
060031 0.8 80.      * STEAM GENERATOR SECONDARY
*       TIME DEPENDENT VOLUMES
*             N O N E
* SLIP VELOCITY CARD
060001 0. 0. 0. 0. 0.
* JUNCTION DATA CARDS
080011  1 3   0 0 32654. 39.88   18.056  0.  0.     0.     0 0 2 3 0.   1. 11 0 1. 0
080021 21 4   0 4 0.      1.000 27.04 1.   1.      .5     0 0 0 0 0.   1. 11 0 0. 0
080031  3 5   0 0 32684. 28.00    5.467  0.  .734   .432   0 0 2 3 1.5  1. 11 0 1. 0
080041 23 37  0 3 0.      1.242 27.04 40.  8.99   8.99   0 0 0 3 0.   1. 11 0 0. 0
080051  5 6   0 0 32476. 23.387  10.07  0.  0.     0.     0 0 3 3 0.   1. 11 2 0. 0
080061  6 7   0 0 32476. 53.457  13.868 0.  0.     0.     0 0 3 0 0.   1. 11 3 0. 0
080071  7 8   0 0 32476. 53.457  17.666 0.  0.     0.     0 0 3 0 0.   1. 11 3 0. 0
080081  8 9   0 0 32476. 28.41   21.464 0.  0.91   0.85   0 0 3 3 0.   1. 11 1 0. 0
080091  5 10  0 0  205.7 .2000   10.07 .637 0.    0.     1 0 1 3 0.   1. 11 0 0. 0
080101 10 9   0 0 159.80 .639    22.687 .654 0.    0.     1 0 1 3 0.   1. 11 0 0. 0
080111 10 11  0 0   46.30 .0668  21.464 0.  0.     0.     0 0 3 3 0.   1. 11 0 0. 0
080121 11 12  0 0   46.30 .923   34.93  0.  0.     0.     0 0 3 3 0.   1. 11 0 0. 0
080131 12 9   0 0   1199. 34.372 32.07  0.  0.     0.     0 0 3 3 0.   1. 11 0 0. 0
080141  9 13  0 0 16914. 9.621   27.04  0.  .45    1.     0 0 2 3 0.   1. 11 0 0. 0
080151 13 14  0 0 16914. 9.621   27.04  0. 1.195 1.195   0 0 2 0 0.   1. 11 0 0. 0
080161 14 15  0 0 16914. 19.873  34.76  0.  .0     .0     0 0 3 0 0.   1. 11 2 0. 0
080171 15 16  0 0 16915. 19.873  50.76  0.  .06    .06    0 0 2 0 0.   1. 11 3 0. 0
080181 16 17  0 0 16916. 19.873  50.76  0.  .06    .06    0 0 2 0 0.   1. 11 3 0. 0
080191 17 18  0 0 16917. 19.873  34.76  0.  .0     .0     0 0 3 0 0.   1. 11 1 0. 0
080201 18 19  0 0   8460. 4.909  26.545  0.  .436 .680   0 0 2 3 0.   1. 11 0 0. 0
080211 19 20 -1 0   8460. 2.455   20.54 3.604 .023 .023  0 0 0 0   .0 1. 11 0 0. 0
080221 20 21  1 0   8461. 2.455   27.04 .847 0.   0.     0 0 0 0 0.   1. 11 0 0. 0
080231  1 12  0 0 1150.0  .6840 32.07 50.  1.45 1.45     0 0 0 3 0.   1. 11 0 0. 0
080241 28 29  0 0 0.       .559 28.79 0.   2.92 2.38     0 0 2 3 0.   1. 11 0 0. 0
080251 39 28  0 0 0.       .559 36.04 0.  2.38 2.93      0 0 2 3 0.   1. 11 0 0. 0
080261 21 1   0 0   8461. 4.909   27.04  0.  1.    .45    0 0 2 3 0.   1. 11 0 0. 0
080271 18 25  0 0   8457.  4.909 26.545 0.  .436 .680   0  0 2 3 0.   1. 11 0 0. 0
080281 25 26 -2 0   8458.  4.909 20.54 0.  .091 .091    0  0 2 0 0.   1. 11 0 0. 0
080291 26 27  2 0   8458.  4.909 27.04 0.  0.    0.     0  0 2 0 0.   1. 11 0 0. 0
080301 38 21  0 1 0.        .621 27.04 40.  8.99  8.99   0 0 0 3 0.   1. 11 0 0. 0
080311 27 1   0 0   8458.  4.909 27.04  0.  1.    .45   0  0 2 3 0.   1. 11 0 0. 0
080321  9 29  0 0 16918.   9.621 27.04 0.  .45  1.      0  0 2 3 0.   1. 11 0 0. 0
080331 29 30  0 0 16912.   9.621 27.04 0.  1.195 .645   0  0 2 0 0.   1. 11 0 0. 0
080341 30 31  0 0 16912. 19.873 34.76 0.  .0    .0      0  0 3 0 0.   1. 11 2 0. 0
080351 31 32  0 0 16913. 19.873 50.76 0.  .06   .06     0  0 2 0 0.   1. 11 3 0. 0
080361 32 33  0 0 16914. 19.873 50.76 0.  .06   .06     0  0 2 0 0.   1. 11 3 0. 0
080371 33 34  0 0 16915. 19.873 34.76 0.  .0    .0      0  0 3 0 0.   1. 11 1 0. 0
080381 34 35  0 0 16915.   9.818 26.545  0. .436 .680    0 0 2 3 0.   1. 11 0 0. 0
080391 35 36 -3 0 16916.   9.818 20.54 0.  .091 .091     0 0 2 0 0.   1. 11 0 0. 0
080401 36 37  3 0 16916.   9.818 27.04 0.  0.   0.       0 0 2 0 0.   1. 11 0 0. 0
080411 24 27  0 2 0.        .621 27.04 40.  8.99  8.99   0 0 0 3 0.   1. 11 0 0. 0
080421 37 1   0 0 16916.   9.818 27.04 0.  1.   .45      0 0 2 3 0.   1. 11 0 0. 0
080431 0 37 2 0 0.        .25 27.04 1.               0. 0. 0 0 1  3 0. 1. 11 0 0. 0
080441 0 37 1 0 0.        .50 27.04 1.               0. 0. 0 0 1  3 0. 1. 11 0 0. 0
080451 0 37 1 0 0.        .50 27.04 1.               0. 0. 0 0 1  3 0. 1. 11 0 0. 0
080461 0 22 3 0  1565.3 1.0 35.0  1.                 0. 0. 0 0 1  3 0. 1. 11 0 0. 0
```

TABLE C-III (contd.)

```
080471 0  2 3 0  1565.3 1.0 35.0  1.              0. 0. 0 0 1  3 0. 1. 11 0 0. 0
080481 0 22 4 0 -1565.3 1.0 136.  1.              0. 0. 0 0 1 -2 0. 1. 11 0 0. 0
080491 0  2 4 0 -1565.3 1.0 136.  1.              0. 0. 0 0 1 -2 0. 1. 11 0 0. 0
080501 0 22 5 0 0.      1.00 136.  1.             1. .5 0 0 0 -2 0. 1. 11 0 0. 0
080511 0  2 5 0 0.      1.00 136.  1.             1. .5 0 0 0 -2 0. 1. 11 0 0. 0
080521 0 21 2 0 0.       .25 27.04 1.             0. 0. 0 0 1  3 0. 1. 11 0 0. 0
080531 0 21 1 0 0.       .50 27.04 1.             0. 0. 0 0 1  3 0. 1. 11 0 0. 0
080541 0 27 2 0 0.       .25 27.04 1.             0. 0. 0 0 1  3 0. 1. 11 0 0. 0
080551 0 27 1 0 0.       .50 27.04 1.             0. 0. 0 0 1  3 0. 1. 11 0 0. 0
080561 0 37 2 0 0.       .25 27.04 1.             0. 0. 0 0 1  3 0. 1. 11 0 0. 0
*        PUMP DATA
*          PUMP CURVE INPUT
100000  16  0  0  0
*        PUMP DESCRIPTION
090011 1 2 0 1 0 888. 1.  80987. 195.96 25000. 101900. 46.977 0. 0.      0.
090021 1 2 0 1 0 888. 1.  80987. 195.96 25000. 101900. 46.977 0. 0.       0.
090031 1 2 0 1 0 888. 1. 161974. 195.96 50000. 203800. 46.977 0. 0.       0.
*          PUMP SHUTDOWN DATA
095011 0.0 0. 0.
095021 0.0 0. 0.
095031 0.0 0. 0.
*          PUMP HEAD MULTIPLIER
091001 -11 0. 0. .1 0. .15 .05 .24 .8 .3 .96 .4 .98 .6 .97
091002    .8 .9 .9 .8 .96 .5 1.0 0.
*          TORQUE MULTIPLIER
092001 2  0. 0. 1. 0.
*          PUMP HEAD AND TORQUE DATA
101011
101012
101013
101021
101022
101023
101031
101032
101033
101041
101042
101043
101051
101052
101053
101061
101062
101063
101071
101072
101073
101081
101082
101083
101091
101092
101093
101101
101102
101102
101103
101111
101112
```

PROPRIETARY INFORMATION

TABLE C-III (contd.)

```
101113
101121
101122
101123
101131
101132
101133
101141
101142
101143                       PROPRIETARY INFORMATION
101151
101152
101153
101161
101162
101163
* CHECK VALVE DATA
110010 27 0 0 1.E-8 4.0 1.E20 1.E20
110020 28 0 0 1.E-8 4.0 1.E20 1.E20
110030 29 0 0 1.E-8 4.0 1.E20 1.E20
110040 -2 0 0 0. 0. 0. 0.
110050  6 0 0 0. 0. 0. 0.
110060 -6 0 0 0. 0. 0. 0.
* FILL TABLE DATA CARDS
130100 5 2 15 4 'GAL/MIN' 14.7 120.  * HIGH PRESSURE INJECTION PUMPS
130101 0. 645. 15. 640. 215. 590. 415. 520. 615. 480. 815. 410.
130102 915. 370. 1015. 320. 1065. 290. 1115. 250. 1165. 205.
130103 1215. 145. 1265. 60. 1300. 0. 5000. 0.
130200 4 2 14 4 'GAL/MIN' 14.7 120.  * LOW PRESSURE INJECTION PUMPS
130201 0. 2930. 15. 2800. 40. 2600. 65. 2360. 90. 2120. 115. 1840.
130202 140. 1500. 165. 1090. 175. 890. 185. 650. 190. 500. 195. 170.
130203 197. 0.  3000. 0.
130300 3 1 4 4 'LBS/SEC' 850. 443.   * STEAM GEN. FEEDWATER FLOW
130301 0.  1565.3 1.  1565.3 2.  78.25 5000.  78.25
130400 3 1 4 3 'LBS/SEC' 443. 1.0    * STEAM FLOW
130401 0. -1565.3 1. -1565.3 2.  00.00 5000.  00.00
130500 2 2 4 4 'LBS/SEC' 14.7 120.   * STEAM GEN. RELIEF VALVE FLOW
130501 0. 0. 1000. 0. 1100. -1691. 3000. -1691.
*          KINETICS CONSTANTS DATA
140000  3  1    237.4  0.  .8  0. 0. 0.* BEFF=.006885 , L=29E-6
*          SCRAM TABLE
141001 -2  2  0.0 0.0 100.0 0.0
*          DENSITY VS REACTIVITY TABLE
142001 -20 0. -65.05   .2222 -30.36
142002    .2667 -24.69 .3333 -17.28 .400 -11.62 .4444 -8.86 .4889 -5.51
142003     .5556 -3.92 .5778 -3.34 .6111 -2.45 .6667 -1.23 .7222 -.363
142004     .7556 -.174 .7778 .0726 .8444 .3195 .8889 .305 .9333 .276
142005     1.000 0.00 1.064 -.2643 2.222 -5.05
*          DOPPLER TABLE
143001 -10  400. 3.57 800. 2.79 1200. 2.05 1600. 1.44 2000. .901
143002     2400. .392 2800. -.0726 3200. -.523 3600. -.901 4000. -1.23
*          REACTIVITY COEFFICIENT DATA
140010 .236248  .236248  0.  0.
140020 .521535  .521535  0.  0.
140030 .236248  .236248  0.  0.
*          HEAT SLAB DATA
150011  0  6 1 0 0 0 0 0. 16138.5 147.94 0. .04445 0. 0. 0. 11.392 0. 0.
150021  0  7 1 1 0 0 0 0. 16138.5 147.94 0. .04445 0. 0. 0. 11.392 0. 0.
150031  0  8 1 1 0 0 0 0. 16138.5 147.94 0. .04445 0. 0. 0. 11.392 0. 0.
150041 15  2 2 0 2 0 0 23266.2 26763.2 102.143 0. 0. 0. 0. 16.  3. 0. 16.
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150051 16   2 2 0 2 0 0 23266.2 26763.2 102.143 0. 0. 0. 0. 16.  3. 16. 22.
150061 17   2 2 0 2 0 0 23266.2 26763.2 102.143 0. 0. 0. 0. 16.  3. 0. 16.
150071 31 22 2 0 2 0 0 23266.2 26763.2 102.143 0. 0. 0. 0. 16.  3. 0. 16.
150081 32 22 2 0 2 0 0 23266.2 26763.2 102.143 0. 0. 0. 0. 16.  3. 16. 22.
150091 33 22 2 0 2 0 0 23266.2 26763.2 102.143 0. 0. 0. 0. 16.  3. 0. 16.
150101  5  0 3 0 0 0 0 180.118  0.0 67.338 0. 0. 0. 0. 0. 0. 0. 4.
150111 12  0 4 0 0 0 0 298.185  0.0 191.12 0. 0. 0. 0. 0. 0.     0. 0.
150121  3 0 5 0 0 0 0 671.8431  0.      507.0997 0. 0. 7.2 0.   0. 0. 0. 0.
150131 1  0 5 1 0 0 0 671.8431  0.      507.0997 0. 0. 7.2 0.   0. 0. 0. 0.
150141 10 3 6 0 0 0 0 441.3205 446.5387  65.1188 0. 0. 6.2 6.3 0. 0. 3.531 0.
150151 10 1 6 1 0 0 0 131.7375 133.2951  19.4384 0. 0. 6.2 6.3 0. 0. 0. 3.4
150161  9 1 6 1 0 0 0 410.7109 414.5672  60.6023 0. 0. 6.2 6.3 0. 0. 3.41 14.
*  CORE SECTION DATA
160010 1 7 9 17 .0021667  .3587
160020 2 7 9 17 .0021667  .4582
160030 3 7 9 17 .0021667  .1831
*        PIN DATA
160015 0 0 00.000 .8 .67 .965 .945 .055 0. 0. 0. 0. 0. .555 00.000 .01 0. 0. 1.
160016      0.        0 .029 .00633 1.1
160025 0 0 00.000 .8 .67 .965 .945 .055 0. 0. 0. 0. 0. .555 00.000 .01 0. 0. 1.
160026      0.        0 .029 .00633 1.1
160035 0 0 50.394 .8 .67 .965 .945 .055 0. 0. 0. 0. 0. .555 17.672 .01 0. 0. 1.
160036 21523. 1033088. .029 .00633 1.1
* HEAT SLAB GEOMETRY CARDS
170101 2 3 1 6 0. .0158125  1.0
170102 1 2 2   .0003542  0.
170103 0 3 8   .0021667  0.
170201 2 1 4 6 .02730   .004083 0.0
170301 2 2 5 6 6.16667 .026042 0.0
170302 0 6 6 .338542 0.
170401 2 2 5 6  7.16667 .026042  0.0
170402 0 6 6 .588542 0.
170501 2 2 5 6 7.16667  .026042  0.0
170502 0 6 6 .6928 0.
170601 2 1 5 8 6.16667  .14583    0.0
* THERMAL CONDUCTIVITY DATA
180100 -20  500.   3.341  650.   2.971  800.   2.677  950.   2.439  1100.  2.242
180101      1250.  2.078  1400.  1.940  1550.  1.823  1700.  1.724  1850.  1.639
180102      2000.  1.568  2150.  1.507  2300.  1.457  2450.  1.415  2600.  1.382
180103      3100.  1.323  3600.  1.333  4100.  1.406  4600.  1.538  5100.  1.730
180200    2          32.       .41562     5400.      .41562
180300 -11 392. 6.936 752. 8.092 1112. 9.827 1472. 10.983 1832. 12.717
180301 2192. 14.451 2552. 17.341 2912. 20.809 3272. 25.433 3632. 31.792
180302 3992. 39.306
180400 -4 100. 8.5 300. 9.58 600. 11.15 1100. 13.65
180500 -4  32. 8.0 212. 9.4  572. 10.9  932. 12.4
180600 -4  32. 26.5 212. 26. 572. 25.0  932. 22.0
* HEAT CAPACITY DATA
190100   16               32. 34.45           122. 38.35             212. 40.95
190101                   392. 43.55           752. 46.8             2012. 51.35
190102                  2732. 52.65      3092. 56.55  3452. 63.05
190103                  3812. 72.8           4352. 89.7             4532. 94.25
190104                  4712. 98.15          4892. 100.1            5144. 101.4
190105                  8000. 101.4
190200    2          32.       .000075    5400.      .000075
190300   5   0.0   28.392
190301   1480.3   34.476   1675.0   85.176
190302   1787.5   34.476   3500.0   34.476
190400   -4  100. 57.18  400. 61.14  600. 63.77  800. 66.41
190500 -2  32.  53.79  500.  53.79
```

TABLE C-III (contd.)

```
190600 -2  32.  53.79  500.  53.79
*        LINEAR EXPANSION COEFFICIENT DATA
200101  -2 0. 3.718E-6 5000. 1.2653E-5
200201 -2 0. 0. 5000. 0.
200301 -4 0. 3.094E-6 1652. 4.706E-6  1653. 5.389E-6 5000. 5.389E-6
200401  -2  0  0  5000.  0
200501 -2 0. 0. 5000. 0.
200601 -2 0. 0. 5000. 0.
*        BLOCKAGE, SWELL, GAP REDUCTION DATA
250001 1 2 3 0 .048333
*        EOB DATA
260001 23 24 38 0 6  0  0 0 3  0. 5 3 1 21 27 37
*        MULTIPLE PIN RUPTURE DATA
270001  14  2500. 0  2200.  100.  1820.  200.  1730.  400.  1660.  600.
270002  1600.  800.  1540.  1000.  1480.  1200.  1440.  1400.  1400.  1600.
270003  1370.  1800.  1335.  2000.  1310.  2200.  1280.  2400.
*        MULTIPLE PIN FLOW BLOCKAGE DATA
280001  14 80. 0 80. 100. 60. 200. 30. 400. 35. 600. 55. 800. 70. 1000.
280002  78. 1200. 77. 1400. 73. 1600. 67. 1800. 57. 2000. 52. 2200. 30. 2400.
*        SINGLE PIN RUPTURE DATA
290001  14  2500. 0  2200.  100.  1820.  200.  1730.  400.  1660.  600.
290002  1600.  800.  1540.  1000.  1480.  1200.  1440.  1400.  1400.  1600.
290003  1370.  1800.  1335.  2000.  1310.  2200.  1280.  2400.
*        SINGLE PIN FLOW BLOCKAGE
300001  -14 123. 0. 123. 100. 59. 200. 44. 400. 65. 600. 89. 800. 108. 1000.
300002  123. 1200. 128. 1400. 123. 1600. 113. 1800. 94. 2000. 71. 2200. 54.
300003  2400.
```

APPENDIX D

BWR LARGE RECIRCULATION LINE BREAK - GENERAL ELECTRIC PLANT

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APPENDIX D

BWR LARGE RECIRCULATION LINE BREAK - GENERAL ELECTRIC PLANT

1. INTRODUCTION

The Hope Creek General Electric Boiling Water Reactor (BWR) was modeled using RELAP4/MOD5 to represent a 200% double-ended offset shear break in the pump suction side of one of the jet pump recirculation lines. The system model and assumptions used, the calculated results, and the conclusions drawn from this run are presented in the following sections. Some interpretation of results is based on digital data output which was too voluminous to be included in this appendix. The model presented was used for program checkout and should not be considered a comprehensive study of the LOCA response of the actual plant.

2. SYSTEM MODEL AND ASSUMPTIONS

The RELAP4/MOD5 model used to describe the BWR system is shown in Figure D-1. It consists of 23 volumes, 33 junctions, and 25 heat slabs. The volumes and the vertical slip and fill junctions shown in Figure D-1 are identified in Table D-I.

The interior of the reactor vessel is described by 15 regions or volumes, as follows. Volume 1 is the upper plenum region and includes the volume of the steam separators. Volume 2 is the saturated (upper) downcomer region and extends from the feedwater entry location upward to the bottom of the steam dryers. Volume 3 is the steam dome and contains high quality steam above the driers. Volume 4 is the subcooled (lower) downcomer region and contains the subcooled water between the feedwater entry location and the bottom of the downcomer. Volumes 19 and 20

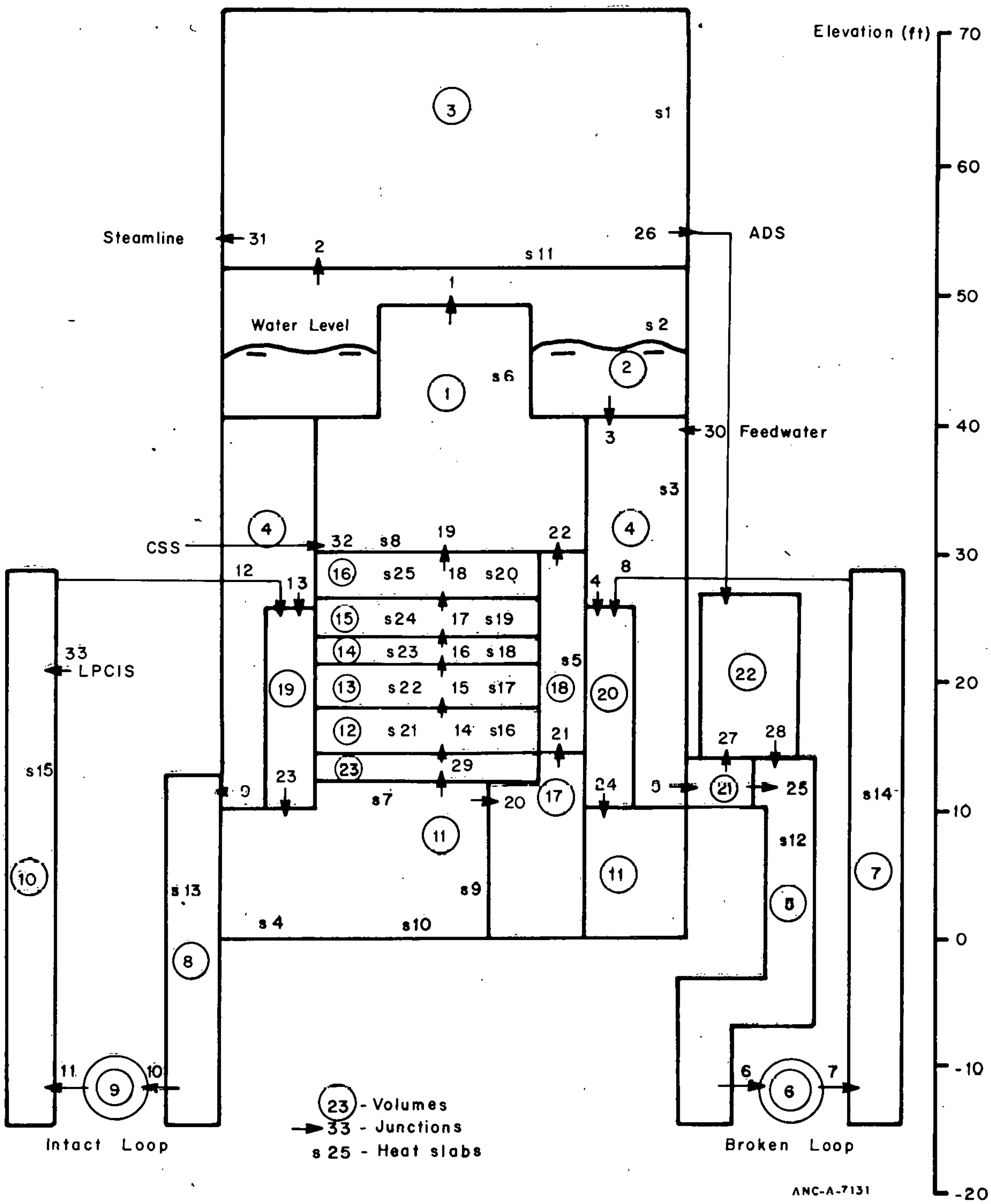

Fig. D-1 Nodalization for 200% break - General Electric Plant.

TABLE D-I

VOLUME AND JUNCTION IDENTIFICATION FOR 200% BREAK - GE BWR PLANT

Volume No.	Description
1	Upper Plenum and Steam Separator
2	Upper Downcomer
3	Steam Dome
4	Lower Downcomer
5	Broken Loop Recirculation Suction Line
6	Broken Loop Recirculation Pump
7	Broken Loop Recirculation Discharge Line
8	Intact Loop Recirculation Suction Line
9	Intact Loop Recirculation Pump
10	Intact Loop Recirculation Discharge Line
11	Lower Plenum
12, 13, 14, 15, 16	Heated Core Sections
17	Guide Tubes
18	Core Bypass
19	Intact Loop Jet Pump
20	Broken Loop Jet Pump
21	Break Volume in Broken Loop
22	Containment
23	Unheated Segment of Core

TABLE D-I (contd.)

Fill Junction No.	
30	Feedwater Inlet
31	Steam Outlet
32	Core Spray - (212°F Water)
33	Low Pressure Coolant Injection - (212°F Water)
Vertical Slip Junction No.	
1	Top of Upper Plenum
14	Core Junction
15	Core Junction
16	Core Junction
17	Core Junction
18	Core Junction
19	Top of Core
21	Bottom of Bypass
22	Top of Bypass
29	Core Inlet

represent the unbroken and broken loop jet pumps. Each bank of 10 jet pumps (broken and unbroken loops) was modeled as a single volume with areas and volumes 10 times those of each actual BWR jet pump. Volume 11 represents the lower plenum region and Volume 17 the guide tubes. Volume 18 represents the core bypass, comprising the region between the fuel assemblies. Volumes 12 through 16 include heat slabs and were used to represent the heated portion of the core. Volume 23 was used to represent the unheated portion of the core.

The containment was modeled with a single volume of 3.43×10^6 ft^3. No attempt was made to represent the containment pressure-suppression system.

As shown in Table D-I, the vertical slip model was used in 10 of the 33 system junctions. These were in the upper plenum, core, and core bypass regions of the reactor vessel. The junction smoothing option was not used. The RELAP4 phase separation (Bubble Rise) model with a bubble velocity of 3 ft/sec was used in the core, lower plenum, upper plenum, and downcomer. The Henry-Fauske/HEM critical flow model was used in the break junctions (Junctions 27 and 28), both with multipliers of 0.9. The stagnation pressure subroutine was not used. Fill junctions were utilized for the feedwater, steamline, core spray, and low pressure injection system (LPIS) flows. The LPIS was modeled for the intact recirculation loop only in order to conform to the functional arrangement of the GE BWR plant.

3. RESULTS

RELAP4/MOD5 ran quite smoothly and had a reasonable processing time. The transient time from break initiation until lower plenum refill was 165 sec. This required 36.1 min of CPU time on the CDC 7600 computer at the Brookhaven National Laboratory.

A listing of the major events which occurred during the transient is given in Table D-II. The output data traces are shown as Figures D-2 through D-12 in Section 5 of this appendix. A summary discussion of the transient is as follows.

The transient began when the break junctions J27 and 28 opened and power to the recirculation pumps was tripped. The trips for the reactor scram and for the feedwater and steamline valve closure were initiated shortly thereafter.

The vessel pressure began to decrease after the break opened as shown in Figure D-2. When the steamline valve closed at 4 sec, the pressure rose rapidly. This caused a brief condensation to occur in the lower part of the core which resulted in a brief depressurization. The pressure increased as more steam was generated in the core until it reached a maximum of 1,090 psi. The pressure then began to decrease when the core flow decreased. The vessel pressure continued to decrease until it equaled the containment pressure near 50 psia at the end of the program run.

The break flows are shown in Figure D-3. It should be noted that Figure D-1 shows one break flow junction (J28) modeled for a positive flow direction into the system. This was done for purposes of convention. The data trace (Figure D-3) has been corrected to show the actual flow direction out of the system as positive. The flow from the vessel side of the break increased very rapidly when the break opened, then decreased as the flow became choked and increased in quality. The flow increased again when the steamline closed at 4 sec and then decreased as the quality of the break flow continued to increase. It remained relatively constant until the downcomer emptied at 14 sec when the break flow quality increased rapidly and the flow decreased very sharply. The break flow then continued to decrease slowly following the vessel pressure drop. The break flow again increased slightly when the downcomer started to fill at 110 sec. The break flow from the pump side of the break also initially increased rapidly but decreased shortly thereafter because the recirculation pump and jet pump drive nozzle

TABLE D-II

MAJOR EVENTS SUMMARY FOR 200% BREAK - GE BWR PLANT

Time (sec)	Event
0.001 to 0.002	Break opened, pump power off, scram tripped, feedwater tripped.
1 to 4	Feedwater stopped
3 to 4	Steamline closed
5	Upper downcomer emptied (Figure D-6)
7	Jet pump suction uncovered
14	Lower downcomer emptied (Figure D-6)
47	Core spray and LPCIS started
123	Liquid mass in lower plenum began to increase (Figure D-10)
125	ADS opened and lower plenum mixture level dropped below jet pumps (Figure D-11)
161	Lower plenum mixture level began to increase and liquid mass leveled off (Figures D-10 and 11)
164	Lower plenum mixture level reached top of volume (Figure D-11)
165	Problem run stopped

restricted flow through the broken loop. The break flow from the pump side followed the depressurization of the system but approached zero earlier than the vessel side break flow because of the greater resistance to reverse flow through the jet pump and the recirculation pump.

The broken loop jet pump flows are shown in Figure D-4. The drive flow reversed very rapidly upon break initiation, as it fed the break. The reverse drive flow caused the discharge flow and the induced flow to reverse. The magnitude of these three reverse flows decreased as the system depressurized.

The intact loop jet pump flows are shown in Figure D-5. The decrease in drive flow was caused primarily by coastdown of the recirculation pump in the intact loop. At 7 sec the mixture level in the lower downcomer fell below the top of the jet pumps and the induced flow reversed causing the discharge flow to reverse. The jet pump induced and discharge flows remained negative throughout the remainder of the transient, as they fed the lower downcomer and the break.

The mixture level in the downcomer is shown in Figure D-6 . The upper downcomer (Volume 2) emptied at 5 sec. The lower downcomer (Volume 4) emptied at 14 sec, which caused a change in break flow from two-phase to steam. This, in turn, induced a discharge flow change in both the broken loop jet pump (Figure D-4) and the intact loop jet pump (Figure D-5). The downcomer mixture level began to increase slowly at 125 sec when the automatic depressurization system (ADS) valve opened and the system depressurized to a balance with the containment pressure.

The core inlet and outlet flows are shown in Figures D-7 and D-8. The effect of uncovering at the top of the intact loop jet pump can be seen at 7 sec in both figures. That is, when the top of the jet pump uncovered, the flow into the lower plenum through the jet pump was greatly reduced (Figure D-5). Flow into the bottom of the core, therefore, decreased rapidly and reversed. Lower plenum flashing was evident at 14 sec when core flow increased sharply in the positive direction.

The core flow quickly returned to negative and remained that way most of the remainder of the transient. That is, following lower plenum flashing, the predominant flows were from the lower plenum through the jet pumps in reverse direction, into the lower downcomer, and out the break. The upper plenum fed the lower plenum in the process. Although it is not readily apparent, the core flow became slightly positive at 163 sec when the mixture level in the lower plenum reached the bottom of the core.

The bypass and guide tube flows are shown in Figure D-9. Jet pump suction uncovering and lower plenum flashing are evident. The flow after lower plenum flashing was out the top of the bypass and out the bottom of the guide tube. After the core spray system (CSS) started at 50 sec, the flow out the top of the bypass increased due to the condensation of steam in the upper plenum from the mixing with CSS subcooled water. After 60 sec, the CSS water flowed down through the bypass to the guide tubes into the lower plenum.

The liquid mass and mixture levels in the lower plenum are shown in Figures D-10 and D-11. Although the liquid mass began to decrease at 14 sec when the lower plenum flashed, the mixture level remained at the bottom of the core until the ADS valve opened at 125 sec. The lower plenum mass began to increase at 123 sec. At 162 sec the liquid mass leveled off, being caused by the rise of the mixture level to the bottom of the core. A two-phase mixture of very low quality then began to flow into the core.

The clad surface temperature at the center of the core is shown in Figure D-12. The clad surface temperature followed the fluid saturation temperature until the core volume reached a low quality. The heat transfer mode then switched from nucleate boiling to forced convection vaporization at 11 sec. Just prior to lower plenum flashing, the volume dried out and then rewet at lower plenum flashing. Clad temperature followed the saturation temperature again until 23 sec when the volume dried out again. The heat transfer mode switched from nucleate boiling to forced convection vaporization and shortly thereafter to forced convection with superheated steam. From 34 to 62 sec the heat transfer mode was stable film boiling. It then changed to low pressure flow film boiling for most of the remainder of the transient.

4. CONCLUSIONS

The BWR large break problem was run without any major difficulty and within the established time limit of one hour on the CDC 7600 computer. The completion criteria listed in Volume III, Section 7.2 for the MOD5 checkout runs were satisfied.

The only difficulty in running the problem occurred at a transient time of 14 sec with lower plenum flashing. The code was using the maximum time step allowed (0.01 sec) and encountered a failure in subroutine BAL. The problem was restarted at 13 sec with a smaller maximum time step (0.005) and the problem continued to run to completion. The maximum time step was increased to 0.01 at 25 sec.

5. OUTPUT DATA

The output data traces for the 200% break GE BWR plant model are shown as Figures D-2 through D-12 in this section.

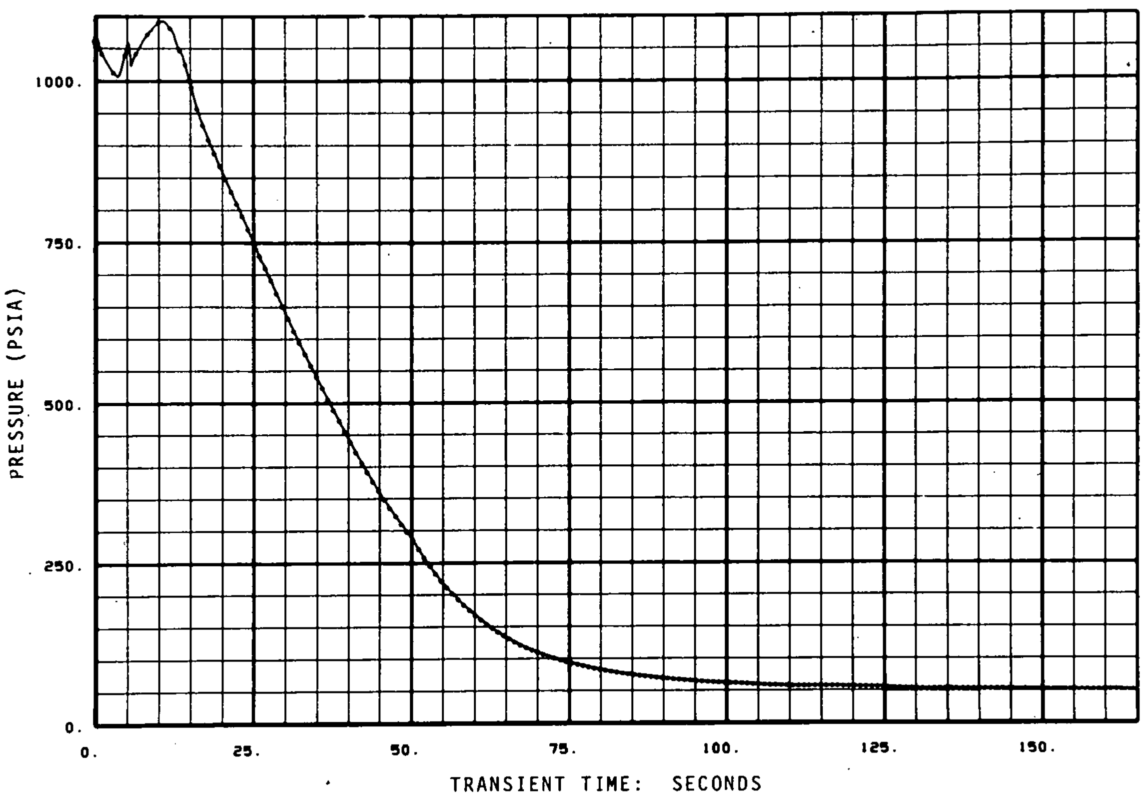

Fig. D-2 Lower plenum pressure - General Electric Plant (200% break).

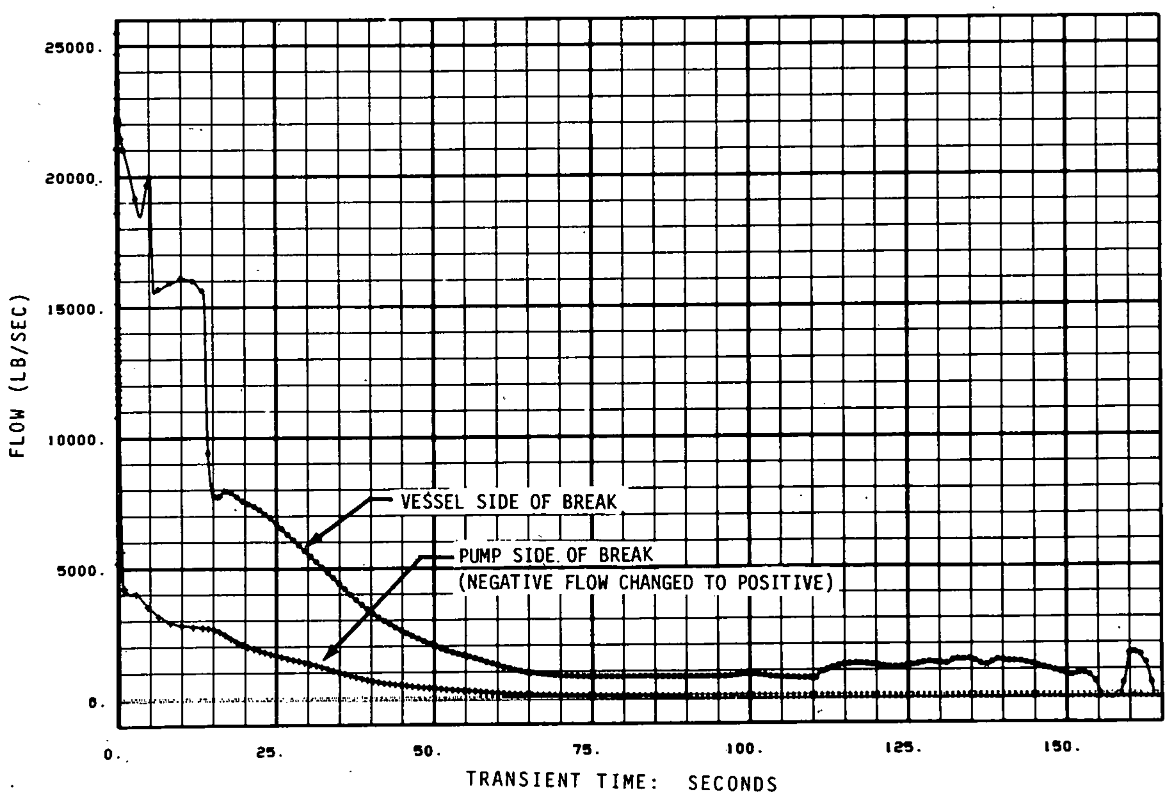

Fig. D-3 Break flow - General Electric Plant (200% break).

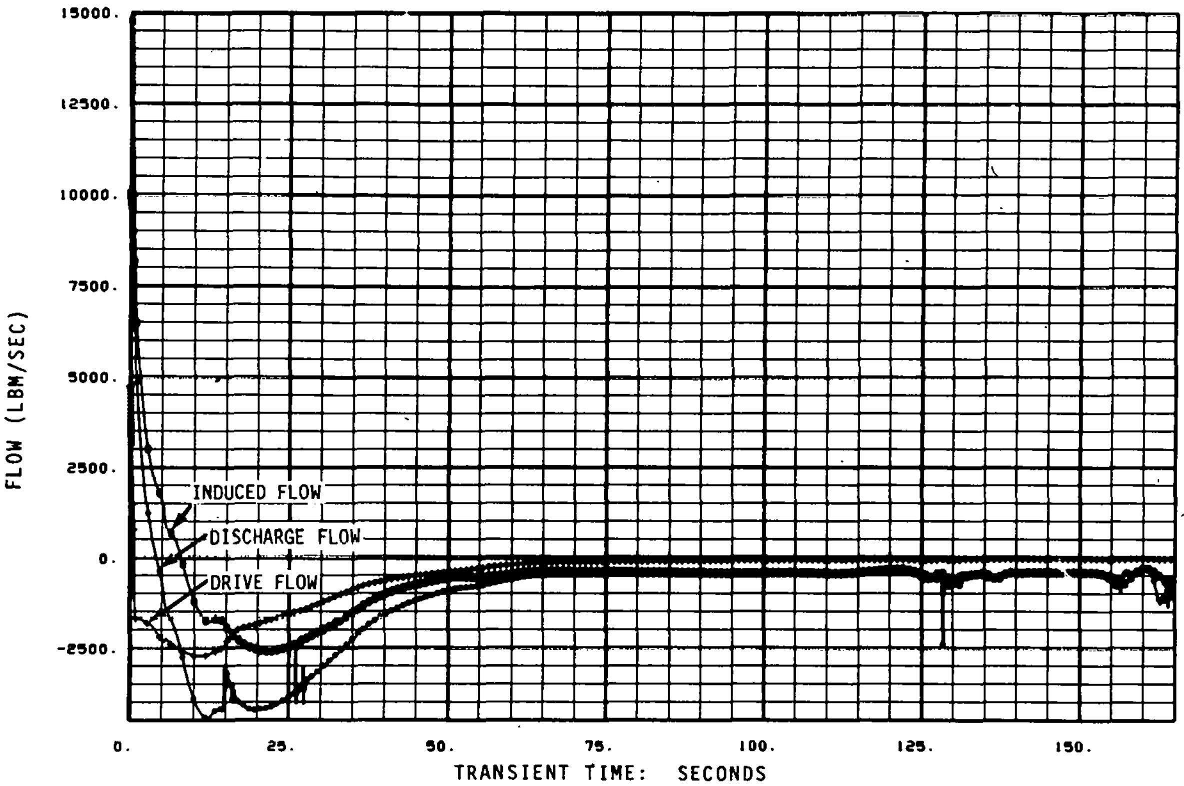

Fig. D-4 Broken loop jet pump flow - General Electric Plant (200% break).

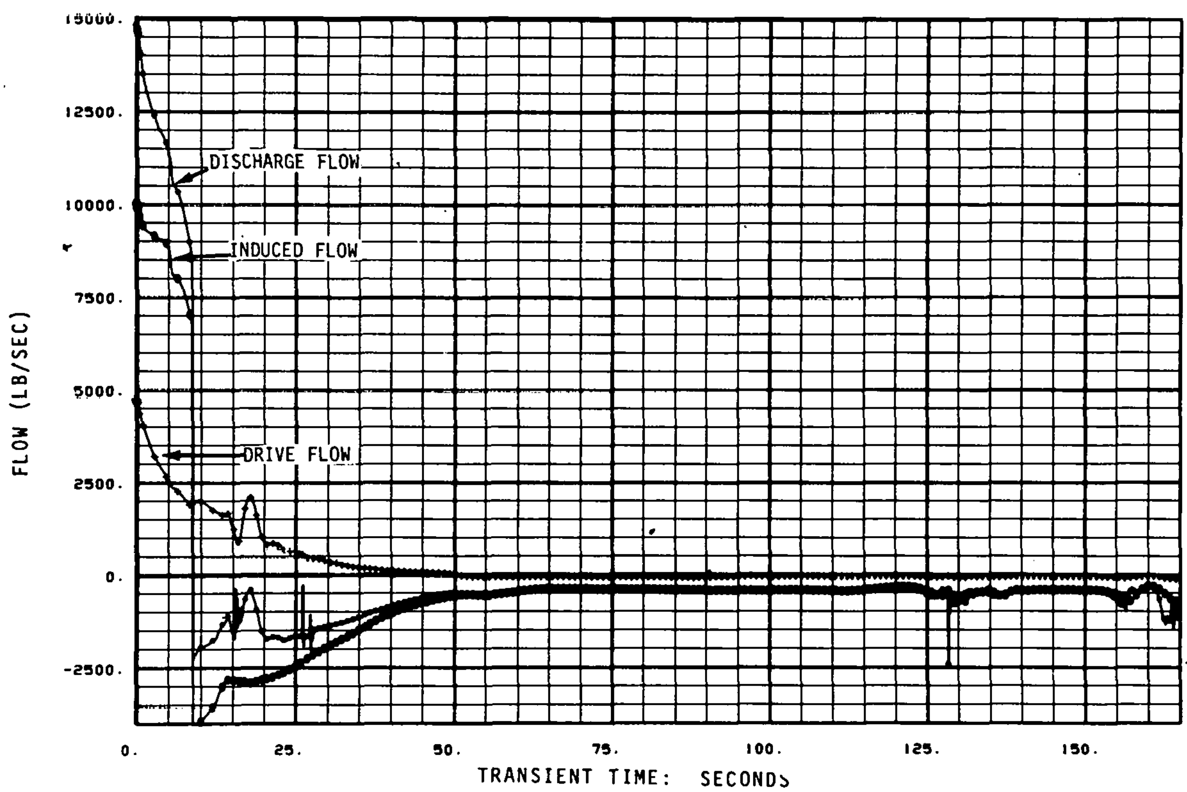

Fig. D-5 Intact loop jet pump flow - General Electric Plant (200% break).

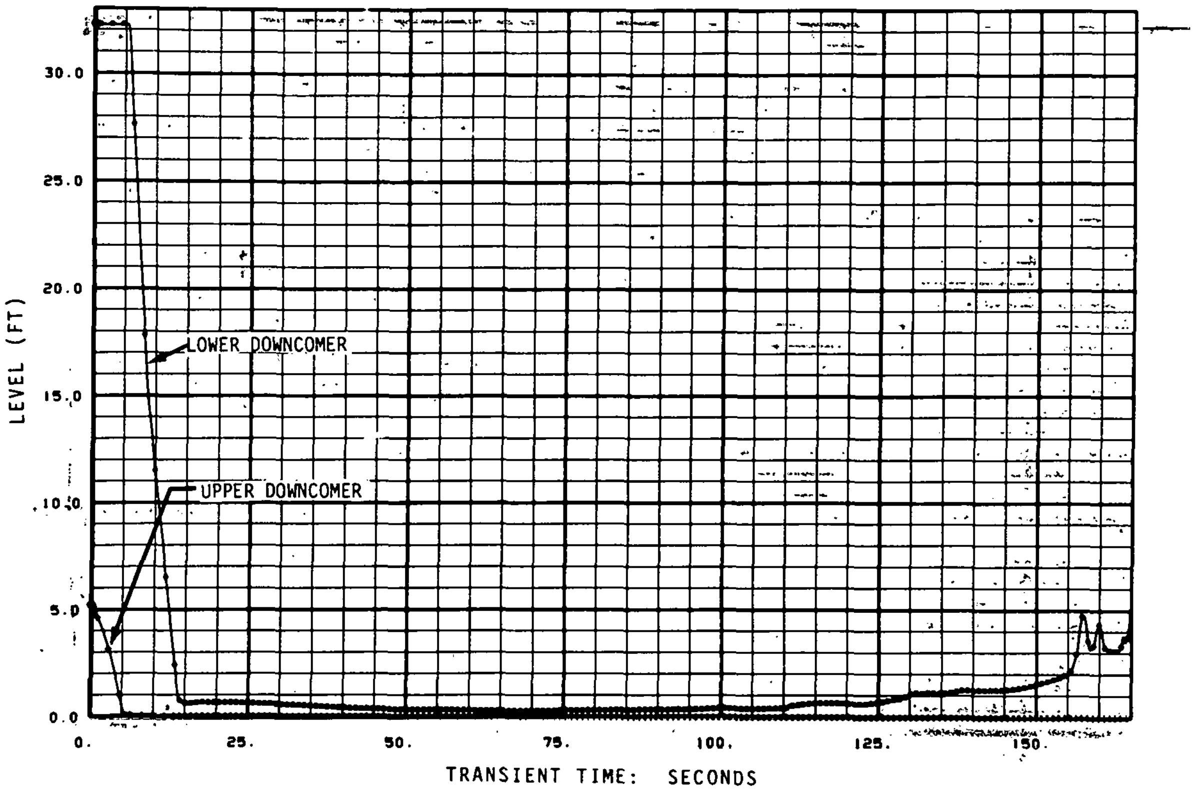

Fig. D-6 Downcomer mixture level - General Electric Plant (200% break).

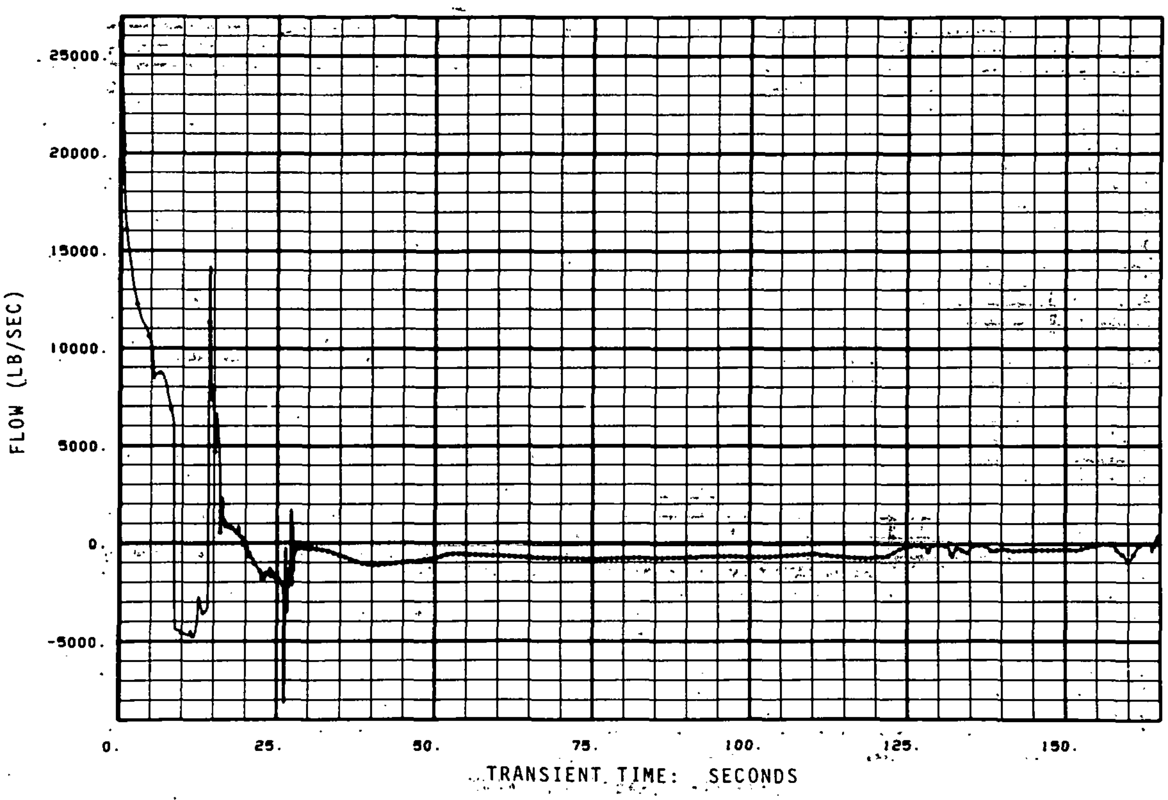

Fig. D-7 Core inlet flow - General Electric Plant (200% break).

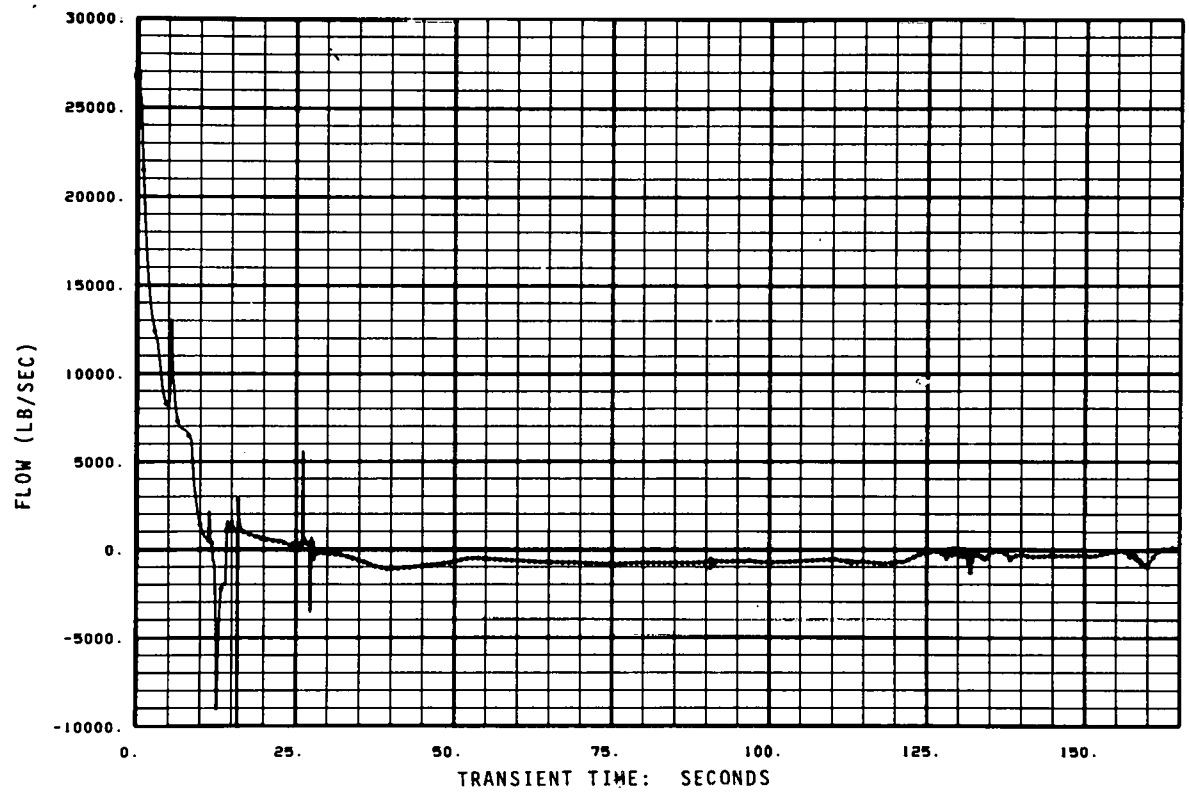

Fig. D-8 Core outlet flow - General Electric Plant (200% break).

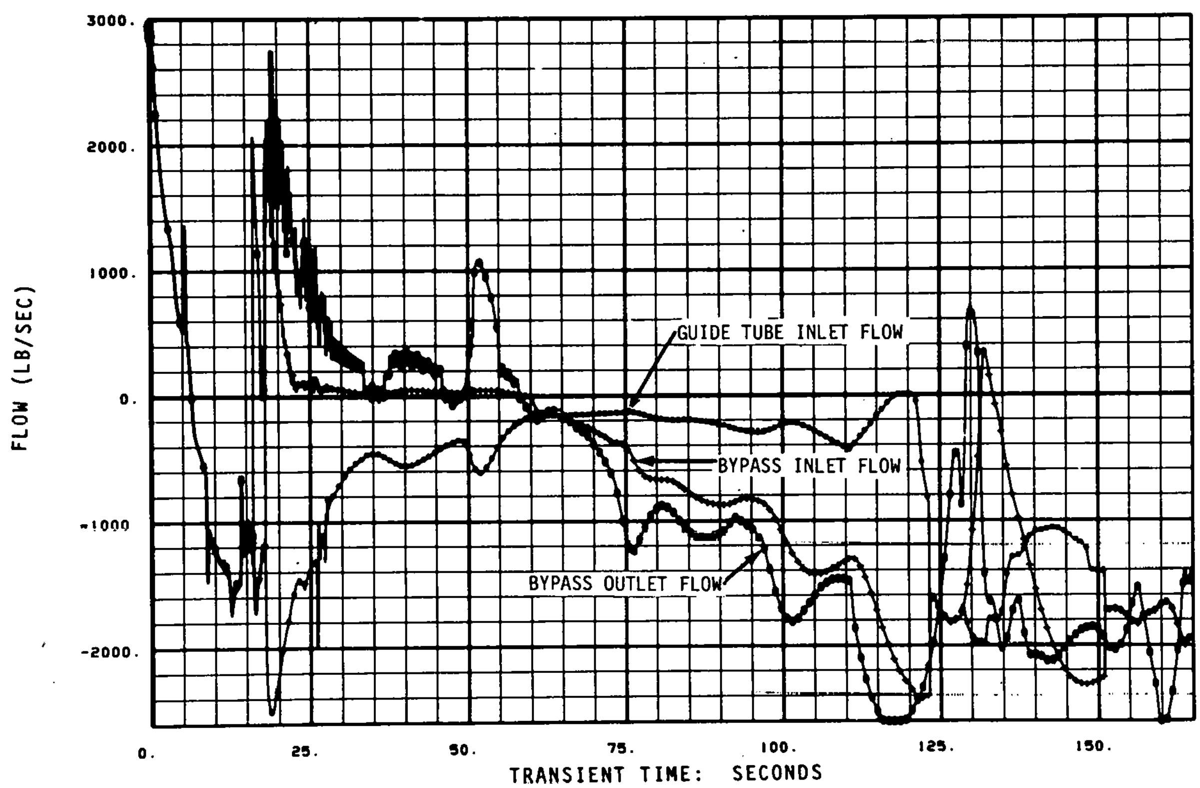

Fig. D-9 Bypass and guide tube flow - General Electric Plant (200% break).

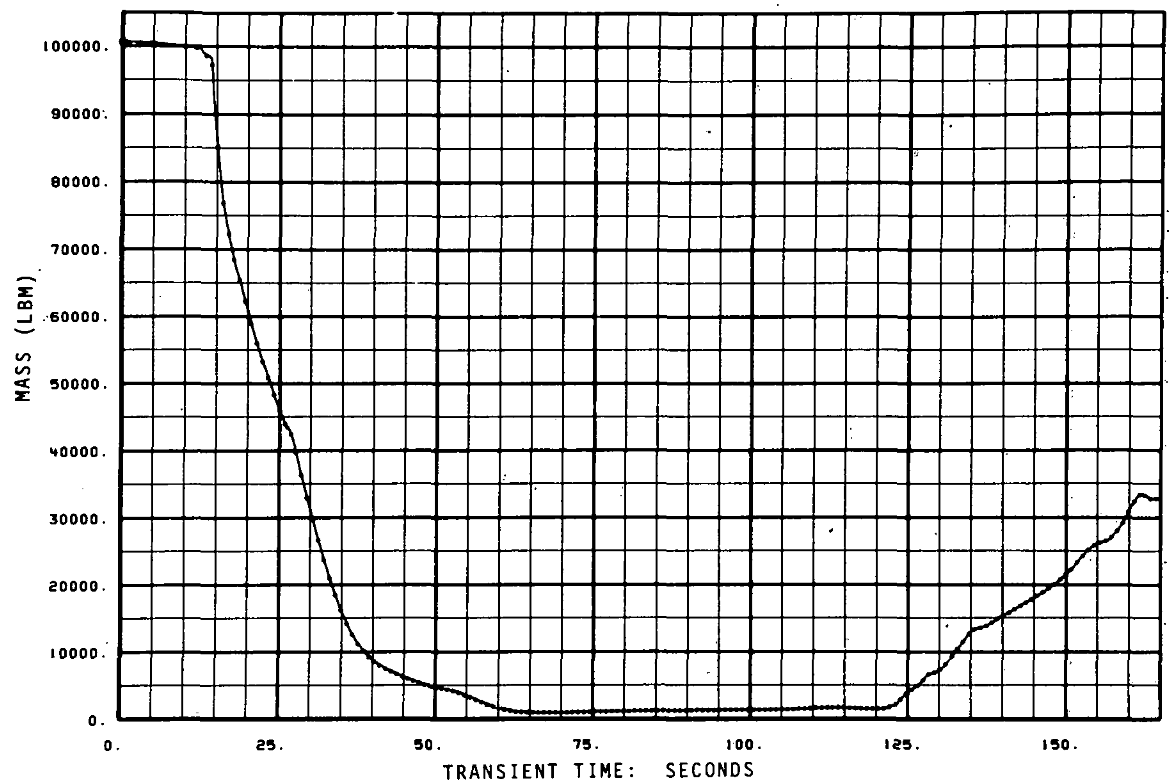

Fig. D-10 Liquid mass in lower plenum - General Electric Plant (200% break).

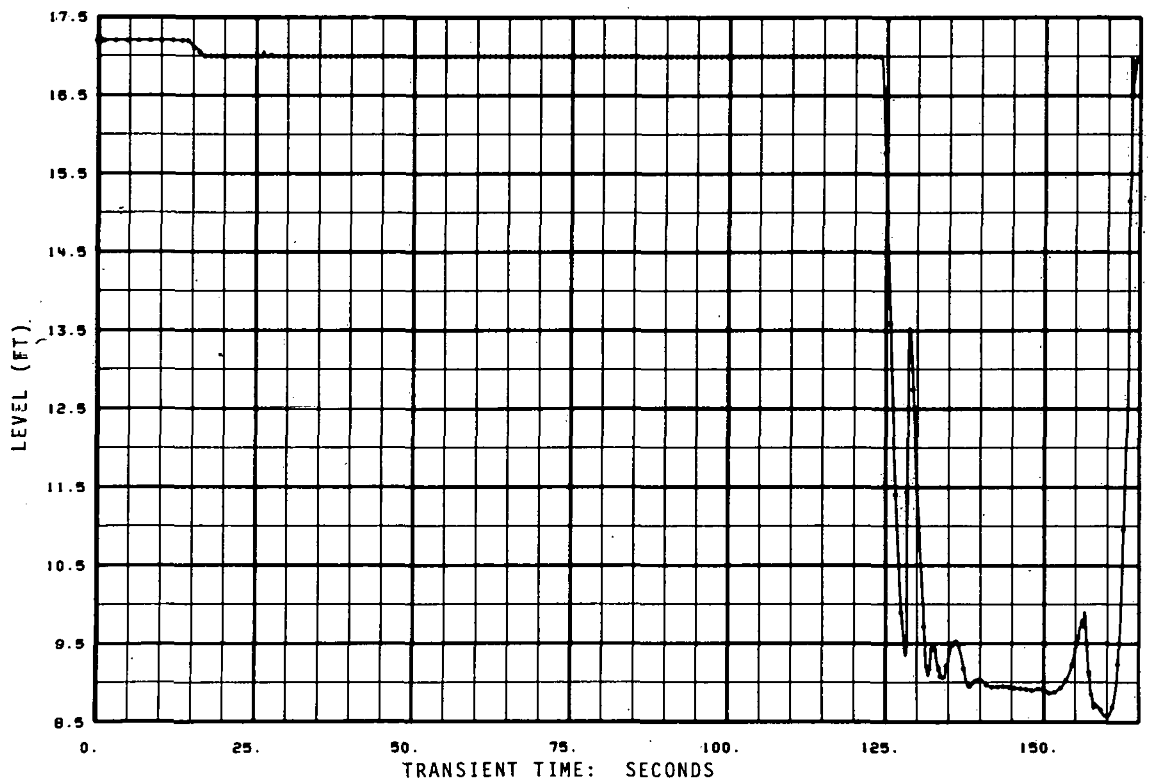

Fig. D-11 Lower plenum mixture level - General Electric Plant (200% break).

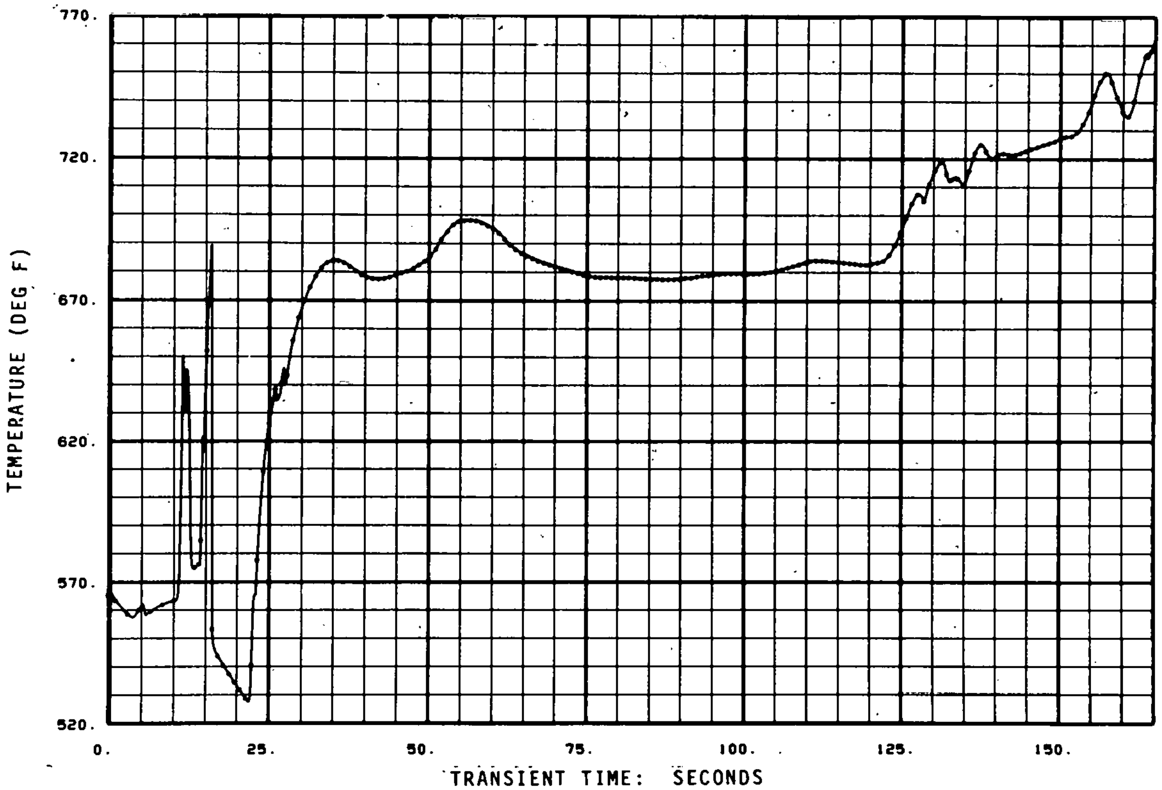

Fig. D-12 Cladding surface temperature - General Electric Plant (200% break).

6. INPUT LISTING

An input listing for this run is given in Table D-III which follows.

TABLE D-III

INPUT LISTING

```
=BWR BEST ESTIMATE 200% BRK
*234567890123456789012345678901234567890123456789012345678901234567890
*10001 LDM EDI NTS TRP VOL BUB TDV JUN PMP CKV NLK FLL SLB GOM MAT COR HTX EMF
010001 -2   9   5   10  23  4   0   33  2   4   1   3   25  10  5   5   0   0
010001 -2   9   5   10  23  4   0   33  2   4   2   3   25  10  5   5   0   0
010001 -2   9   5   10  23  4   0   33  2   4   2   4   25  10  5   5   0   0
010002     3388.      1.0
*20000 EDIT VARIABLE CARD
020000 KR 21 KR 22 KR 23 KR 24 KR 25 TD 27 TD 28 JH 14 JH 15
020000 JW 27 JW 28 JW 29 JW 19 JW 22 ML 2 ML 4 ML 11 JW 32
020000 NQ 0 TR 0 JW 29 MB 0 JW 5 JW 9 JW 22 JW 1 ML 2
020000 AP 1 AP 2 JW 29 JW 19 JW 5 JW 9 JW 22 JW 1 MI 2
*3XXX0 TIME STEP
*3XXX0 NMIN NMAJ NDMP NCHK DELTMAX DELTMIN  TLAST
030010  1   100   5     0    .001   .00001   .50
030010  1   100   5     0    .001   .00001   .2 1200.
030010  1   100   5     0    .001   .00001   .2 2000.
030010  1   100   5     0    .001   .00001   .2 3200.
030020  5   8     3     0    .01    .000001  1.
030030  20  10    2     0    .01    .000001  60.
030040  20  25    1     0    .01    .000001  130.
030050 20 25  1  0  .010       .00001     2000.
030003 50
*4XXX0 TRIP CARDS
*400X0 TRP SIG IX1 IX2 SETPT, DELAY
040010  1  1  0  0  150.       0.
040010  1  1  0  0  300.       0.
040010  1  1  0  0 100.0       0.
040010  1  1  0  0  10.0       0.
040010  1  1  0  0   0.0       0.
040010  1  1  0  0 200.0       0.
040020  1 -4  3  0  40.        0.
040030  2  1  0  0  0.         0.
040040  3  1  0  0  .001       0.
040050  4  1  0  0  .002       0.
040060  5  1  0  0  1.0        0.
040070  6  1  0  0 1.E6     0.
040080  7 -5  4  0  21.5    26.5
040090  8  1  0  0 .001     1.E6
040100   9  -5  4  0  21.38  120.
*5XXXX VOLUME DATA CARDS
*234567890123456789012345678901234567890123456789012345678901234567890
*5XXXY B R PRES    TEMP   HORX    VOL     HT    MIX   TP FLOWA DIA    ELEV   IAMBLO
050011 2 0 1039.    -1. .092104 1548.   22.25 22.25 0 224.   0.     29.92    0
050011 2 0 1039.    -1. .092022 1548.   22.25 22.25 0 224.   0.     29.92    0
050011 2 0 1039.    -1. .091742 1548.   22.25 22.25 0 224.   0.     29.92    0
050011 2 0 1039.    -1. .091627 1548.   22.25 22.25 0 224.   0.     29.92    0
050011 2 0 1039.    -1. .091632 1548.   22.25 22.25 0 224.   0.     29.92    0
050021 2 0 1028.28 -1. .002448 6703.   12.25 5.27  0 497.   0.     41.75    0
050031 1 0 1024.98 -1. .999    3777.   21.25 21.25 0 497.   0.     51.25    0
050041 3 0 1031.93 532.3  -1.  3177.   32.23 32.23 0 165.   0.     10.02    0
050051 0 0 1024.   532.3  -1.  125.25 26.    26.   0 3.67   0.    -14.      0
050061 0 0 1126.17 533.25 -1.  63.     3.    3.    0 4.0    0.    -14.      0
050071 0 0 1226.17 533.25 -1.  366.    40.53 40.53 0 3.2    0.    -14.      0
050081 0 0 1024.   532.30 -1.  136.    26.   26.   0 3.67   0.    -14.      0
050091 0 0 1126.17 533.25 -1.  63.     3.    3.    0 4.0    0.    -14.      0
050101 0 0 1226.17 533.25 -1.  366.    40.53 40.53 0 3.2    0.    -14.      0
050111 2 0 1062.16 532.53 -1.  2131.5 17.20 17.20 0 120.   0.     0.       23
050121 2 0 1054.67 549.337 -1. 223.    2.85  2.85  0 81.091 .0473 17.82    13
050131 2 0 1052.97 -1. .037418 223.    2.75  2.75  0 81.091 .0473 20.67    14
```

TABLE D-III (contd.)

```
050131 2 0 1052.97 -1. .037287 223.    2.75  2.75  0 81.091 .0473 20.67     14
050131 2 0 1052.97 -1. .037157 223.    2.75  2.75  0 81.091 .0473 20.67     14
050141 2 0 1051.52 -1. .050597 81.09   1.    1.    0 81.091 .0473 23.42     15
050141 2 0 1051.52 -1. .050579 81.09   1.    1.    0 81.091 .0473 23.42     15
050141 2 0 1051.52 -1. .050567 81.09   1.    1.    0 81.091 .0473 23.42     15
050151 2 0 1049.87 -1. .092060 223.    2.75  2.75  0 81.091 .0473 24.42     16
050151 2 0 1049.87 -1. .091994 223.    2.75  2.75  0 81.091 .0473 24.42     16
050161 2 0 1047.65 -1. .139989 223.    2.75  2.75  0 81.091 .0473 27.17     1
050161 2 0 1047.65 -1. .139840 223.    2.75  2.75  0 81.091 .0473 27.17     1
050161 2 0 1047.65 -1. .139875 223.    2.75  2.75  0 81.091 .0473 27.17     1
050171 2 0 1054.28 532.53 -1.  942.47 18.12 18.12 0 52.301 0.    0.        18
050181 2 0 1045.86 532.67 -1.  534.53 12.35 12.35 0 43.635 0.    17.92     1
050191 0 0 1059.2  532.53 -1.  115.   15.7  15.7  0 19.69  0.    10.02     0
050201 0 0 1059.2  532.53 -1.  115.   15.7  15.7  0 19.69  0.    10.02     0
050211 0 0 1030.8  532.30 -1.  10.75  2.2   2.2   0 3.67   0.    10.       0
050221 4 0 14.7    100.   0.6  1.98E6 250.  0.0   1 1000.  100.  -10.      0
050221 4 0 14.7    100.   0.6  3.43E6 250.  0.0   1 1000.  100.  -10.      0
050231 2 0 1055.48 532.53 -1.  20.5   1.25  1.25  0 81.09  0.    16.77     12
*60000 LIQUID LEVEL CALCULATION CARD
060000 11 23 12 13 14 15 16 17 18 19 20 1
*60001 SLVAMX  SLVELZ SLVPWR SLVSL1 SLVDPF
060001  0.0     0.0    0.0    0.0    0.0
*60002 WALLIS SLIP CORRELATION CARD
*60002 WALSC1 WALSC2
*6XXX1 BUBBLE DATA CARDS
*6XX11 ALPH VBUB
060011 1.0  0.0
060021 0.0  3.0
060031 0.8  3.0
060041  0.  1.E6
*60001 SLIP VELOCITY CARD
*8XXXY JUNCTION DATA CARDS
*8???? IN  OT P V FLOW     AJUN   ZJUN  IN  FJUF  FJUR V C I EQ DM CC C  E COS AJ
*234567890123456789012345678901234567890123456789012345678901234567890123456789O
080011  1  2  0 0 29583.   191.1  52.17 0.  0.    0.   1 5 3 0 0.0 0. 0  0 1.0  0
080021  2  3  0 0 4074.3135 312.  52.25 0.  0.    0.   1 5 3 0 0.0 0. 0  0 0.0  0
080031  2  4  0 0 25444.   165.   42.0  0.  0.    0.   1 5 3 0 0.0 0. 0  0 0.0  0
080041  4 20  0 0 10041.5  3.112  25.0  30. .2084 1.17 2 5 0 2 0.0 0. 0  0 0.0  0
080051  4 21  0 0 4750.    3.67   11.0  0.  0.    0.   1 5 3 0 0.0 0. 0  0 0.0  0
080061  5  6 -1 0 4750.    3.67   -13.  0.  0.    0.   0 5 3 0 0.  0. 0  0 0.0  0
080071  6  7  1 0 4750.    3.2    -13.  0.  0.    0.   0 5 3 0 0.  0. 0  0 0.0  0
080081  7 20  0 0 4750.    0.538  25.   47. .2373 6.8  0 5 0 2 0.  0. 0  0 0.0  0
080091  4  8  0 0 4750.    3.67   11.   0.  0.    0.   1 5 3 0 0.0 0. 0  0 0.0  0
080101  8  9 -2 0 4750.    3.67   -13.  0.  0.    0.   0 5 3 0 0.  0. 0  0 0.0  0
080111  9 10  2 0 4750.    3.2    -13.  0.  0.    0.   0 5 3 0 0.  0. 0  0 0.0  0
080121 10 19  0 0 4750.    0.538  25.   47. .2373 6.8  0 5 0 2 0.  0. 0  0 0.0  0
080131  4 19  0 0 10041.5  3.112  25.   30. .2084 1.17 2 5 0 2 0.0 0. 0  0 0.0  0
080141 23 12  0 0 26639.   81.09  17.92 0.  0.    0.   0 5 3 0 0.  0. 0  0 1.0  0
080151 12 13  0 0 26639.   81.09  20.67 0.  0.    0.   0 5 3 0 0.  0. 0  0 1.0  0
080161 13 14  0 0 26639.   81.09  23.42 0.  0.    0.   0 5 3 0 0.  0. 0  0 1.0  0
080171 14 15  0 0 26639.   81.09  24.42 0.  0.    0.   0 5 3 0 0.  0. 0  0 1.0  0
080181 15 16  0 0 26639.   81.09  27.17 0.  0.    0.   0 5 3 0 0.  0. 0  0 1.0  0
080191 16  1  0 0 26639.   37.13  29.92 0.  0.    0.   0 5 3 0 0.  0. 0  0 1.0  0
080201 11 17  0 0 2944.    2.246  17.0  0.  0.    0.   1 5 3 0 1.0 0. 0  0 0.0  0
080211 17 18  0 0 2944.    26.20  18.02 0.  0.    0.   0 5 3 0 0.  0. 0  0 0.0  0
080221 18  1  0 0 2944.    43.635 30.02 0.  0.    0.   0 5 3 0 0.  0. 0  0 1.0  0
080231 19 11  0 0 14791.5  19.69  10.12 0.  0.    0.   1 5 3 0 0.0 0. 0  0 0.0  0
080241 20 11  0 0 14791.5  19.69  10.12 0.  0.    0.   1 5 3 0 0.0 0. 0  0 0.0  0
080251 21  5 0 1 4750.     3.67   11.0  0.  0.    0.   0 5 3 0 0. 0.  0  0 0.0  0
080261  5  7 0 3 0.        3.20   -13.  0.  0.    0.   0 5 3 0 0. 0.  0  0 0.0  0
```

TABLE D-III (contd.)

```
080261   3 22  0 3 0.         .484     55.0  1.   1.      1.    0 5 0 0 0. 0.  0   0 0.0   0
080271 21 22  0 4 0.         3.67     11.   0.   1.0     0.5   0 5 2 0 0. .9 0    0 0.0   0
080281 22   5 0 4 0.         3.67     11.   0.   0.5     1.0   0 5 2 0 0. .9 0    0 0.0   0
080291 11 23  0 0 26639.     20.32    17.0  0.   0.      0.    1 5 3 0 0. 0.  0   0 1.0   0
080301  0   4 1 0 4074.3135 4.712 40.   0.   0.      0.    0 5 3 0 0. 0.  0   0 0.0   0
080311  0   3 2 2 -4074.3135 14.75 72.  0.   0.      0.    0 5 3 0 0. 0.  0   0 0.0   0
080321  0   1 3 0 0.         1.0      30.   0.   0.      0.    0 5 3 0 0. 0.  0   0 0.0   0
080331  3   0 1 0 0.         .484     55.   1.   1.      1.    0 5 0 0 0. 0.  0   0 0.0   0
080331  0 10 4 0 0.          1.00     25.   1.   0.      0.    0 5 0 0 0. 0.  0   0 0.0   0
*234567890123456789012345678901234567890123456789012345678901234567890123456789O
*90XXY PUMP DESCRIPTION DATA CARDS
*900XY IP TAP RI TP T REV   RATIO FLOW    HEAD   TORQ     INER    DEN     FRIZ TOR
090011   3   4   0   1 0 1668.  1.0  44943.  710.3  22200.  20000.  47.17     0.  0
090021   3   4   0   1 0 1668.  1.0  44943.  710.3  22200.  20000.  47.17     0.  0
*910YY PUMP HEAD MULTIPLIER CARDS
091001 -11 0.  0.   .1   0.   .15  .05  .24  .8   .3   .96  .4   .98  .6   .97
091002      .8  .9   .9   .8   .96  .5   1.0  0.
*920YY PUMP TORQUE MULTIPLIER CARDS
092001 -2 0. 0. 1. 0.
*95XX1 PUMP STOP DATA CARDS
095011  0.   0.  0.
095021  0.   0.  0.
*100000 PUMP CURVE INPUT INDICATOR DATA CARD
100000  0  0 16  0
*10XYYZ PUMP HEAD AND TORQUE DATA CARDS
103011   1  1   5 0.0    1.31   0.25   1.25   0.5   1.20   0.75   1.12   1.0   1.0
103021   1  2   5 0.0    -0.9   .25    -.5    .5    -.05   .75    .4     1.0   1.0
103031   1  3   5 -1.0   2.1    -.75   1.775  -0.5  1.54   -.25   1.4    0.    1.31
103041   1  4   5 -1.0   2.1    -.75   1.50   -0.5  1.13   -.25   .92    0.    .825
103051   1  5   5 0.     .4     .25    .53    .5    .625   .75    .80    1.0   1.0
103061   1  6   5 0.     .825   .25    .79    .5    .815   .75    .90    1.0   1.0
103071   1  7   5 -1.0   -1.8   -.75   -1.    -.5   -.4    -.25   .1     0.    .4
103081   1  8   5 -1.0   -1.8   -.75   -1.72  -.5   -1.54  -.25   -1.27  0.    -.9
103091   2  1   5 0.     .55    .25    .63    .5    .71    .75    .86    1.0   1.0
103101   2  2   5 0.     -.55   .2     -.175  .4    .0     .75    .58    1.0   1.0
103111   2  3   5 -1.0   1.77   -.75   1.23   -.5   .83    -.25   .62    0.    .55
103121   2  4   5 -1.0   1.77   -.75   1.52   -.5   1.32   -.25   1.13   0.    1.0
103131   2  5   5 0.     -.8    0.2    -.375  0.5   -.1    .75    .15    1.0   .43
103141   2  6   5 0.     1.0    .25    .88    .5    .75    .75    .61    1.0   .43
103151   2  7   5 -1.    -3.45  -.75   -2.75  -.50  -2.0   -.25   -1.375 0.    -.8
103161   2  8   5 -1.    -3.45  -.75   -2.62  -.50  -1.583 -.25   -1.15  0.    -.55
*11XXX0 VALVE DATA CARDS
110010  4   0.    0  0.   0.   0. 0.
110020  5   2     0  0.   0.   0. 0.
110030 -9   0.    0  0.   0.   0. 0.
110040 -3   0.    0  0.   0.   0. 0.
*12XXYY LEAK TABLE DATA CARDS
120101   -2   9  30.   0  1.  1000.  1.
120201 6 5 14.7 0. 1. 2.25 1. 2.5 .667 2.75 .333  3. 0. 10000. 0.
*13XXYY FILL TABLE DATA CARDS
*3XX00 TRIP TYPE POINTS ICALC UNITS      PORT      HORX
130100  2     1      4     1     LBS/SEC  1050.     401.11324
130101 0. 864.6676 1. 864.6676 4.0 0. 10000. 0.
130200  2     2      4     3     LBS/SEC  548.      .999
130201 0. 0. 940. 0. 1025. -276.2246 3000. -276.2246
130300  7     2      11    3     GAL/MIN  292.      0.0
130300  7     2      11    3     GAL/MIN  212.      0.0
130301 0. 15150. 59. 14200. 137. 12500. 178. 11550. 237. 9470. 268. 7576.
130302 280. 5682. 287. 3788. 297. 1894. 304. 0. 10000. 0.
130400  7   2 9 3  GAL/MIN  212.  0.
```

TABLE D-III (contd.)

```
130401    17.6  4355.  23.7  4309.  26.1  4291.  41.2  4175.  42.4  4166.
130402 98.  3708.  102.  3672.  310.  0.  3000.  0.
*14000 KINETICS CONSTANTS
*14000 PWR MUL  BIL  REC  UDUF
140000  3    0  116.  0.  1.
*141001 SCRAM TABLE DATA CARDS
141001 -8  4 0. 0. 0.9 0. 1.075 -.4 1.6 -4. 2.7 -10. 5.7 -28.1 8. -30. 10. -30.
*142001 DENSITY REACTIVITY DATA CARDS
142001 -10  .2  -11.55  .3  -8.830  .4  -6.690  .5  -5.01  .6  -3.64  .7  -2.51
142002 .8  -1.55  .9  -0.73  1.  0.  1.1  0.
*143001 DOPPLER TABLE DATA CARDS
143001 -6  0. 1.85  1000. 0. 2000. -1.71 3000. -3. 4000. -4.28 5000. -5.43
*140XX0 REACTIVITY COEFFICIENT DATA CARDS
140010 .148289 .148289 0. 0.
140020 .341782 .341782 0. 0.
140030 .019858 .019858 0. 0.
140040 .341782 .341782 0. 0.
140050 .148289 .148289 0. 0.
*15XXX HEAT SLAB DATA
*15XX1 VL VR  G S X H H ASUL  ASUR      VOL    HDL HDR HEDL HEDR CHL    CHR
*15XX2 ZBOT ZTOP
*234567890123456789012345678901234567890123456789012345678901234567890123456789O
150011  0  3  2 0 0 0 0 0.        687.      422.     0. 0.    0. 0.    0.     0.
150012  0.    0.
150021  0  2  2 0 0 0 0 0.        1368.     698.     0. 0.    0. 0.    0.     0.
150022  0.    0.
150031  0  4  2 0 0 0 0 0.        1916.     977.     0. 0.    0. 0.    0.     0.
150032  0.    0.
150041  0 11  2 0 0 0 0 0         687.      385.     0. 0.    0. 0.    0.     0.
150042  0.    0.
150051  4 18  3 0 0 0 0 1355.     1355.     239.     0. 0.    0. 0.    0.     0.
150052  0.    0.
150061  1  2  4 0 0 0 0 2288.     2288.     286.     0. 0.    0. 0.    0.     0.
150062  0.    0.
150062  0.    10.42
150071 11 23  5 0 0 0 0 197.      197.      65.      0. 0.    0. 0.    0.     0.
150072  0.    0.
150081 16  1  5 0 0 0 0 94.       94.       31.      0. 0.    0. 0.    0.     0.
150082  0.    0.
150091 11 17  6 0 0 0 0 6884.     6884.     95.      0. 0.    0. 0.    0.     0.
150092  0.    17.1
150101  0 11  7 0 0 0 0 0.        736.      46.      0. 0.    0. 0.    0.     0.
150102  0.    0.
150111  2  3  8 0 0 0 0 4380.     4380.     184.     0. 0.    0. 0.    0.     0.
150112  0.    0.
150121  0  5  9 0 0 0 0 0         450.      36.      0. 0.    0. 0.    0.     0.
150122  0.    0.
150131  0  8  9 0 0 0 0 0.        450.      36.      0. 0.    0. 0.    0.     0.
150132  0.    0.
150141  0  7  9 0 0 0 0 0.        838.      67.      0. 0.    0. 0.    0.     0.
150142  0.    0.
150151  0 10  9 0 0 0 0 0.        838.      67.      0. 0.    0. 0.    0.     0.
150152  0.    0.
150161 12 18 10 0 0 0 0 1096.8 1096.8     25.67    0. 0.    0. 0.    1.375  1.375
150162  0.    2.74
150171 13 18 10 1 0 0 0 1096.8 1096.8     25.67    0. 0.    0. 0.    4.125  4.125
150172  2.76 5.49
150181 14 18 10 1 0 0 0 398.84 398.84     9.334    0. 0.    0. 0.    6.0    6.0
150182  5.51 6.49
150191 15 18 10 1 0 0 0 1096.8 1096.8     25.67    0. 0.    0. 0.    7.875  7.875
```

TABLE D-III (contd.)

```
150192  6.51 9.24
150201 16 18 10 1 0 0 0 1096.8 1096.8    25.67    0. 0.    0. 0.     10.625 10.625
150202  9.26 11.99
150211  0 12  1 0 0 0 0 0.      15175.52 178.039 0. .048 0. .0588 1.375  1.375
150212  0.    0.
150221  0 13  1 1 0 0 0 0.      15175.52 178.039 0. .048 0. .0588 4.125  4.125
150222  0.    0.
150231  0 14  1 1 0 0 0 0.      5518.372 64.741  0. .048 0. .0588 6.0    6.0
150232  0.    0.
150241  0 15  1 1 0 0 0 0.      15175.52 178.039 0. .048 0. .0588 7.875  7.875
150242  0.    0.
150251  0 16  1 1 0 0 0 0.      15175.52 178.039 0. .048 0. .0588 10.625 10.625
150252  0.    0.
*2345678901234567890123456789012345678901234567890123456789012345678901234567890
*16000 CORE SECTION DATA
*16000 SLB   NODE     CLAD     QFRAC
160010 21   7 9 15    0.     .17721
160020 22   7 9 15    0.     .26902
160030 23   7 9 15    0.     .10754
160040 24   7 9 15    0.     .26902
160050 25   7 9 15    0.     .17721
*17XXYY SLAB GEOMETRY DATA CARDS
*7XXYY IG NR MI NPX XO       WIDTH    POW
170101  2  3  1  6 0.0      .020071 1.0
170102  1     2  2          .000721 0.
170103  0     3  8          .00267  0.
170201  1  2  4  3 0.0      .4      0.
170202  0     5  1          .0208   0.
170301  1  1  5  1 0.       .17     0.
170401  1  1  5  1 0.       .125    0.
170501  1  1  5  1 0.       .33     0.
170601  1  1  5  1 0.       .0138   0.
170701  1  1  5  1 0.       .0625   0.
170801  1  1  5  1 0.       .042    0.
170901  1  1  5  1 0.       .08     0.
171001  1  1  5  1 0.       .0234   0.
*18XXYY THERMAL CONDUCTIVITY DATA CARDS
180100 -20  500.   3.341  650.   2.971  800.   2.677  950.   2.439  1100.  2.242
180101      1250.  2.078  1400.  1.940  1550.  1.823  1700.  1.724  1850.  1.639
180102      2000.  1.568  2150.  1.507  2300.  1.457  2450.  1.415  2600.  1.382
180103      3100.  1.323  3600.  1.333  4100.  1.406  4600.  1.538  5100.  1.730
180200     2           32.        .41562      5400.       .41562
180300    18           32.        7.812       212.        7.992       392.       8.208
180301                 572.       8.784       752.        9.540       932.       10.404
180302                 1112.      11.268      1292.       12.492      1472.      13.176
180303                 1652.      13.968      1832.       14.796      2012.      16.128
180304                 2192.      17.784      2372.       19.656      2552.      21.780
180305                 2732.      24.048      3092.       28.908      3360.      33.120
180401 -5  32. 30. 212. 29.5 392. 28.3 572. 26.6 752. 24.7
180501 -2  200. 8.33 1200. 12.92
*19XXYY VOLUMETRIC HEAT CAPACITY DATA CARDS
190100    16                    32. 34.45           122. 38.35            212. 40.95
190101                         392. 43.55           752. 46.8            2012. 51.35
190102                        2732. 52.65     3092. 56.55  3452. 63.05
190103                        3812. 72.8          4352. 89.7             4532. 94.25
190104                        4712. 98.15         4892. 100.1            5144. 101.4
190105                        8000. 101.4
190200     2          32.        .000075    5400.      .000075
190300    5   0.0   28.392
190301    1480.3   34.476   1675.0   85.176
```

TABLE D-III (contd.)

```
190302    1787.5   34.476   3500.0   34.476
190401 -7 130. 56.9 350. 60.8 450. 62.3 530. 65.2 620. 67.2 710. 70.2 800. 77.5
190501 -10 68. 52.8 200. 56.7 400. 61.6 600. 64. 800. 66. 1000. .67
190502      1200. 68.4 1400. 71.8 1600. 75.8 1800. 80.6
*20XXYY LINEAR EXPANSION COEFFICIENT DATA CARDS
200101 -2 0. 3.718E-6  5000.  1.2653E-5
200201 -2 0. 0. 5000. 0.
200301  -4  0.  3.094E-6  1652.  4.706E-6  1653.  5.389E-6  5000. 5.389E-6
200401 -2  0.  0. 5000. 0.
200501 -2  0.  0. 5000. 0.
.  END TERMINATOR CARD
```

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APPENDIX E

BWR SMALL RECIRCULATION LINE BREAK - GENERAL ELECTRIC PLANT

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APPENDIX E

BWR SMALL RECIRCULATION LINE BREAK - GENERAL ELECTRIC PLANT

1. INTRODUCTION

The Hope Creek General Electric BWR plant was modeled using RELAP4/MOD5 to represent a 6% break in the pump suction side of one of the recirculation lines. The system model and assumptions used, the calculated results, and the conclusions drawn from this problem run are presented in the following sections. Some interpretation of results is based on digital data output which was too voluminous to be included in this appendix. The model presented was used for program checkout and should not be considered a comprehensive study of the LOCA response of the actual plant.

2. SYSTEM MODEL AND ASSUMPTIONS

The RELAP4/MOD5 model describing the BWR system is shown in Figure E-1. It consisted of 16 volumes, 25 junctions, and 17 heat slabs. The volumes and fill junctions shown in Figure E-1 are identified in Table E-I.

The system nodalization for the BWR small break analysis differed from that used for the 200% break (Appendix D) in the following respects. The 6 core volumes (5 heated and 1 unheated) and 10 core heat slabs used in the large break model were replaced by a single core volume and two core heat slabs. The two volumes representing the core bypass and the guide tubes in the large break case were combined into a single volume for the small break analysis. The two break volumes (V21 and 5) used

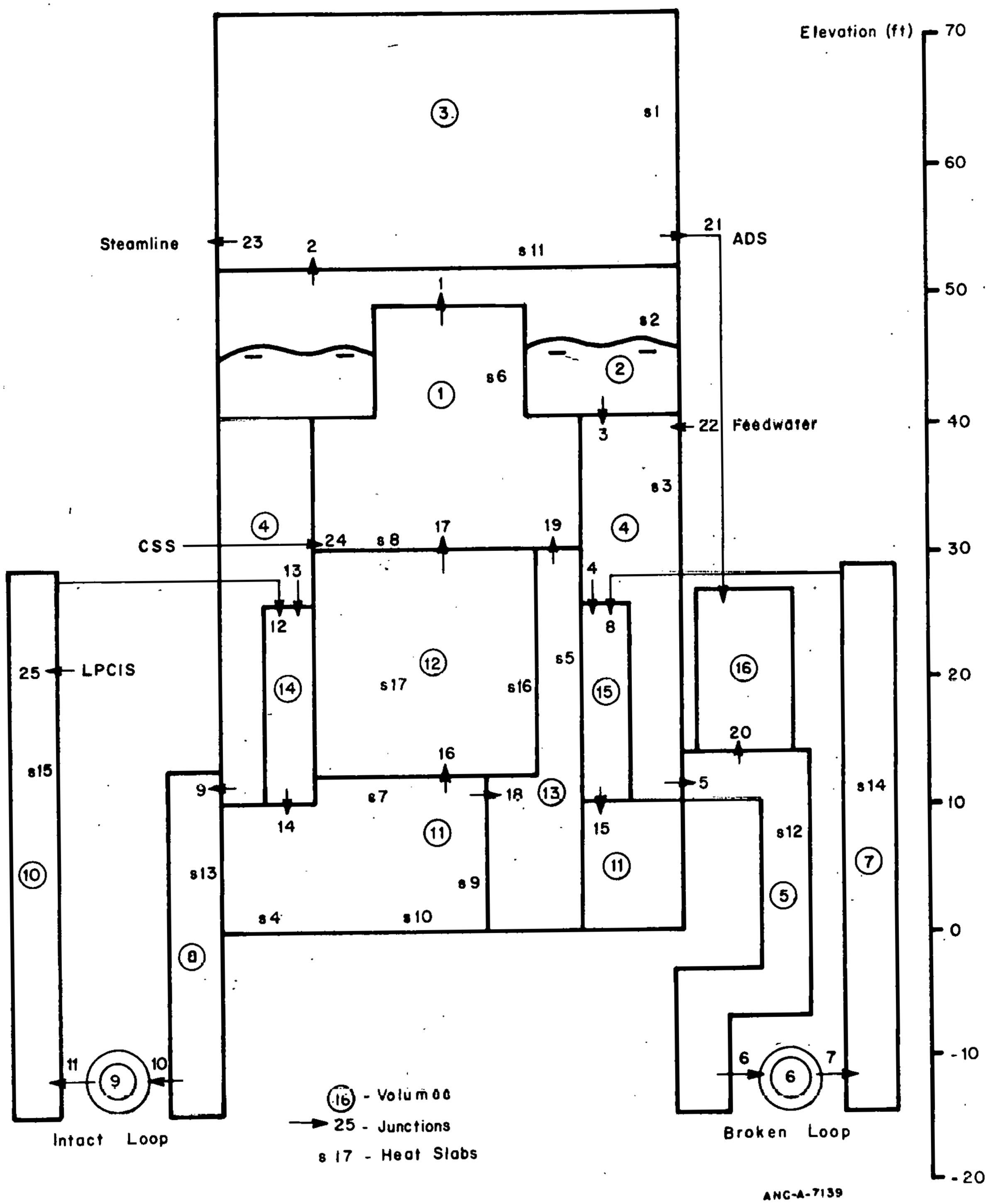

Fig. E-1 Nodalization for 6% break - General Electric Plant.

TABLE E-I

VOLUME AND FILL JUNCTION IDENTIFICATION FOR 6% BREAK - GE BWR PLANT

Volume No.	Description
1	Upper Plenum and Steam Separator
2	Upper Downcomer
3	Steam Dome
4	Lower Downcomer
5	Broken Loop Recirculation Line - Suction Side
6	Broken Loop Recirculation Pump
7	Broken Loop Recirculation Line - Discharge Side
8	Intact Loop Recirculation Line - Suction Side
9	Intact Loop Recirculation Pump
10	Intact Loop Recirculation Line - Discharge Side
11	Lower Plenum
12	Core
13	Bypass and Guide Tubes
14	Intact Loop Jet Pump
15	Broken Loop Jet Pump
16	Containment
Fill Junction No.	
22	Feedwater Inlet
23	Steam Outlet
24	Core Spray (212F Water)
25	Low Pressure Coolant Injection (100F Water)

in the large break analysis were combined into a single volume for the small break analysis. Thus, the small break model utilized seven fewer volumes, eight fewer heat slabs, and eight fewer junctions than the large break model.

The vertical slip model was used in 4 of the 25 junctions, as summarized in Table E-II. The junction smoothing option was not used. The RELAP4 phase separation (Bubble Rise) model with bubble velocity of 3 ft/sec was used in the core, the upper and lower plenums, the bypass, and the upper and lower downcomer. The foregoing used a gradient of 0.0 except the lower downcomer which used 0.8. The Henry-Fauske/HEM critical flow model with a multiplier of 1.0 was used at the break junction. The stagnation pressure subroutine was not used. Fill junctions were utilized for the feedwater, steamline, core spray, and low pressure injection system (LPIS) flows. The last was modeled for the intact recirculation loop only in order to conform to the functional design of the GE BWR Plant.

3. RESULTS

RELAP4/MOD5 ran smoothly (except during the initial part of core spray) and had a reasonable processing time. Core spray into the upper plenum resulted in a high degree of steam condensation with consequent pressure and flow oscillations. This led to a temporary reduction in allowable time step and increased running time. The transient time from break initiation until lower plenum refill was 450 sec. This required 27 min of CPU time on the CDC 7600 at the Brookhaven National Laboratory.

The major events which occurred during the transient are given in Table E-III. The output data traces are shown as Figures E-2 through E-11 in Section 5 of this appendix. A summary discussion of the transient follows.

TABLE E-II

JUNCTIONS MODELED WITH VERTICAL SLIP
FOR 6% BREAK - GE BWR PLANT

Junction No.	Location
1	Top of Upper Plenum
16	Bottom of Core
17	Top of Core
19	Top of Bypass

TABLE E-III

MAJOR EVENTS SUMMARY
FOR 6% BREAK - GE BWR PLANT

Time (sec)	Event
0.001 to 0.002	Break opened, pump power off, scram tripped, feedwater and steamline tripped
1 to 4	Feedwater stopped
3 to 4	Steamline closed
21	Upper downcomer emptied (Fig. E-6)
120	Lower downcomer emptied (Fig. E-6)
184	ADS started
288	System pressure dropped to 300 psia, CSS started and downcomer began to fill
428	Intact loop jet pump drive flow became positive and lower plenum began to refill (Fig. E-5)
448	Lower plenum was full
450	Problem run completed

The transient began when the break junction (J20) opened and power to the recirculation pumps was tripped. The trips for the scram, feedwater valve, and steamline were initiated shortly after the break occurred.

As shown in Figure E-2 the vessel pressure began to drop when the break opened. The steamline valve was fully closed at 4 sec, and the vessel pressure began to increase rapidly, since the core was still generating steam.

The break flow increased when the vessel pressure increased as shown in Figure E-3. The break flow began to decrease again at 14 sec because of local depressurization near the break and the subsequent decrease in fluid density.

The vessel pressure reached a maximum at 20 sec and then decreased to a somewhat stable value of 1,250 psia as shown in Figure E-2. The pressure remained steady until about 87 sec when the break volume (V5) saturated and the break junction began to flow a two-phase mixture. The break volume fluid quality returned to zero during this small depressurization, and a slightly lower steady pressure was established until the lower downcomer emptied at approximately 120 sec as shown in Figure E-6. The depressurzation then continued as the break flowed a high quality mixture after 120 sec.

The automatic depressurization system (ADS) valve opened at 184 sec and the rate of depressurization, shown in Figure E-2, increased rapidly. The pressure fell until it reached 45 psia which was about 5 psia below containment pressure.

The fluid in the break volume saturated twice between 40 and 100 sec. This caused the decreases in break mass flow evident in Figure E-3. The break flow decreased due to the the change in fluid quality exiting the break at 120 sec when the lower downcomer emptied. It remained fairly constant until the ADS opened (184 sec) which depressurized the steam-dome and pulled liquid from the lower plenum (Figure E-10), through the jet pumps (Figure E-4) and core, into the downcomer and into the break volume (V5). This resulted in a lower quality fluid and increased flow through the break junction as shown by Figure E-3. The break flow decreased again as the break junction quality increased and the pressure decreased.

The break flow increased slightly at 290 sec when the core spray system (CSS) and LPIS started injecting subcooled water into the system. The subcooled water entered the lower downcomer through the intact loop recirculation line, flowed into the break volume (V5), and out the break junction. The break flow reached zero when the pressure in the break volume reached containment pressure at approximately 420 sec.

The broken loop and intact loop jet pump flows are shown in Figures E-4 and E-5. The flows in both jet pumps decreased in the same manner when power to the recirculation pump was tripped at time zero. Both pumps behaved similarly until the LPIS water started flowing into the intact loop at about 290 sec. When the LPIS began to flow into the intact loop, the fluid was forced into the lower downcomer through the recirculation line-lower plenum junction (J9). This resulted from the negative flow through the jet pumps into the downcomer which restricted the drive flow. The downcomer mixture level was increasing during this time as is evident in Figure E-6. At approximately 428 sec, the LPIS began to flow through the drive nozzle of the intact loop jet pump, activating the pump and drawing downcomer fluid into the lower plenum. Since the downcomer was filled with water slightly cooler than the lower plenum, and since the LPIS fluid was at 100°F, the lower plenum began filling with subcooled water as shown by Figure E-10.

The broken loop did not receive separate LPIS water injection due to system design. The jet pump discharge and induced flow accordingly remained negative (or slightly positive) during the last 150 sec of the transient even though the drive flow was positive. The positive drive flow resulted from the lower pressure in the steam dome which drew fluid into the lower downcomer from the drive line.

The downcomer mixture levels are shown in Figure E-6. The upper downcomer emptied at 21 sec and the lower downcomer at 120 sec. The ADS valve opened at 184 sec and the mixture level in the lower downcomer temporarily increased because the reduced pressure in the steam dome allowed an increase in the negative flow through the jet pumps. The lower downcomer mixture level then increased since the break was small. Break flow caught up by 205 sec and the lower downcomer level started dropping. When the LPIS came on at 288 sec, the mixture level again increased and refilled the lower downcomer at 355 sec. The mixture level decreased at approximately 395 sec when the flow from the downcomer became small and the bubbles escaped. The mixture level increased again when the jet pumps took fluid from the downcomer and began refilling the lower plenum at 428 sec.

The core inlet and outlet flows are shown in Figures E-7 and E-8. The flow decay early in the transient followed the jet pump flow decay. The inlet flow oscillated around zero and then stabilized until the core spray came on at 288 sec. The core spray caused severe oscillations in the core inlet and outlet flows because the subcooled CSS water condensed steam in the upper plenum. The flow again stabilized after 335 sec and remained negative until the lower plenum was filled at 448 sec. The perturbations beginning at 428 sec are attributed to the restarting the intact loop jet pump recirculation with cold LPIS fluid. This caused water surge and then condensation in the lower plenum. The condensation resulted in a flow into the lower plenum through the core.

The flow through the guide tube and bypass is shown in Figure E-9. Shortly after the break occurred, the flow reversed, as did the core inlet and jet pump flows. The bypass and guide tubes provided a path for the fluid in the upper plenum to return to the lower plenum and the flow thus was negative during most of the transient. The flow became very oscillatory when the CSS came on at 288 sec because subcooled fluid mixed with saturated fluid in the upper plenum. After the flow became relatively stable, it was evident that the bypass was helping to fill the lower plenum with the CSS water.

Figure E-10 shows the liquid mass in the lower plenum. The mass did not decrease significantly until 184 sec when the ADS opened and water was drawn into the downcomer. The subcooled CSS water was injected into the upper plenum at 288 sec and condensed some of the steam. This caused a depressurization which again decreased the mass in the lower plenum. As has been discussed previously, the lower plenum filled when the intact loop jet pump began to flow in the normal direction at 428 sec.

Cladding surface temperature is shown in Figure E-11. The cladding temperature followed the fluid saturation temperature until about 250 sec. The heat transfer mode was nucleate boiling until about 230 sec, when it changed to forced convection vaporization. About 237 sec, the temperature again began to follow the saturation temperature until about 250 sec when the heat transfer mode changed to that of forced convection to superheated vapor. The heat transfer mode was primarily stable film boiling during the remainder of the transient although it also went into free convection and into forced convection to superheated vapor. The temperature decreased at 432 sec because of the increased negative core flow when the lower plenum started to refill.

4. CONCLUSIONS

The BWR small break problem was run without major difficulty and within the established time limit of one hour on the CDC 7600 computer. Calculations during the initial part of core spray required a reduction in maximum allowable time step. This was due to steam condensation and consequent pressure and flow oscillations in the upper plenum. The completion criteria listed in Volume III, Section 7.2 for the MOD5 checkout runs were satisfied.

5. OUTPUT DATA

The output data traces for the General Electric BWR 6% break problem run are shown as Figures E-2 through E-11 in this section.

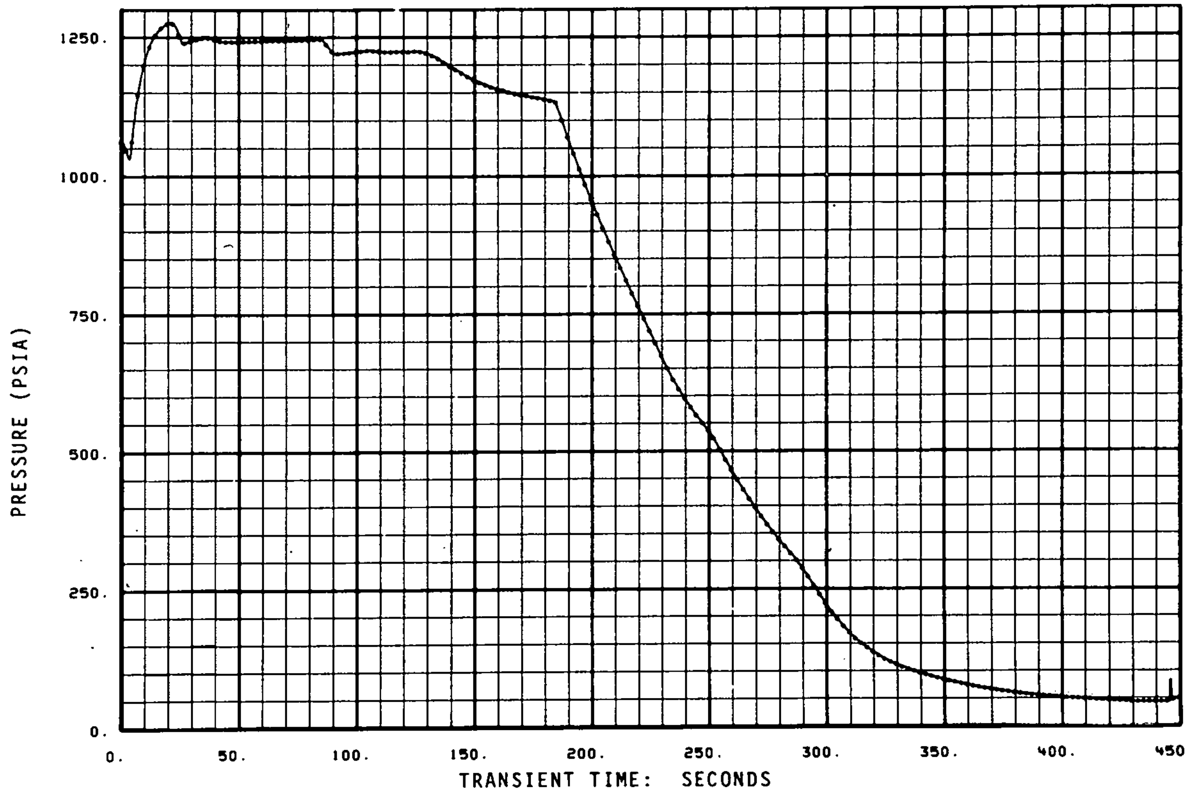

Fig. E-2 Lower plenum pressure - General Electric Plant (6% break).

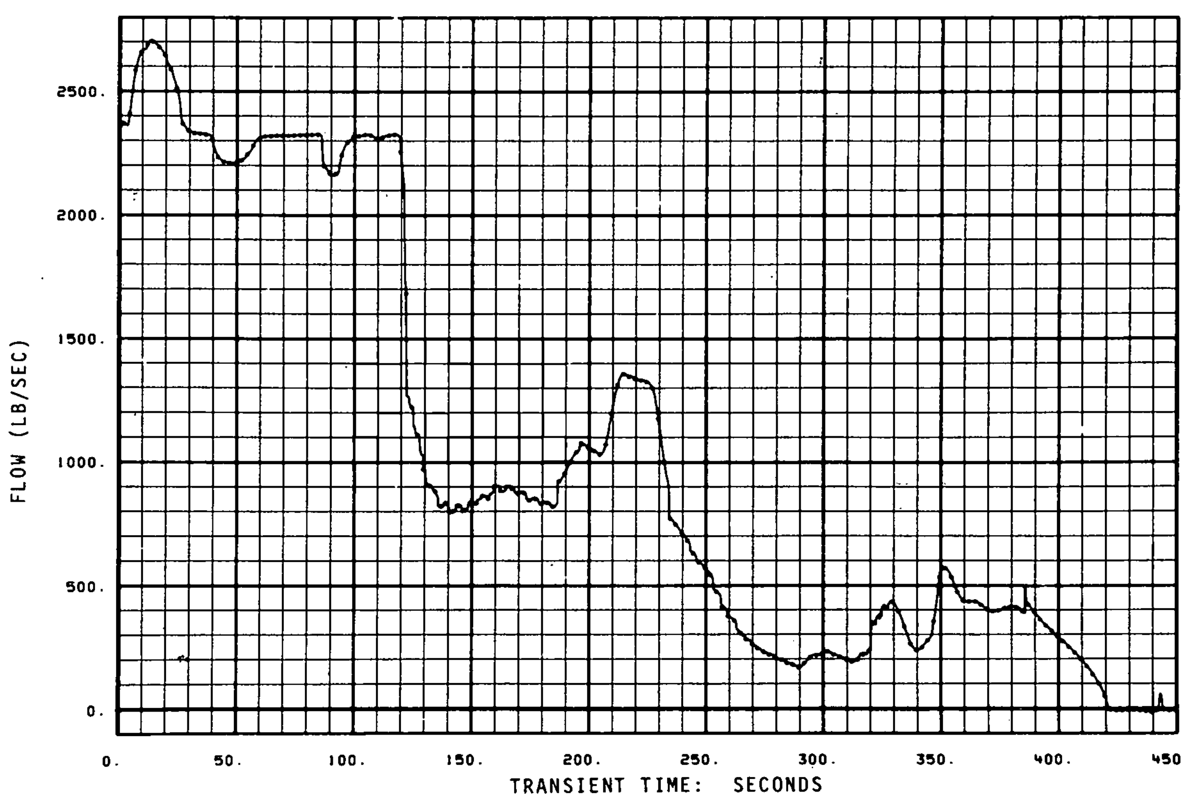

Fig. E-3 Break flow - General Electric Plant (6% break).

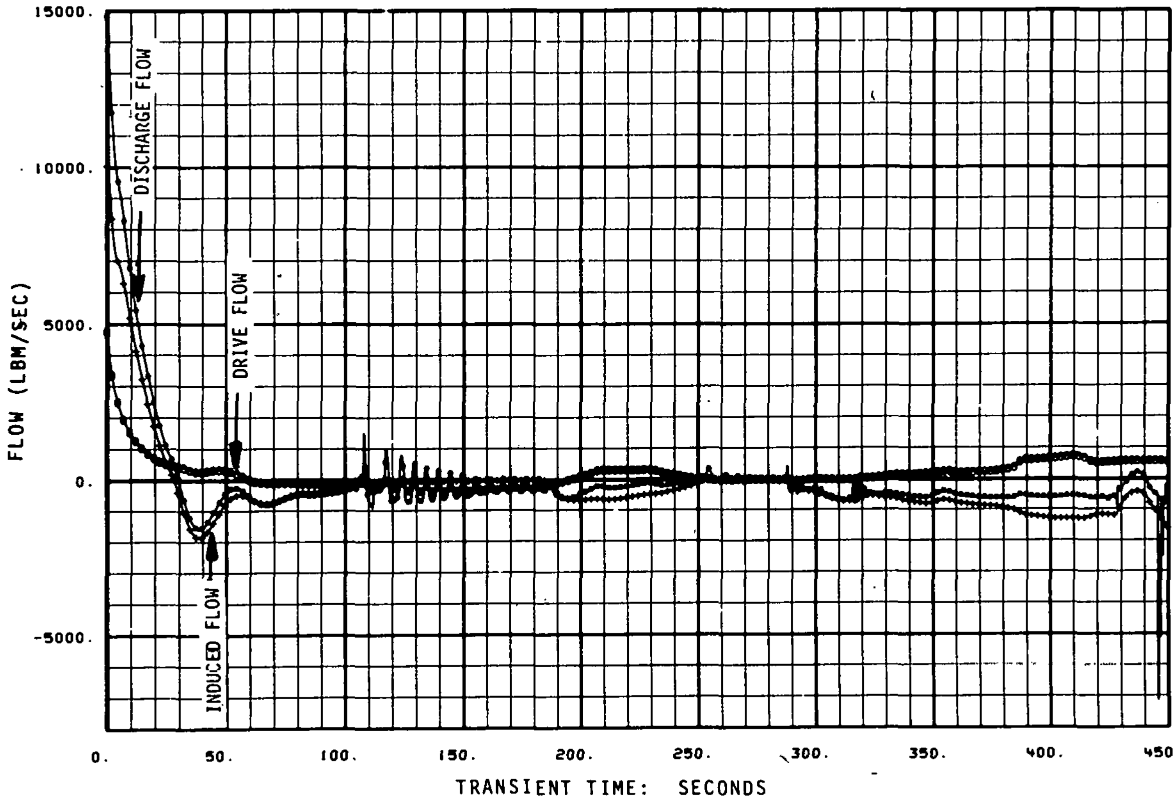

Fig. E-4 Broken loop jet pump flow - General Electric Plant (6% break).

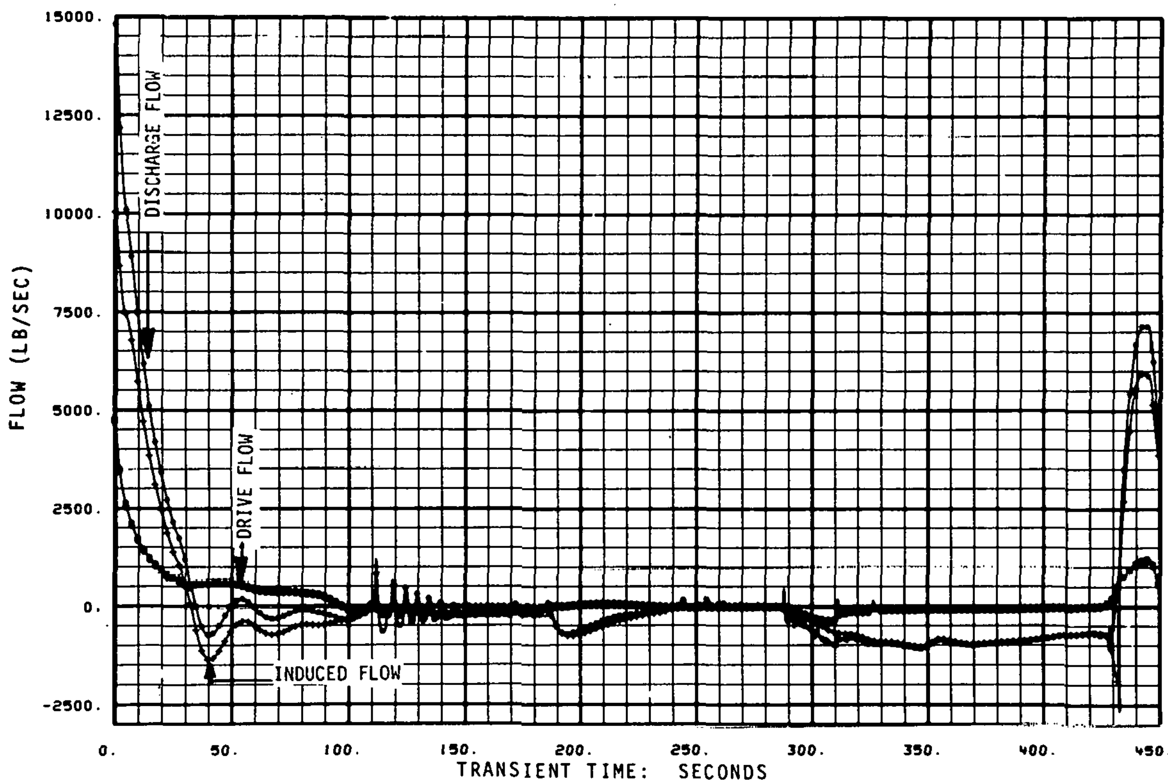

Fig. E-5 Intact loop jet pump flow - General Electric Plant (6% break).

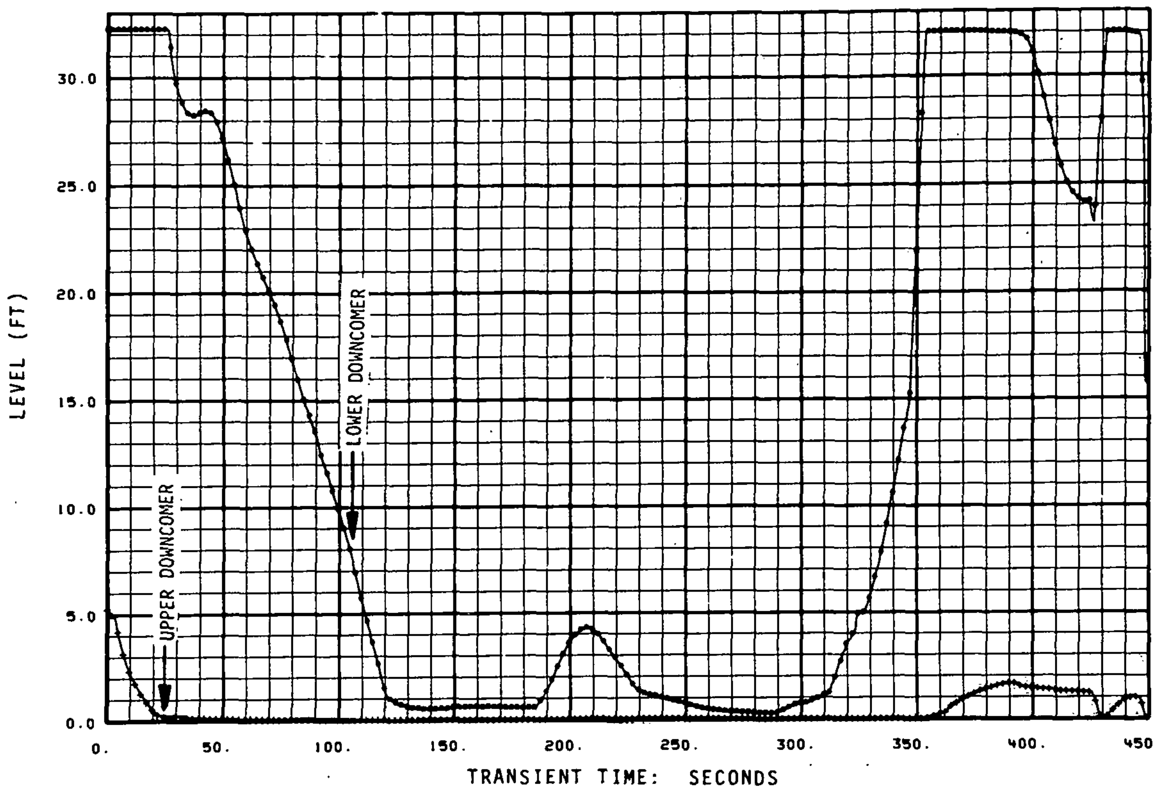

Fig. E-6 Downcomer mixture level - General Electric Plant (6% break).

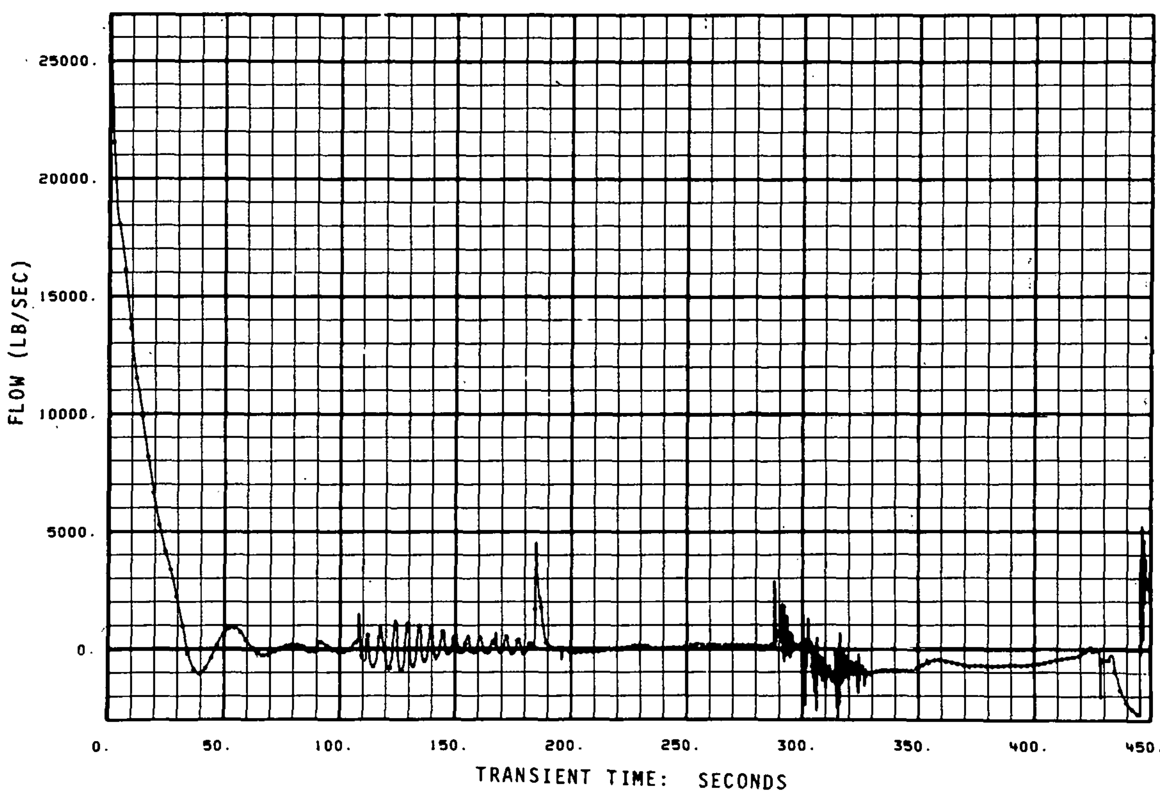

Fig. E-7 Core inlet flow - General Electric Plant (6% break).

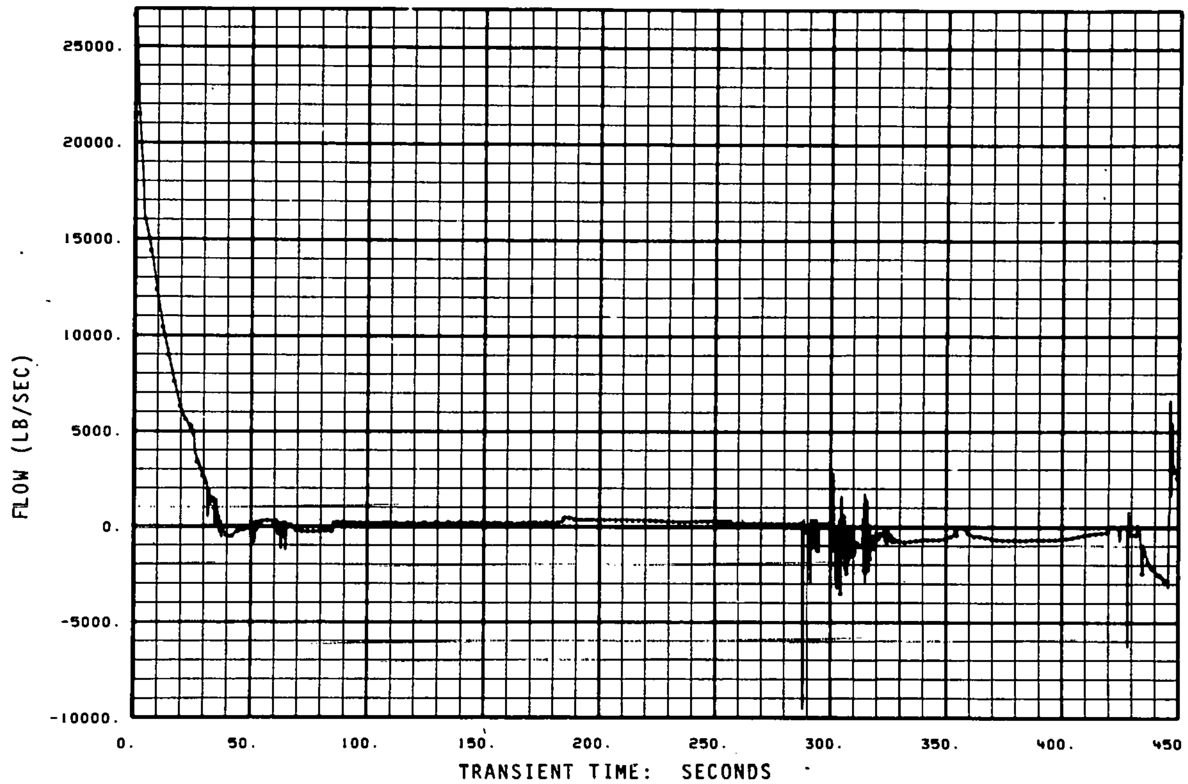

Fig. E-8 Core outlet flow - General Electric Plant (6% break).

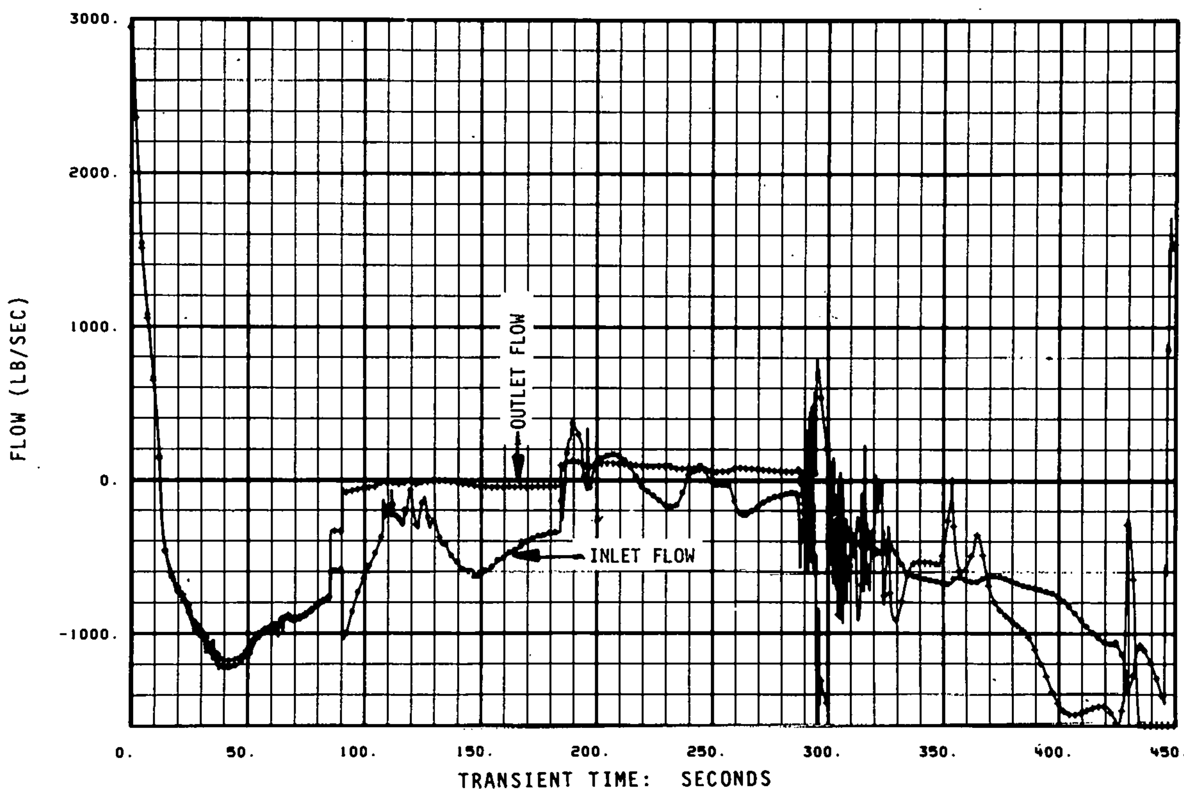

Fig. E-9 Bypass flow - General Electric Plant (6% break).

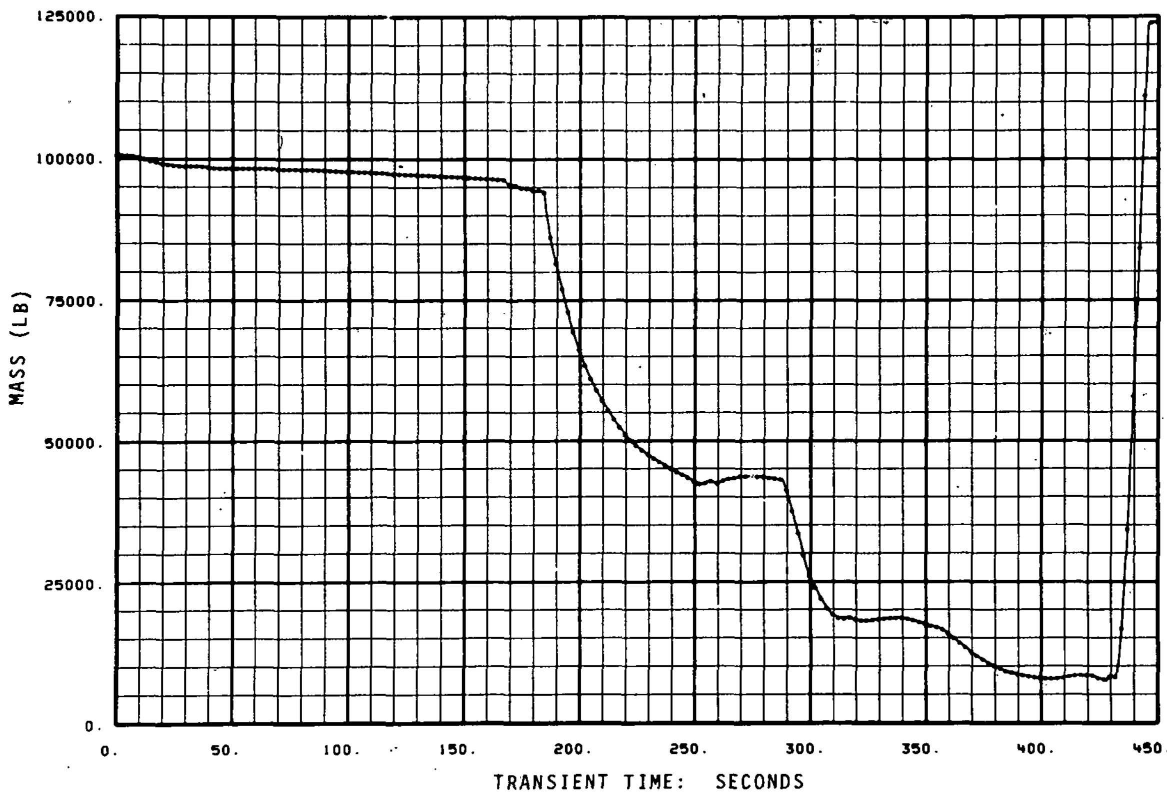

Fig. E-10 Liquid mass in the lower plenum - General Electric Plant (6% break).

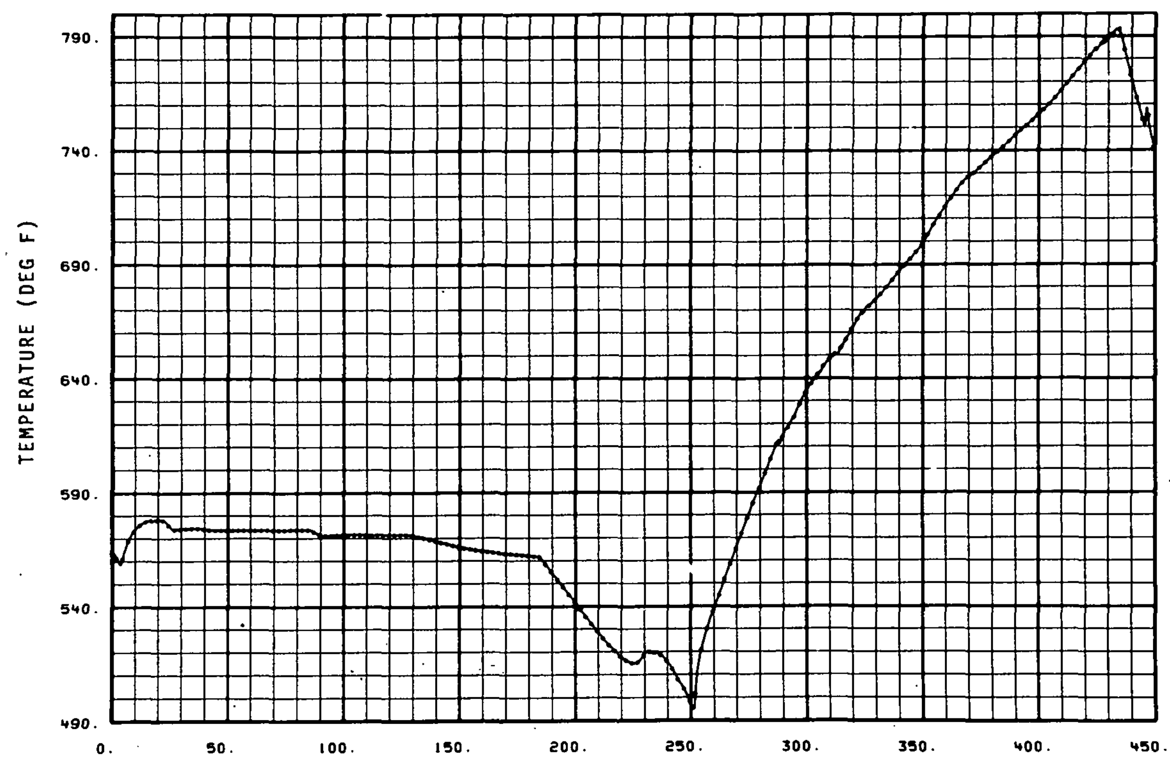

Fig. E-11 Cladding surface temperature - General Electric Plant (6% break).

6. INPUT LISTING

input listing for this run is given is Table E-IV, which follows.

TABLE E-IV

INPUT LISTING

```
= GE BWR SMALL BREAK
010001 -2    9    5    10   16   4    0   25   2    4    2    4    17   10   5    1    0    0
010002     3388.        1.0
*3XXX0 TIME STEP
*3XXX0 NMIN NMAJ NDMP NCHK DELTMAX DELTMIN  TLAST
030010  1   2      1    0    .001    .00001   .2 4000.
030010  100 2      1    0    .001    .00001   .2 4000.
030010. 100 2      1    0    .001    .00001   .2 200.
*4XXX0 TRIP CARDS
*400X0 TRP SIG IX1 IX2 SETPT, DELAY
040010  1  1  0  0  150.        0.
40010  1  1  0  0   5.        0.
040010  1  1  0  0  0.0         0.
040010  1  1  0  0  0.01        0.
40010  1  1  0  0  15.        0.
040010  1  1  0  0  10.0        0.
40010  1  1  0  0  50.        0.
040030  2  1  0  0  0.          0.
040040  3  1  0  0  .001        15.
040040  3  1  0  0  .001        0.
040050  4  1  0  0  .002        15.
040050  4  1  0  0  .002        0.
040060  5  1  0  0  3.0         15.
040060  5  1  0  0  1.0         0.
040070  6  1  0  0 1.E6    0.
040080  7 -5  4  0  21.5    26.5
040090  8  1  0  0 .001     1.E6
040100   9  -5  4  0  21.38  120.
*5XXXX VOLUME DATA CARDS
*2345678901234567890123456789012345678901234567890123456789012345678901234567890
*5XXXY B R PRES    TEMP   HORX     VOL      HT    MIX   TP FLOWA DIA     ELEV   IAMBLO
050011 2 0 1039.    -1.  .091632 1548.    22.25 22.25 0 224.    0.      29.92    0
050021 2 0 1028.28 -1.  .002448 6703.    12.25 5.27  0 497.    0.      41.75    0
050031 1 0 1024.98 -1.  .999     3777.    21.25 21.25 0 497.    0.      51.25    0
050041 3 0 1031.93 532.3  -1.    3177.    32.23 32.23 0 165.    0.      10.02    0
050051 0 0 1024.    532.3  -1.    125.25 26.    26.    0 3.67   0.     -14.      0
050051 0 0 1024.    532.3  -1.    136.00 26.    26.    0 3.67   0.     -14.      0
050061 0 0 1126.17 533.25 -1.    63.     3.     3.     0 4.0    0.      -14.     0
050071 0 0 1226.17 533.25 -1.    366.    40.53 40.53 0 3.2    0.      -14.     0
050081 0 0 1024.    532.30 -1.    136.    26.    26.    0 3.67   0.      -14.     0
050091 0 0 1126.17 533.25 -1.    63.     3.     3.     0 4.0    0.      -14.     0
050101 0 0 1226.17 533.25 -1.    366.    40.53 40.53 0 3.2    0.      -14.     0
050111 2 0 1062.16 532.53 -1.    2131.5 17.20 17.20 0 120.    0.      0.       23
050111 2 0 1062.16 532.53 -1.  2131.50 17.10 17.10 0 120.    0.      0.       12
050121 2 0 1051.52 -1.  .050567 973.09 13.02 13.02 0 81.091 .0473 17.00   1
050121 2 0 1051.52 -1.  .139881 973.09 13.02 13.02 0 81.091 .0473 17.00   1
050121 2 0 1051.52 -1.  .138881 973.09 13.02 13.02 0 81.091 .0473 17.00   1
050121 2 0 1051.52 -1.  .138551 973.09 13.02 13.02 0 81.091 .0473 17.00   1
050131 2 0 1050.07 532.60 -1.  1477.0  30.02 30.02 0 43.635 0.      0.       1
050141 0 0 1059.2  532.53 -1.  115.     15.7  15.7  0 19.69  0.      10.02    0
050151 0 0 1059.2  532.53 -1.  115.     15.7  15.7  0 19.69  0.      10.02    0
050161 4 0 14.7    100.   0.6  3.43E6 250.  0.0   1 1000.  100.   -10.      0
*60000 LIQUID LEVEL CALCULATION CARD
060000 11 12 13 14 15 1
*60001 SLVAMX  SLVELZ SLVPWR SLVSL1 SLVDPF
060001  0.0       0.0      0.0     0.0     0.0
*60002 WALLIS SLIP CORRELATION CARD
*60002 WALSC1 WALSC2
*6XXX1 BUBBLE DATA CARDS
*6XX11 ALPH VBUB
```

TABLE E-IV (contd.)

```
060011 1.0  0.0
060021 0.0  3.0
060031 0.8  3.0
060041  0.  1.E6
*60001 SLIP VELOCITY CARD
*8XXXY JUNCTION DATA CARDS
*8???? IN  OT P V FLOW      AJUN    ZJUN   IN   FJUF   FJUP V C I EQ DM CC C   E COS AJ
*234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
080011  1  2  0 0 29563.    191.1   52.17 0.   0.     0.    1 5 3 0 0.0 0. 0   0 1.0  0
080021  2  3  0 0 4074.3135 312.    52.25 0.   0.     0.    1 5 3 0 0.0 0. 0   0 0.0  0
080031  2  4  0 0 25444.    165.    42.0  0.   0.     0.    1 5 3 0 0.0 0. 0   0 0.0  0
080041  4 15  0 0 10041.5 3.112    25.0  30.  .2084  1.17  2 5 0 2 0.0 0. 0   0 0.0  0
080051  4  5  0 0 4750.    3.67    11.0  0.   0.     0.    1 5 3 0 0.0 0. 0   0 0.0  0
080061  5  6 -1 0 4750.    3.67    -13.  0.   0.     0.    0 5 3 0 0.  0. 0   0 0.0  0
080071  6  7  1 0 4750.    3.2     -13.  0.   0.     0.    0 5 3 0 0.  0. 0   0 0.0  0
080081  7 15  0 0 4750.    0.538   25.   47.  .2373  6.8   0 5 0 2 0.  0. 0   0 0.0  0
080091  4  8  0 0 4750.    3.67    11.   0.   0.     0.    1 5 3 0 0.0 0. 0   0 0.0  0
080101  8  9 -2 0 4750.    3.67    -13.  0.   0.     0.    0 5 3 0 0.  0. 0   0 0.0  0
080111  9 10  2 0 4750.    3.2     -13.  0.   0.     0.    0 5 3 0 0.  0. 0   0 0.0  0
080121 10 19  0 0 4750.    0.538   25.   47.  .2373  6.8   0 5 0 2 0.  0. 0   0 0.0  0
080121 10 14  0 0 4750.    0.538   25.   47.  .2373  6.8   0 5 0 2 0.  0. 0   0 0.0  0
080131  4 19  0 0 10041.5 3.112    25.   30.  .2084  1.17  2 5 0 2 0.0 0. 0   0 0.0  0
080131  4 14  0 0 10041.5 3.112    25.   30.  .2084  1.17  2 5 0 2 0.0 0. 0   0 0.0  0
080141 14 11  0 0 14791.5 19.69    10.12 0.   0.     0.    1 5 3 0 0.0 0. 0   0 0.0  0
080151 15 11  0 0 14791.5 19.69    10.12 0.   0.     0.    1 5 3 0 0.0 0. 0   0 0.0  0
080161 11 12 0 0 26639.    20.32   17.05 0.   0.     0.    1 5 3 0 0. 0.  0   0 1.0  0
080171 12  1  0 0 26639.   37.13   29.97 0.   0.     0.    0 5 3 0 0.  0. 0   0 1.0  0
080181 11 13  0 0 2944.    2.246   17.0  0.   0.     0.    1 5 3 0 1.0 0. 0   0 0.0  0
080191 13  1  0 0 2944.    43.635 29.97 0.   0.     0.    0 5 3 0 0.  0. 0   0 1.0  0
080201 5  16 0 4 0.        .2202   11.   0.   1.0    0.5   0 5 2 0 0. 1. 0    0 0.0  0
080211  3 16 0 3 0.        .484    55.0  1.   1.     1.    0 5 0 0 0. 0.  0   0 0.0  0
080221  0  4 1 0 4074.3135 4.712 40.    0.   0.     0.    0 5 3 0 0. 0.  0   0 0.0  0
080231  0  3 2 2 -4074.3135 14.75 72.   0.   0.     0.    0 5 3 0 0. 0.  0   0 0.0  0
080241  0  1 3 0 0.        1.0     30.   0.   0.     0.    0 5 3 0 0. 0.  0   0 0.0  0
080251  0 10 4 0 0.        1.00    25.   1.   0.     0.    0 5 0 0 0. 0.  0   0 0.0  0
*234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
*90XXY PUMP DESCRIPTION DATA CARDS
*900XY IP TAP RI TP T REV  RATIO FLOW    HEAD   TORQ    INER    DEN     FRIZ TOR
090011  3  4  0  1 0 1668.  1.0  44943.  710.3  22200.  20000.  47.17     0.  0
090021  3  4  0  1 0 1668.  1.0  44943.  710.3  22200.  20000.  47.17     0.  0
*910YY PUMP HEAD MULTIPLIER CARDS
091001 -11 0.  0.   .1   0.   .15  .05  .24  .8   .3   .96  .4   .98  .6   .97
091002      .8  .9   .9   .8   .96  .5   1.0  0.
*920YY PUMP TORQUE MULTIPLIER CARDS
092001 -2 0. 0. 1. 0.
*95XX1 PUMP STOP DATA CARDS
095011  0.  0.  0.
095021  0.  0.  0.
*100000 PUMP CURVE INPUT INDICATOR DATA CARD
100000  0  0 16  0
*10XYYZ PUMP HEAD AND TORQUE DATA CARDS
103011  1  1  5 0.0   1.31   0.25   1.25   0.5   1.20   0.75   1.12   1.0   1.0
103021  1  2  5 0.0   -0.9   .25    -.5    .5    -.05   .75    .4     1.0   1.0
103031  1  3  5 -1.0  2.1    -.75   1.775  -0.5  1.54   -.25   1.4    0.    1.31
103041  1  4  5 -1.0  2.1    -.75   1.50   -0.5  1.13   -.25   .92    0.    .825
103051  1  5  5 0.    .4     .25    .53    .5    .625   .75    .80    1.0   1.0
103061  1  6  5 0.    .825   .25    .79    .5    .815   .75    .90    1.0   1.0
103071  1  7  5 -1.0  -1.8   -.75   -1.    -.5   -.4    -.25   .1     0.    .4
103081  1  8  5 -1.0  -1.8   -.75   -1.72  -.5   -1.54  -.25   -1.27  0.    -.9
103091  2  1  5 0.    .55    .25    .63    .5    .71    .75    .86    1.0   1.0
```

TABLE E-IV (contd.)

```
103101  2  2  5 0.     -.55   .2     -.175  .4    .0     .75   .58    1.0   1.0
103111  2  3  5 -1.0   1.77   -.75   1.23   -.5   .83    -.25  .62    0.    .55
103121  2  4  5 -1.0   1.77   -.75   1.52   -.5   1.32   -.25  1.13   0.    1.0
103131  2  5  5 0.     -.8    0.2    -.375  0.5   -.1    .75   .15    1.0   .43
103141  2  6  5 0.     1.0    .25    .88    .5    .75    .75   .61    1.0   .43
103151  2  7  5 -1.    -3.45  -.75   -2.75  -.50  -2.0   -.25  -1.375 0.    -.8
103161  2  8  5 -1.    -3.45  -.75   -2.62  -.50  -1.583 -.25  -1.15  0.    -.55
*11XXX0 VALVE DATA CARDS
*CHANGED VALVE 1 TRIP FROM 4 TO 6 FOR SMALL BREAK
110010  4  0.   0  0.  0.  0. 0.
110010  6  0.   0  0.  0.  0. 0.
110020  5  0.   0  0.  0.  0. 0.
110020  5  2    0  0.  0.  0. 0.
110030 -8  0.   0  0.  0.  0. 0.
110030 -9  0.   0  0.  0.  0. 0.
110040 -3  0.   0  0.  0.  0. 0.
*12XXYY LEAK TABLE DATA CARDS
120101   2  9  30.  0  1.  1000.  1.
120101  -2  9  30.  0  1.  1000.  1.
120201 6 5 14.7 0. 1. 2.25 1. 2.5 .667 2.75 .333  3. 0. 10000. 0.
*13XXYY FILL TABLE DATA CARDS
*3XX00 TRIP TYPE POINTS ICALC UNITS    PORT     HORX
130100  2    1     4     1    LBS/SEC  1050.    401.11324
130101 0. 878.32 1. 878.32 4. 0. 10000. 0.
130101 0. 864.6676 15. 864.6676 16. 0. 10000. 0.
130101 0. 864.6676 1. 864.6676 4.0 0. 10000. 0.
130200  2    2     4     3    LBS/SEC  548.     .999
130201 0. 0. 940. 0. 1000. -276.2246 3000. -276.2246
130201 0. 0. 940. 0. 1025. -276.2246 3000. -276.2246
130300  7    2     11    3    GAL/MIN  292.     0.0
130300  7    2     11    3    GAL/MIN  212.     0.0
130301 0. 15150. 59. 14200. 137. 12500. 178. 11550. 237. 9470. 268. 7576.
130302 280. 5682. 287. 3788. 297. 1894. 304. 0. 10000. 0.
130400  7  2 9 3  GAL/MIN  212.  0.
130400  7  2 9 3  GAL/MIN  100.  0.
130401    17.6  4355.  23.7  4309.  26.1  4291.  41.2  4175.  42.4  4166.
130402 98.  3708.  102.  3672.  310.  0.  3000.  0.
*14000 KINETICS CONSTANTS
*14000 PWR MUL  BIL  REC  UDUF
140000  3    0  116.  0.  1.  0. 0. 0.
*141001 SCRAM TABLE DATA CARDS
141001 -8  4 0. 0. 0.9 0. 1.075 -.4 1.6 -4. 2.7 -10. 5.7 -28.1 8. -30. 10. -30.
*142001 DENSITY REACTIVITY DATA CARDS
142001 0
142001 -10  .2  -11.55  .3  -8.830  .4  -6.690  .5  -5.01  .6  -3.64  .7  -2.51
142002 .8  -1.55  .9  -0.73  1.  0.  1.1  0.
*143001 DOPPLER TABLE DATA CARDS
143001 0
143001 -6  0. 1.85  1000. 0. 2000. -1.71 3000. -3. 4000. -4.28 5000. -5.43
*140XX0 REACTIVITY COEFFICIENT DATA CARDS
140010 1. 1. 0. 0.
*15XXX HEAT SLAB DATA
*15XX1 VL VR  G S X H H ASUL  ASUR      VOL     HDL HDR HEDL HEDR CHL     CHR
*15XX2 ZBOT ZTOP
*234567890123456789012345678901234567890123456789012345678901234567890123456789O
150011  0  3  2 0 0 0 0 0.      687.     422.     0. 0.   0. 0.    0.     0.
150012  0.    0.
150021  0  2  2 0 0 0 0 0.      1368.    698.     0. 0.   0. 0.    0.     0.
150022  0.    0.
150031  0  4  2 0 0 0 0 0.      1916.    977.     0. 0.   0. 0.    0.     0.
```

TABLE E-IV (contd.)

```
150032  0.    0.
150041  0 11   2 0 0 0 0 0        687.      385.      0. 0.    0. 0.     0.      0.
150042  0.    0.
150051  4 13   3 0 0 0 0 1355.   1355.     239.      0. 0.    0. 0.     0.      0.
150052  0.    0.
150061  1  2   4 0 0 0 0 2288.   2288.     286.      0. 0.    0. 0.     0.      0.
150062  0.    0.
150062  0.    10.42
150071 11 12   5 0 0 0 0 197.    197.      65.       0. 0.    0. 0.     0.      0.
150072  0.    0.
150081 12  1   5 0 0 0 0 94.     94.       31.       0. 0.    0. 0.     0.      0.
150082  0.    0.
150091 11 13   6 0 0 0 0 6884.   6884.     95.       0. 0.    0. 0.     0.      0.
150092  0.    17.1
150101  0 11   7 0 0 0 0 0.      736.      46.       0. 0.    0. 0.     0.      0.
150102  0.    0.
150111  2  3   8 0 0 0 0 4380.   4380.     184.      0. 0.    0. 0.     0.      0.
150112  0.    0.
150121  0  5   9 0 0 0 0 0        450.      36.       0. 0.    0. 0.     0.      0.
150122  0.    0.
150131  0  8   9 0 0 0 0 0.      450.      36.       0. 0.    0. 0.     0.      0.
150132  0.    0.
150141  0  7   9 0 0 0 0 0.      838.      67.       0. 0.    0. 0.     0.      0.
150142  0.    0.
150151  0 10   9 0 0 0 0 0.      838.      67.       0. 0.    0. 0.     0.      0.
150152  0.    0.
150161 12 13 10 0 0 0 0 4786.0 4786.0    112.01    0. 0.    0. 0.     12. 12.  0. 0.
150171  0 12   1 0 0 0 0 0.   66220.5   776.9      0. .048 0. .0588 6. 6.  0. 0.
*234567890123456789012345678901234567890123456789012345678901234567890123456789012345678900
*16000 CORE SECTION DATA
*16000 SLB  NODE     CLAD     QFRAC
160010 17  7 9 15      0.   1.
*17XXYY SLAB GEOMETRY DATA CARDS
*7XXYY IG NR MI NPX XO       WIDTH    POW
170101  2  3  1  6 0.0       .020071 1.0
170102  1     2  2           .000721 0.
170103  0     3  8           .00267  0.
170201  1  2  4  3 0.0       .4      0.
170202  0     5  1           .0208   0.
170301  1  1  5  1 0.        .17     0.
170401  1  1  5  1 0.        .125    0.
170501  1  1  5  1 0.        .33     0.
170601  1  1  5  1 0.        .0138   0.
170701  1  1  5  1 0.        .0625   0.
170801  1  1  5  1 0.        .042    0.
170901  1  1  5  1 0.        .08     0.
171001  1  1  5  1 0.        .0234   0.
*18XXYY THERMAL CONDUCTIVITY DATA CARDS
180100 -20  500.   3.341  650.   2.971  800.   2.677  950.   2.439  1100.  2.242
180101      1250.  2.078  1400.  1.940  1550.  1.823  1700.  1.724  1850.  1.639
180102      2000.  1.568  2150.  1.507  2300.  1.457  2450.  1.415  2600.  1.382
180103      3100.  1.323  3600.  1.333  4100.  1.406  4600.  1.538  5100.  1.730
180200    2          32.       .41562     5400.      .41562
180300   18          32.       7.812      212.       7.992       392.      8.208
180301               572.      8.784      752.       9.540       932.      10.404
180302               1112.     11.268     1292.      12.492      1472.     13.176
180303               1652.     13.968     1832.      14.796      2012.     16.128
180304               2192.     17.784     2372.      19.656      2552.     21.780
180305               2732.     24.048     3092.      28.908      3360.     33.120
180401 -5   32. 30. 212. 29.5 392. 28.3 572. 26.6 752. 24.7
```

TABLE E-IV (contd.)

```
180501 -2  200. 8.33 1200. 12.92
*19XXYY VOLUMETRIC HEAT CAPACITY DATA CARDS
190100   16                 32. 34.45           122. 38.35            212. 40.95
190101                     392. 43.55           752. 46.8            2012. 51.35
190102                    2732. 52.65      3092. 56.55  3452. 63.05
190103                    3812. 72.8           4352. 89.7            4532. 94.25
190104                    4712. 98.15          4892. 100.1           5144. 101.4
190105                    8000. 101.4
190200    2          32.        .000075   5400.      .000075
190300   5   0.0   28.392
190301   1480.3   34.476   1675.0   85.176
190302   1787.5   34.476   3500.0   34.476
190401 -7 130. 56.9 350. 60.8 450. 62.3 530. 65.2 620. 67.2 710. 70.2 800. 77.5
190501 -10 68. 52.8 200. 56.7 400. 61.6 600. 64. 800. 66. 1000. .67
190502     1200. 68.4 1400. 71.8 1600. 75.8 1800. 80.6
*20XXYY LINEAR EXPANSION COEFFICIENT DATA CARDS
200101 -2 0. 3.718E-6  5000.  1.2653E-5
200201 -2 0. 0. 5000. 0.
200301  -4  0.  3.094E-6  1652.  4.706E-6  1653.  5.389E-6  5000. 5.389E-6
200401 -2  0.  0. 5000. 0.
200501 -2  0.  0. 5000. 0.
```

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APPENDIX F

SMALL COLD LEG BREAK - INEL SEMISCALE

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APPENDIX F

SMALL COLD LEG BREAK - INEL SEMISCALE

1. INTRODUCTION

The INEL Semiscale MOD-1 system was modeled using RELAP4/MOD5 to represent a small cold leg break, equivalent in terms of the ratio of break area to system volume to a 6% break in a large PWR. The Semiscale model used represented a single-ended cold leg break area of 0.000156 ft^2 with a valved-off blowdown loop hot leg. While the initial conditions chosen for this model were representative of a typical Semiscale small break, this model was not intended to represent any specific test. The system model and assumptions used, the results, and the conclusions drawn from this run are presented. A short description of the Semiscale facility is included in Section 6 for reference purposes.

2. SYSTEM MODEL AND ASSUMPTIONS

Figure F-1 shows the 15-volume nodalization used. Core heater rods were modeled by three vertically stacked heat slabs. The volumes and fill junctions used in the model are identified in Table F-I. The downcomer and upper annulus were modeled with a single volume. Junctions 1, 2, 3, 4, and 7 were modeled with vertical slip. The RELAP4 bubble rise model, using a bubble rise velocity (VBUB) of 3 ft/sec, was used for Volumes 2, 3, 4, 6, 7, 8, 9, and 14. A bubble rise velocity of 10^6 ft/sec was used for Volumes 12 and 13 to obtain a complete separation of the gas and liquid phases in the accumulator vessels. A velocity of 40 ft/sec was chosen for Volume 15, since this is the minimum bubble velocity required to transport energy through the steam generator

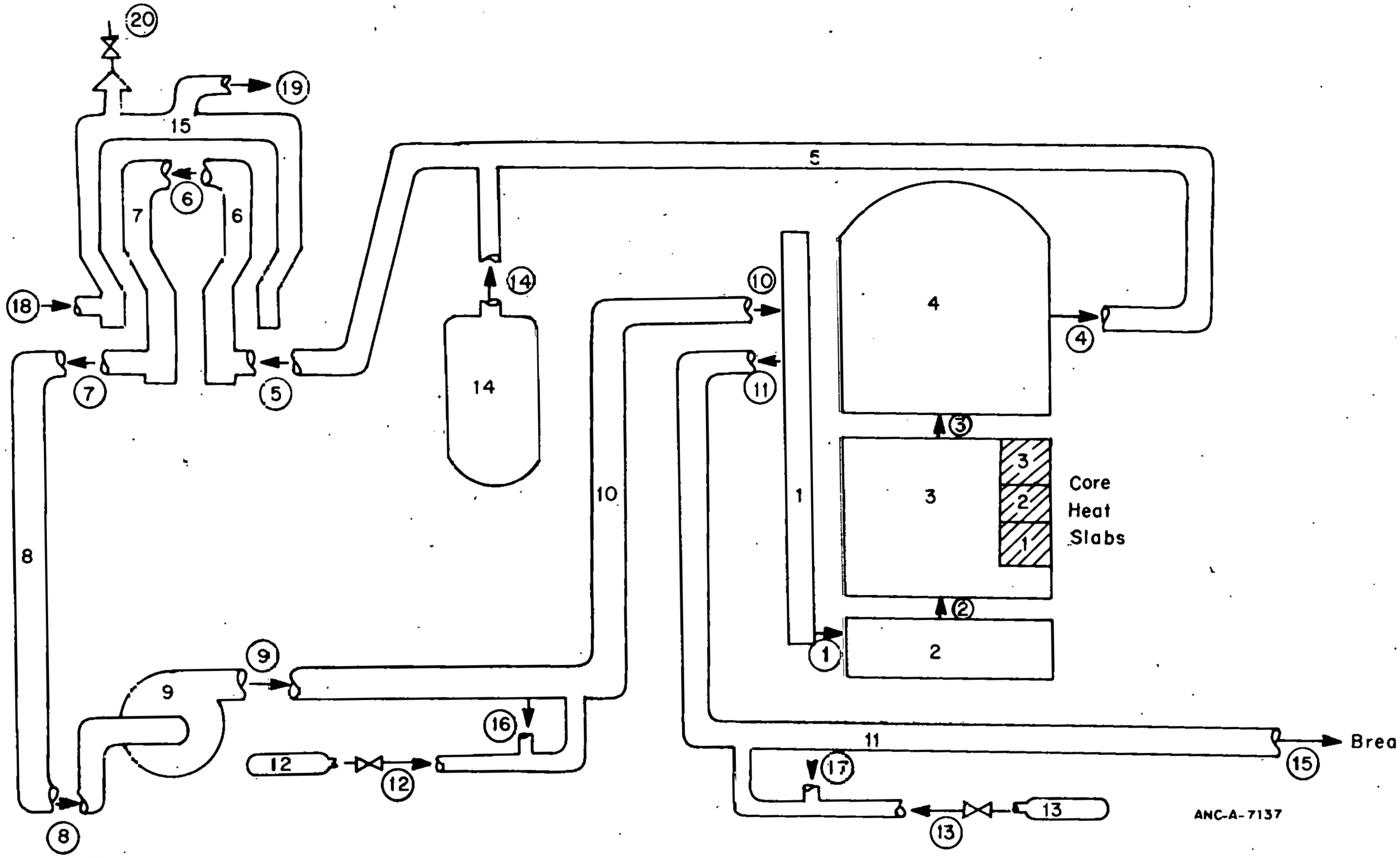

Fig. F-1 Nodalization for 6% break - Semiscale.

TABLE F-I

VOLUME AND FILL JUNCTION IDENTIFICATION FOR SMALL BREAK - SEMISCALE

Volume No.	Description	Fill Junction No.	Description
1	Downcomer	15	Break
2	Lower Plenum	16	HPIS Intact Loop
3	Core	17	HPIS Broken Loop
4	Upper Plenum	18	Steam Generator Inlet
5	Hot Leg - Intact Loop	19	Steam Generator Outlet
6	Steam Generator - Primary Inlet Side	20	Steam Generator Relief Valve
7	Steam Generator - Primary Outlet Side		
8	Intact Loop Cold Leg - Pump Suction		
9	Pump Volume and Suction from Low Elev.		
10	Intact Loop Cold Leg - Pump Outlet		
11	Broken Loop Cold Leg		
12	Accumulator - Intact Loop		
13	Accumulator - Broken Loop		
14	Pressurizer		
15	Steam Generator - Secondary Side		

secondary at the rate that it is initially delivered to this volume. A bubble density gradient (ALPH) of 0.0 was used in all of the foregoing volumes. The IAMBLO parameter was used for Volumes 2, 3, and 8 to insure that all liquid would seek the lowest volume in the stack. All junctions in the operating and blowdown loops were considered to be vertically distributed, with the exception of Junctions 1, 2, and 3 which were horizontal junctions. All junctions used Henry-Fauske choking in the subcooled region with a multiplier of 0.9 and HEM choking in the saturated region with a multiplier of one. The mixture level crossing smoothing option was activated after 70 sec to facilitate junction crossing in the reactor vessel. Horizontal slip and downcomer penetration were not used in this model. The system was modeled with an extended pump inlet as described in the Semiscale Design Description.[F-1]

The form loss coefficients used in the model were obtained from prerupture hydraulic resistance measurements taken during Semiscale Test S-02-3. These data yielded node-to-node frictional pressure differences which were combined with hydrostatic pressure differences and then entered in the form of nodal pressures. The code then calculated its own forward form loss coefficients in the form of residuals needed to balance the system. Reverse form loss coefficients were generally determined from considerations of system symmetry. An initial core power of 1.6 MW was used in addition to an initial operating loop mass flow rate of 17.25 lb/sec, pump speed of 2,629 rpm, lower plenum temperature of 544°F, and upper plenum outlet pressure of 2,262 psia. The Semiscale table for small break power versus time was used to determine transient core power.

The scram sequence was modeled to initiate on a low pressure trip at 1,800 psia in the pressurizer. This trip, which occurred 8.6 sec after break opening, immediately reduced core power and cut off pump power. The steam generator secondary flows were shut off next, following a one second delay. HPIS flows into the operating and blowdown loops began 25 sec after the scram trip. Accumulator flows were set to open when the cold leg pressures fell to 612 psia. The pressurizer was valved off from the system 65 sec after it emptied. This was done to reduce the use frequency of the zero flow crossing time step control so as to reduce computer running time.

A complete listing of input information is given in Section 7 of this appendix.

3. RESULTS

The problem ran quite rapidly from initiation of blowdown until the accumulator emptied 273 sec later. The run was then terminated. The total CPU running time to 273 sec transient time was about 8.3 min on the CDC 7600 at Brookhaven National Laboratory. The significant data output traces are shown as Figures F-2 through F-13 in Section 5 of this appendix. Features of the blowdown were:

(1) System depressurization during the first 5 sec after break opening brought most of the operating loop volumes close to saturation conditions and resulted in a core heat transfer mode change which produced a higher heat transfer to core water. This produced a brief system pressure rise between 5 and 15 sec as shown by Figure F-2. System depressurization after 15 sec was due to core power reduction initiated by the scram.

(2) Core flow reversal at 45 sec, as seen in Figures F-3 and F-4, was caused by the loss of pump driven circulation. The core and upper plenum mixtures found a lower resistance flow path through the downcomer to the break. It should also be noted from Figure F-5 that the upper plenum mixture level remained nearly constant at 6.9 ft during the period from 15 to 50 sec due to uncovering of the hot leg outlet from the upper plenum. This provided a vent path for the steam dome in the upper plenum.

(3) Pump inlet uncovering at 73 sec, as seen in Figure F-6, allowed steam trapped in the upper plenum and the steam generator to escape through the cold leg. The resulting increased system depressurization rate is shown by Figure F-2 for the period between 73 and 83 sec. This also resulted in a brief return of core flow to its normal direction during the transient time period of 73 to 84 sec. Also accounted for was the upward excursion of the upper plenum mixture level as seen in Figure F-5 for the period between 74 and 88 sec, when the core flow once more reversed.

(4) Break flow fluid saturation occurred at 101 sec and resulted in a transition from Henry-Fauske choking to HEM choking. This allowed the rapid decrease in break flow shown in Figure F-7 for the time between 101 and 106 sec.

(5) Complete core volume uncovering at 145 sec led to core fluid superheating as seen in Figure F-8. The mid-core heat slab (cladding) temperature seen in Figure F-9 also began a rapid upward rise when this slab was uncovered by the core mixture level at 114 sec. This heat slab temperature rose to a maximum of 1,520°F at 250 sec. The downward temperature spikes observed in both the average core and mid-core heat slab temperatures between 145 and 150 sec are due to the brief upward mixture level surge observed at this time in the lower plenum and core (Figures F-10 and F-11). This brief surge was due to downcomer outlet uncovering which provided a low resistance escape path for the steam dome in the upper reactor vessel.

(6) Accumulator flow initiation at 232 sec caused rapid subcooling of the fluid issuing from the break. This resulted in the increased break flow rate observed after 232 sec seen in Figure F-7. The lower plenum was refilled with subcooled water by 266 sec, as seen in Figures F-10, F-12, and F-13.

This satisfied the Volume III, Section 2 completion criterion of refilling the lower plenum to the bottom of the core.

The original model had provided for blowdown into a pressure suppression tank. The break modeled was a leak due to unresolved discrepancies between hand-calculated and code-calculated values of break mass flow rate from the Extended Henry-Fauske Tables.

A reduction in the minimum time step size was required to accommodate one of the three mixture level crossings observed in the problem. The problem was normally run with a minimum time step of 0.001 sec and maximum time step of 0.2 sec. It was necessary to briefly reduce the minimum to 0.0001 sec to allow the mixture level to drop out of the upper plenum.

4. CONCLUSIONS

In general, the code was found to run quite smoothly. The problem ran rapidly from initiation of blowdown until the accumulator emptied 273 sec later when the run was terminated. Total CPU running time out to 273 sec problem time was 8.3 min.

The original Semiscale model provided for blowdown into a pressure-suppression tank. It was determined that the break should be modeled as a leak due to unresolved discrepancies between hand-calculated and code-calculated values of break mass flow rate from the Extended Henry-Fauske Tables. This gave good agreement with the table values for break mass flow rate. It was noted from examination of break flow rates, that extrapolation of the Extended Henry-Fauske Tables was sometimes required.

The unresolved discrepancy in critical flow discussed above appears to occur only for very low subcooled break flow rates. The break flow in Semiscale was calculated to be about 3 lb/sec when this problem was encountered. Therefore, for situations in which very low subcooled break flow occurs (on the order of tens to hundreds of pounds per second), the break flow calculations should be thoroughly examined. If a problem is evident, a leak junction should be used at the break. This critical flow discrepancy was not encountered in any of the numerous other checkout problems.

The problem was run without any major difficulty, aside from the critical flow discrepancy discussed above, and within the established time limit of one hour on the CDC-7600 computer. The completion criteria listed in Volume III, Section 2 for the MOD5 checkout runs were satisfied.

5. OUTPUT DATA

The output data for the Semiscale small break model are shown as Figures F-2 through F-13 in this section.

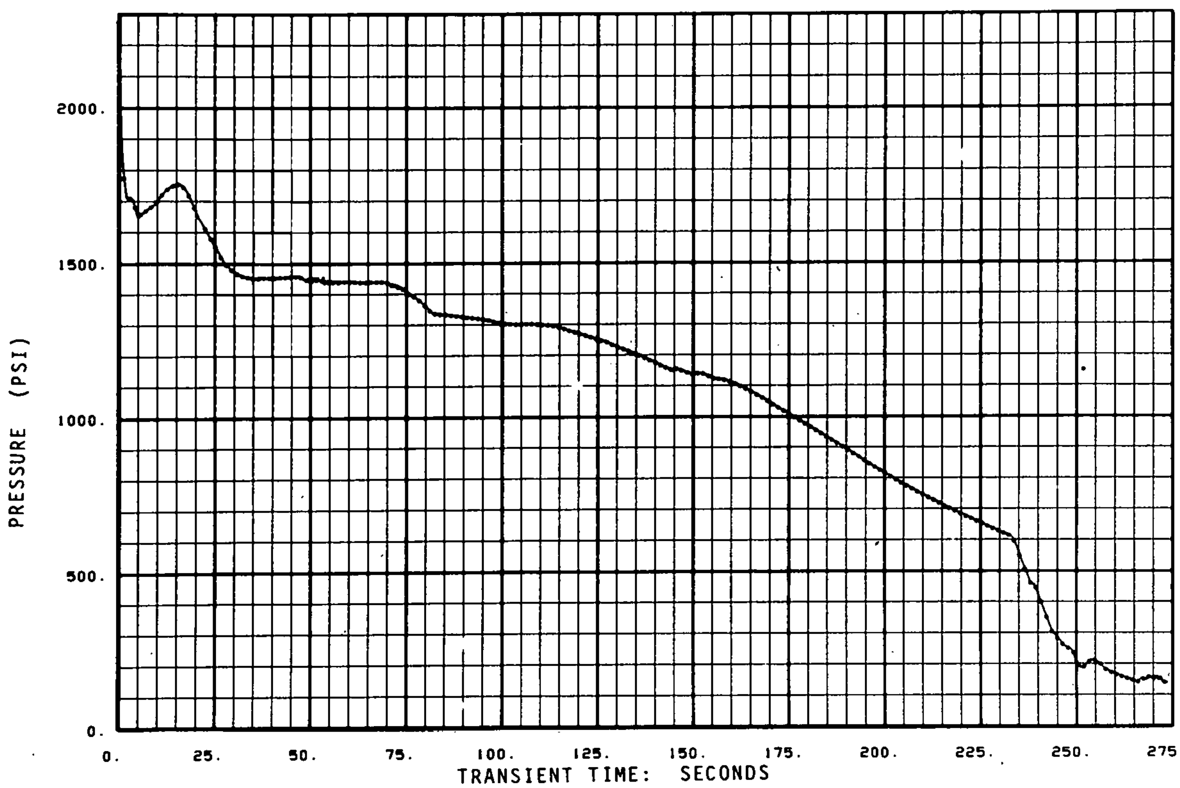

Fig. F-2 Lower plenum pressure - Semiscale (6% break).

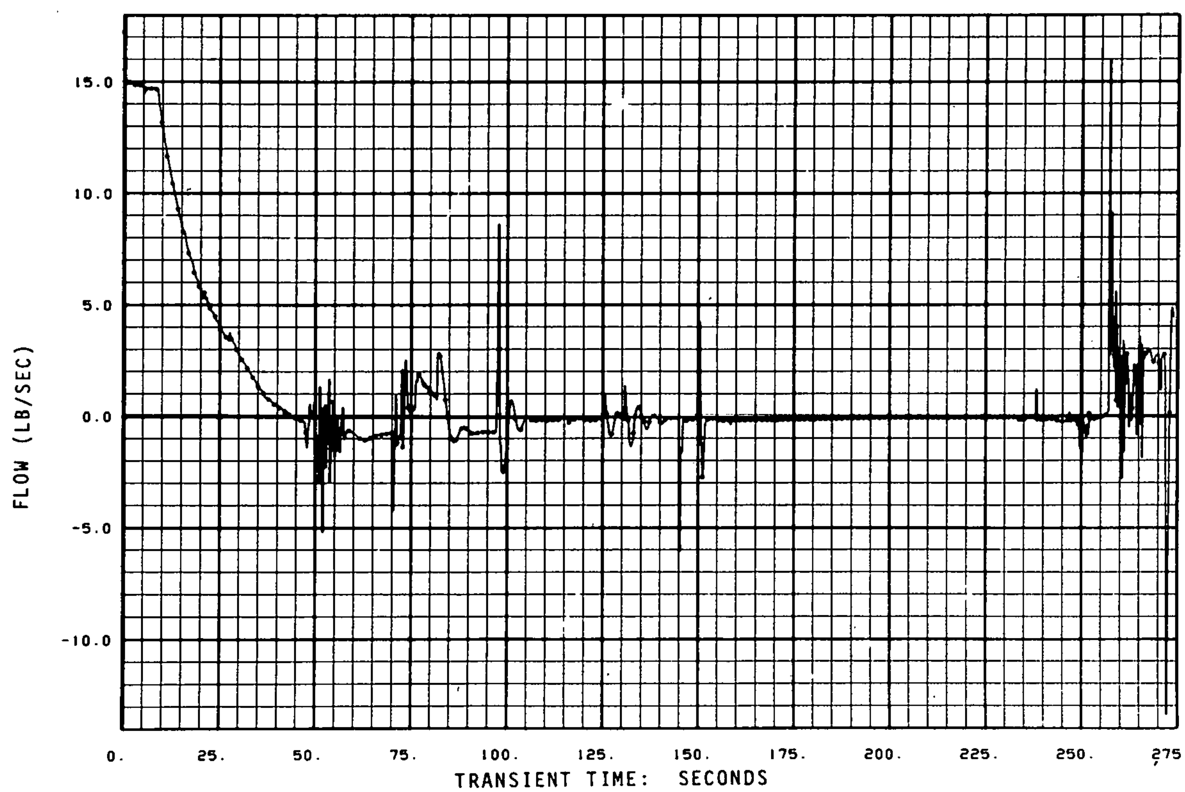

Fig. F-3 Core inlet mass flow rate - Semiscale (6% break).

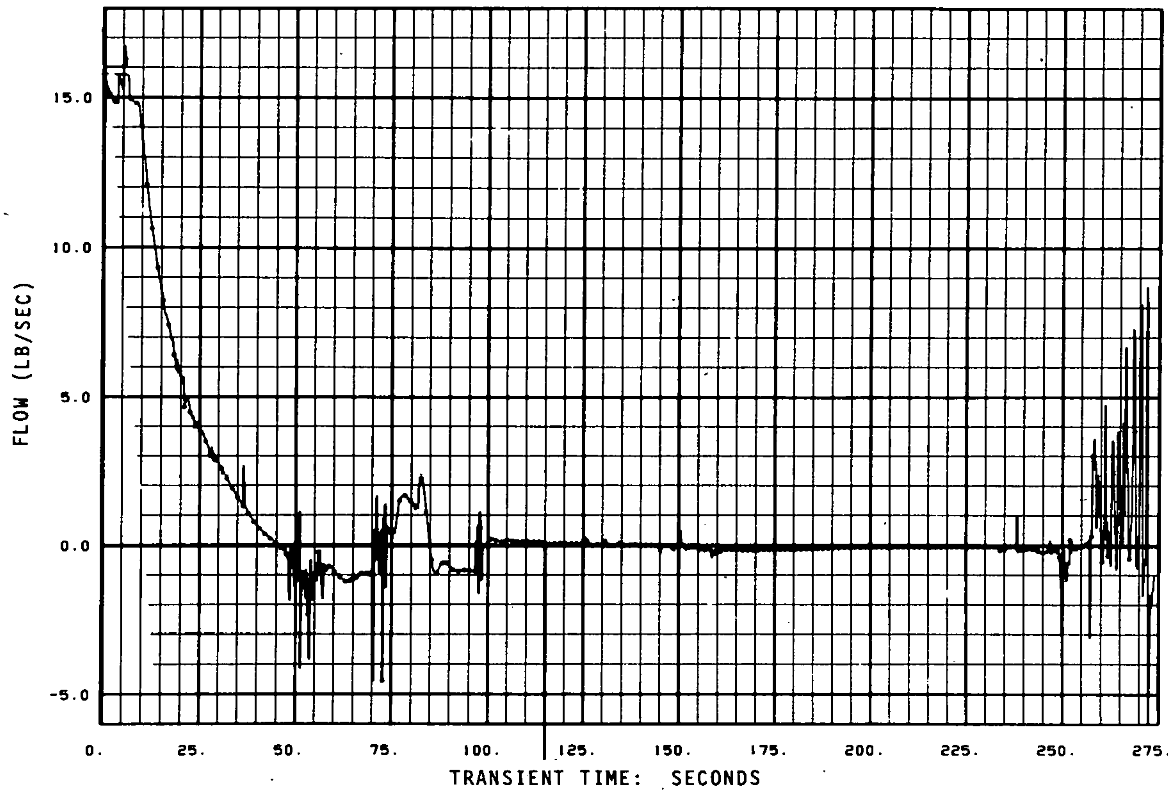

Fig. F-4 Core outlet mass flow rate - Semiscale (6% break).

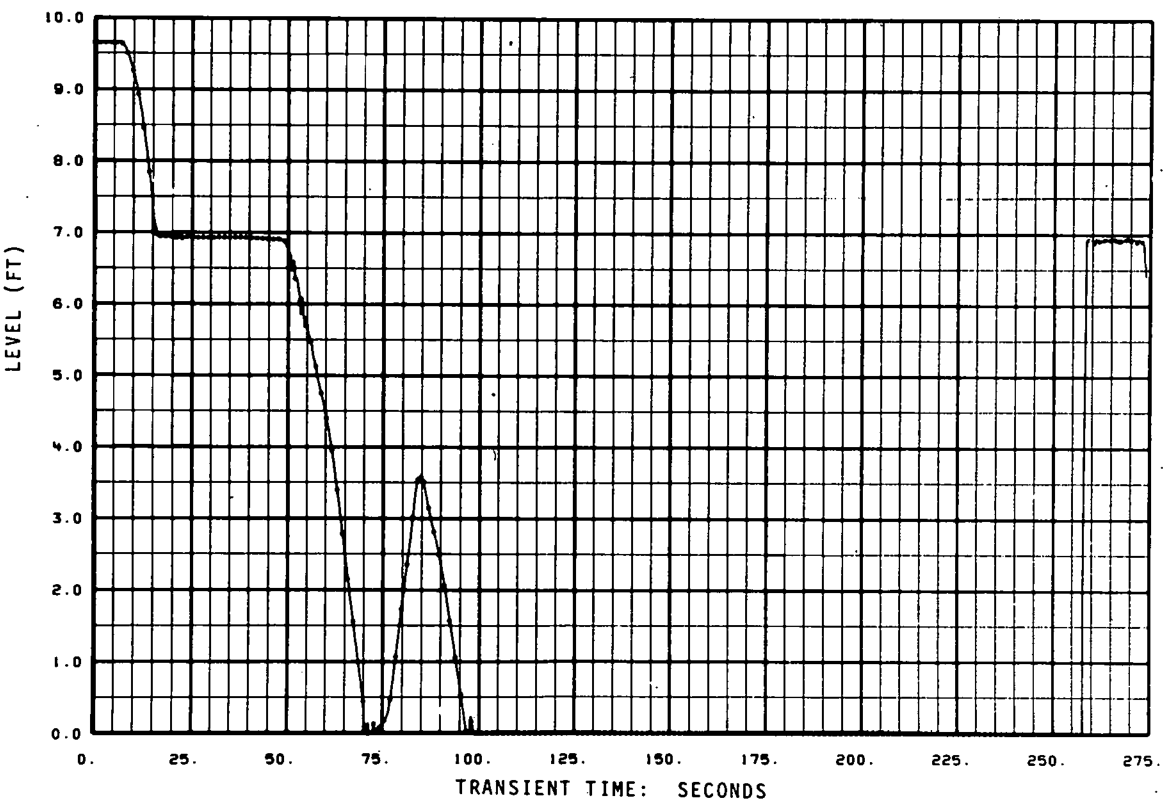

Fig. F-5 Upper plenum mixture level - Semiscale (6% break).

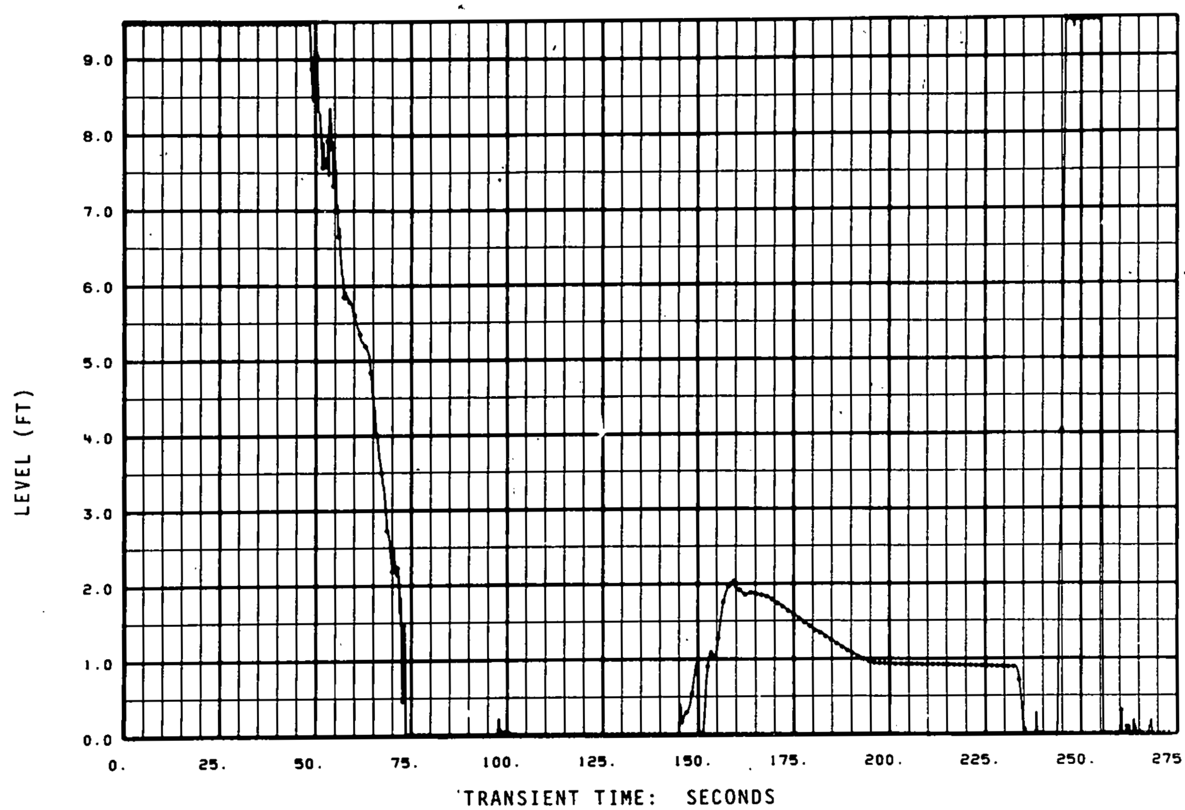

Fig. F-6 Pump suction leg mixture level - Semiscale (6% break).

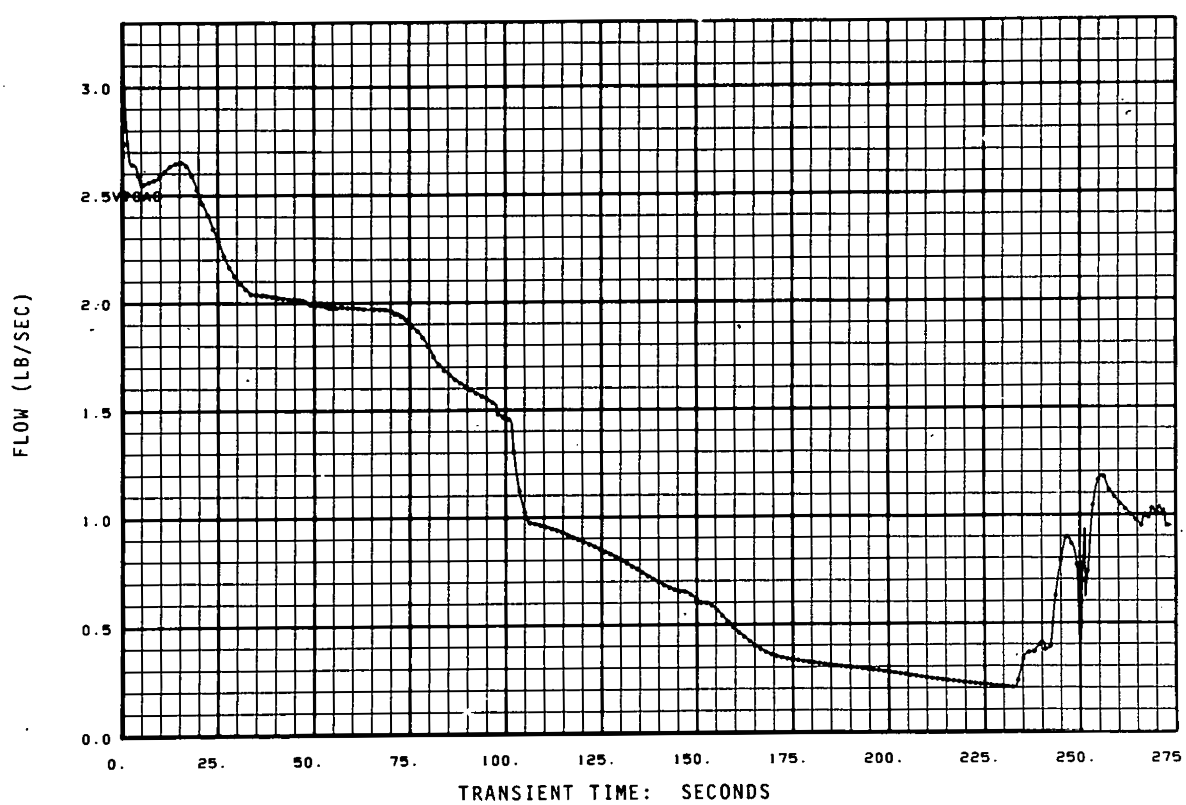

Fig. F-7 Break mass flow rate Semiscale (6% break).

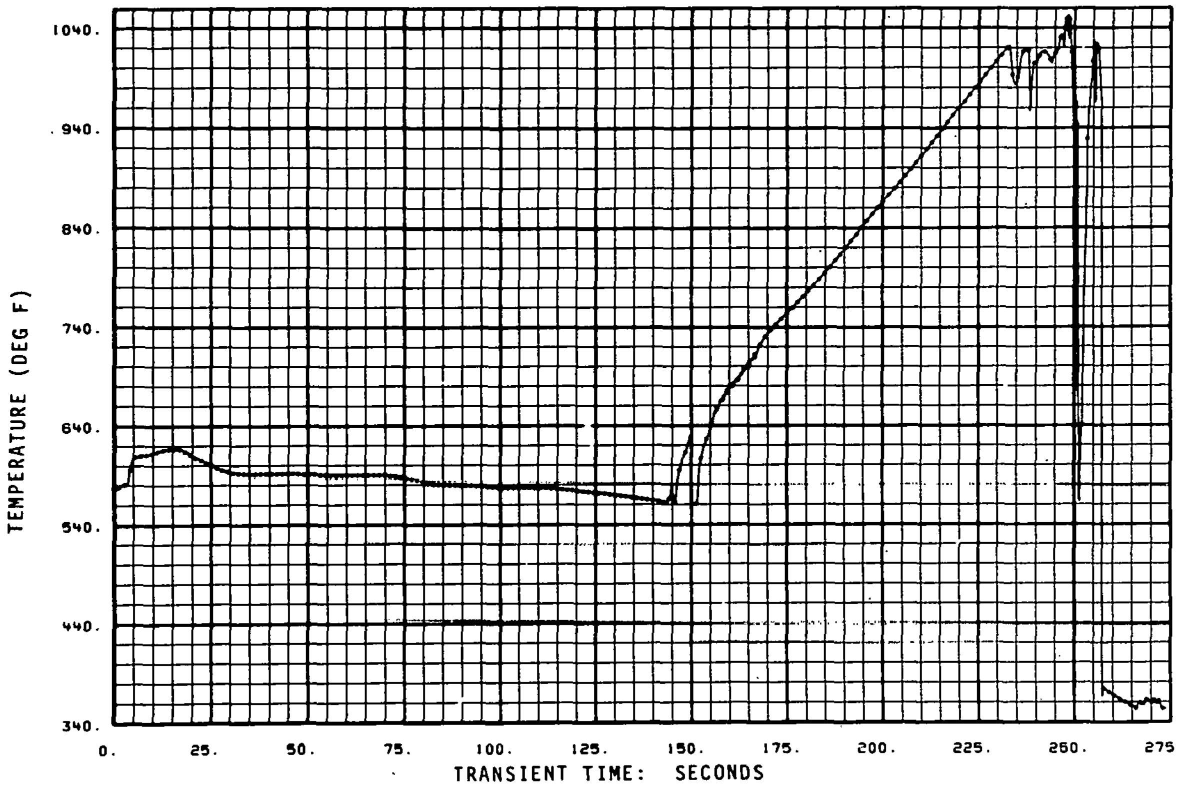

Fig. F-8 Average core volume temperature - Semiscale (6% break).

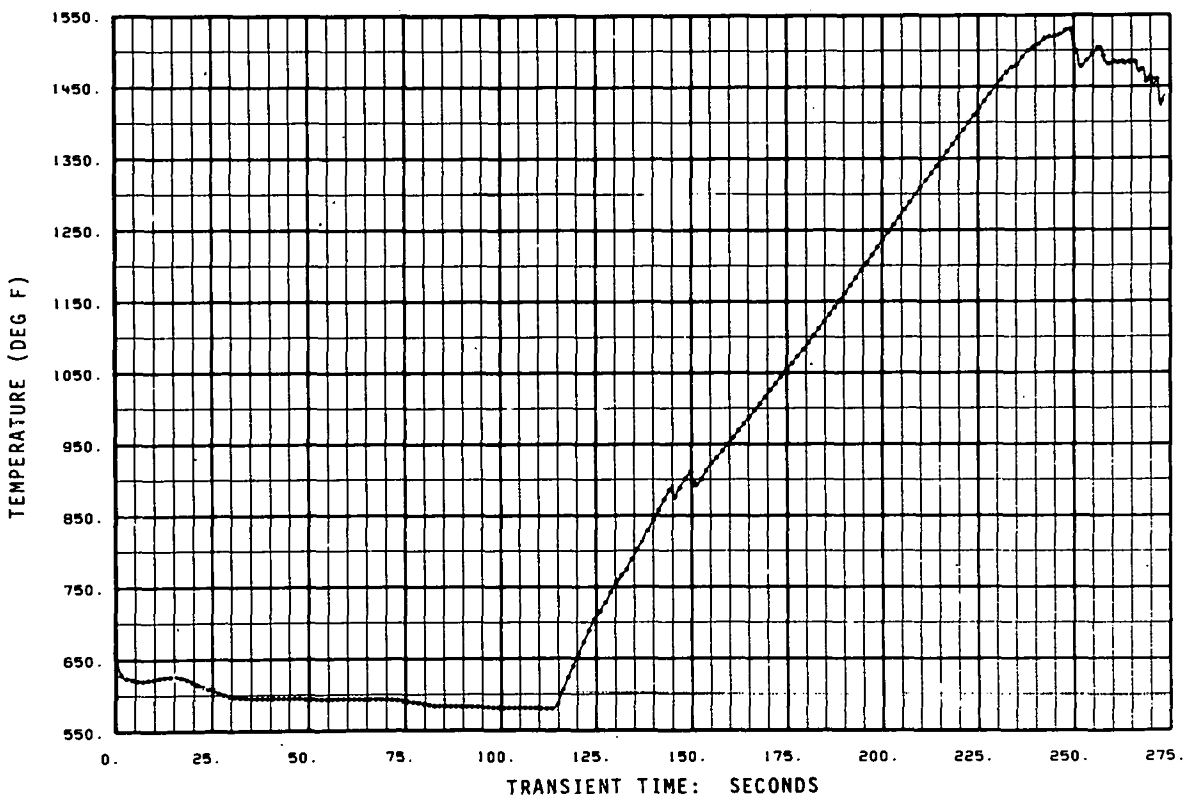

Fig. F-9 Mid-core heat slab (cladding) temperature - Semiscale (6% break).

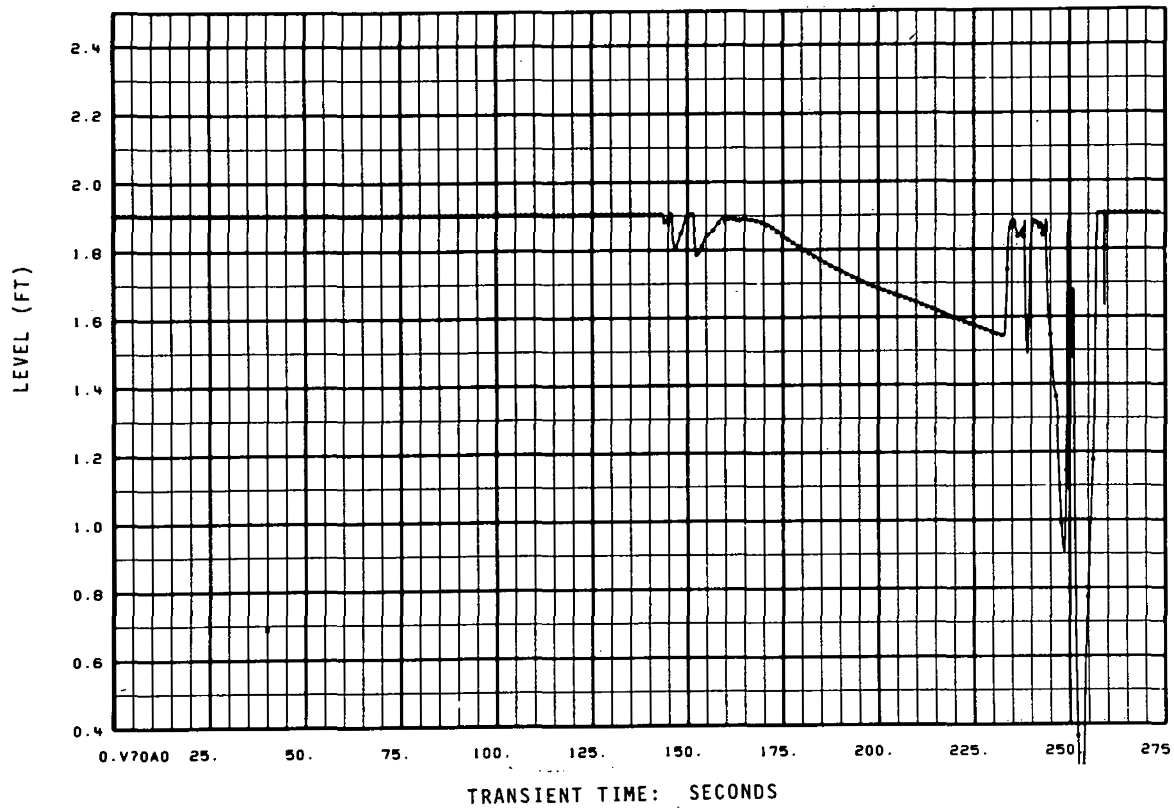

Fig. F-10 Lower plenum mixture level - Semiscale (6% break).

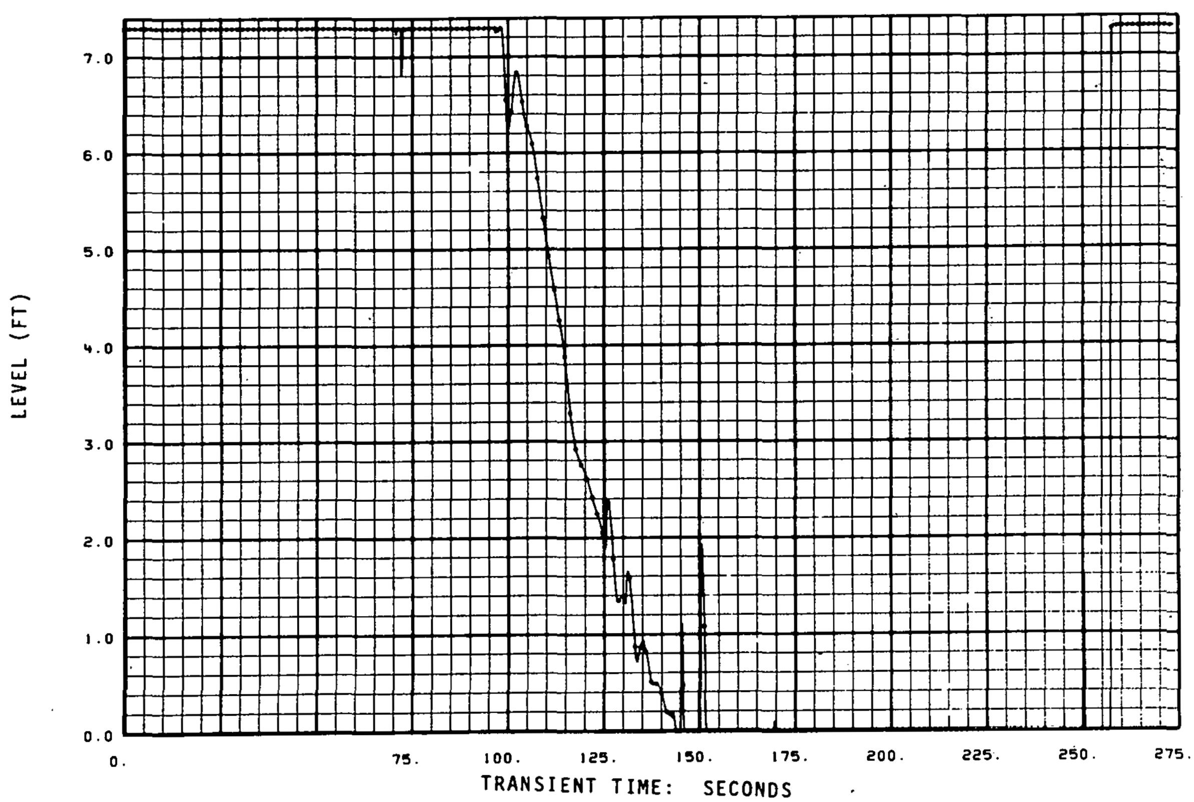

Fig. F-11 Core mixture level - Semiscale (6% break).

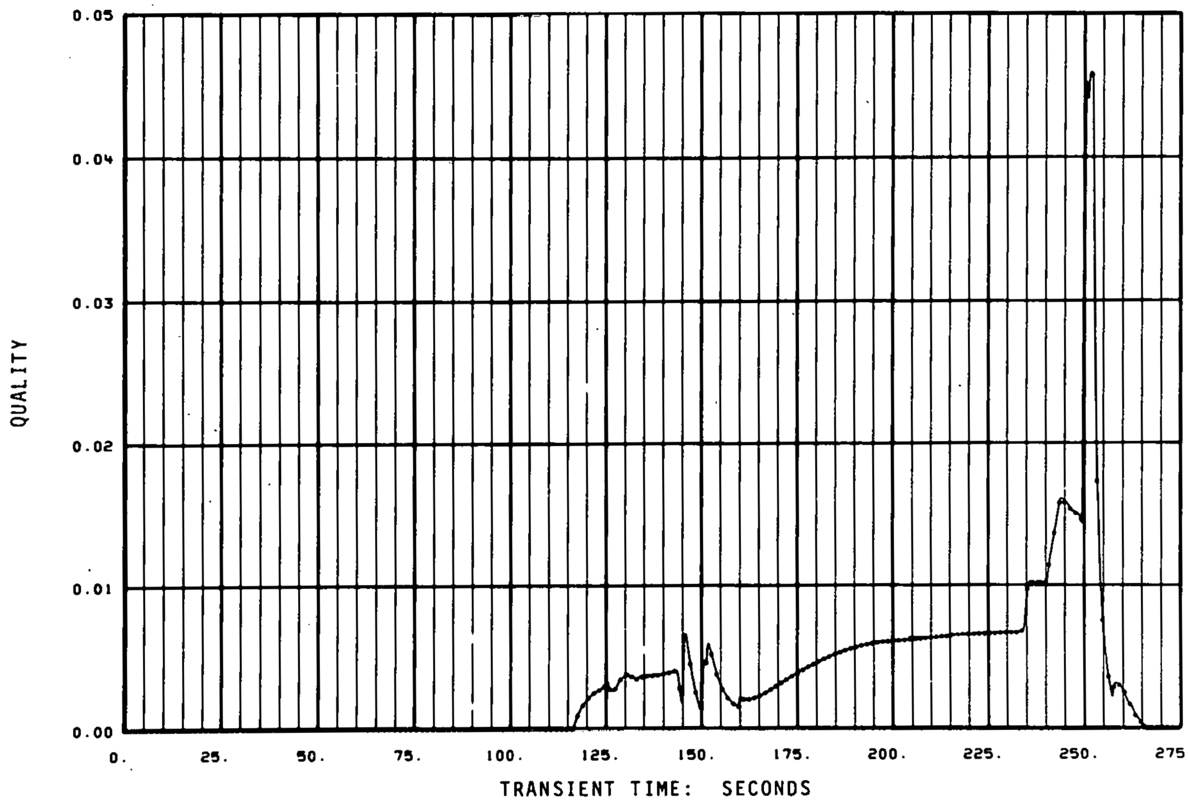

Fig. F-12 Average lower plenum quality - Semiscale (6% break).

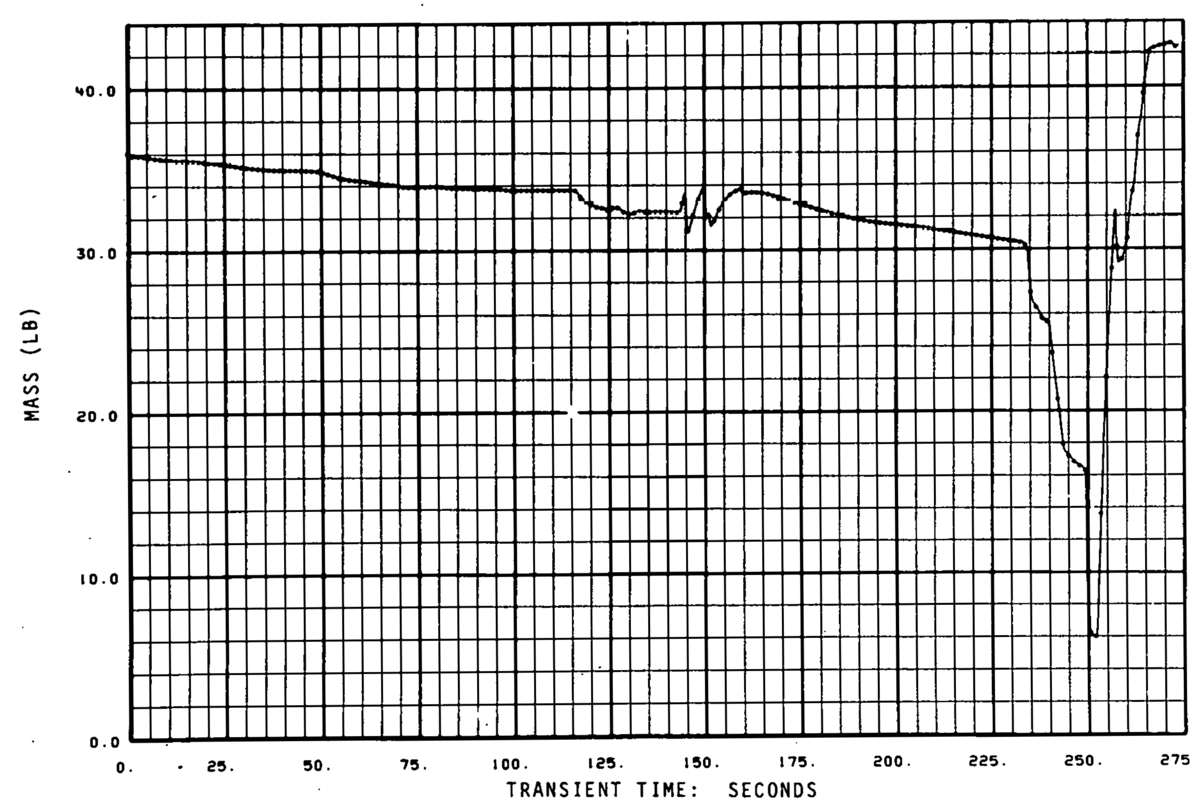

Fig. F-13 Lower plenum total mass - Semiscale (6% break).

6. SEMISCALE TEST FACILITY

The Semiscale Test Facility is shown in Figure F-13 for the 1-1/2 Loop Mod-1 configuration modeled for this RELAP4/MOD5 problem run. The Semiscale facility is an operating scale model that is used to simulate nuclear reactor plants, generally in Loss of Coolant Accident (LOCA) experiments. The Semiscale facility generates heat in the modeled reactor vessel through the use of electrically heated rods rather than fuel elements. It also has heat transfer by means of cooling water circulation through the steam generator secondary rather than by vapor generation.

The operating loop (shown with pressurizer, steam generator, and primary coolant pump) is generally modeled to represent the intact loop or loops of a reactor coolant system. The broken loop is modeled with components that hydraulically simulate a steam generator and loop pump. The breaks are simulated by rupture assemblies having controlled characteristic quick opening values. The blowdown is discharged into a header that conducts the vapor and water mixture to a collection vessel. This vessel has a controllable internal spray for vapor condensation. The combination of the header, vessel, and spray simulate the postulated backpressure of LOCA discharge into the containment of the plant modeled.

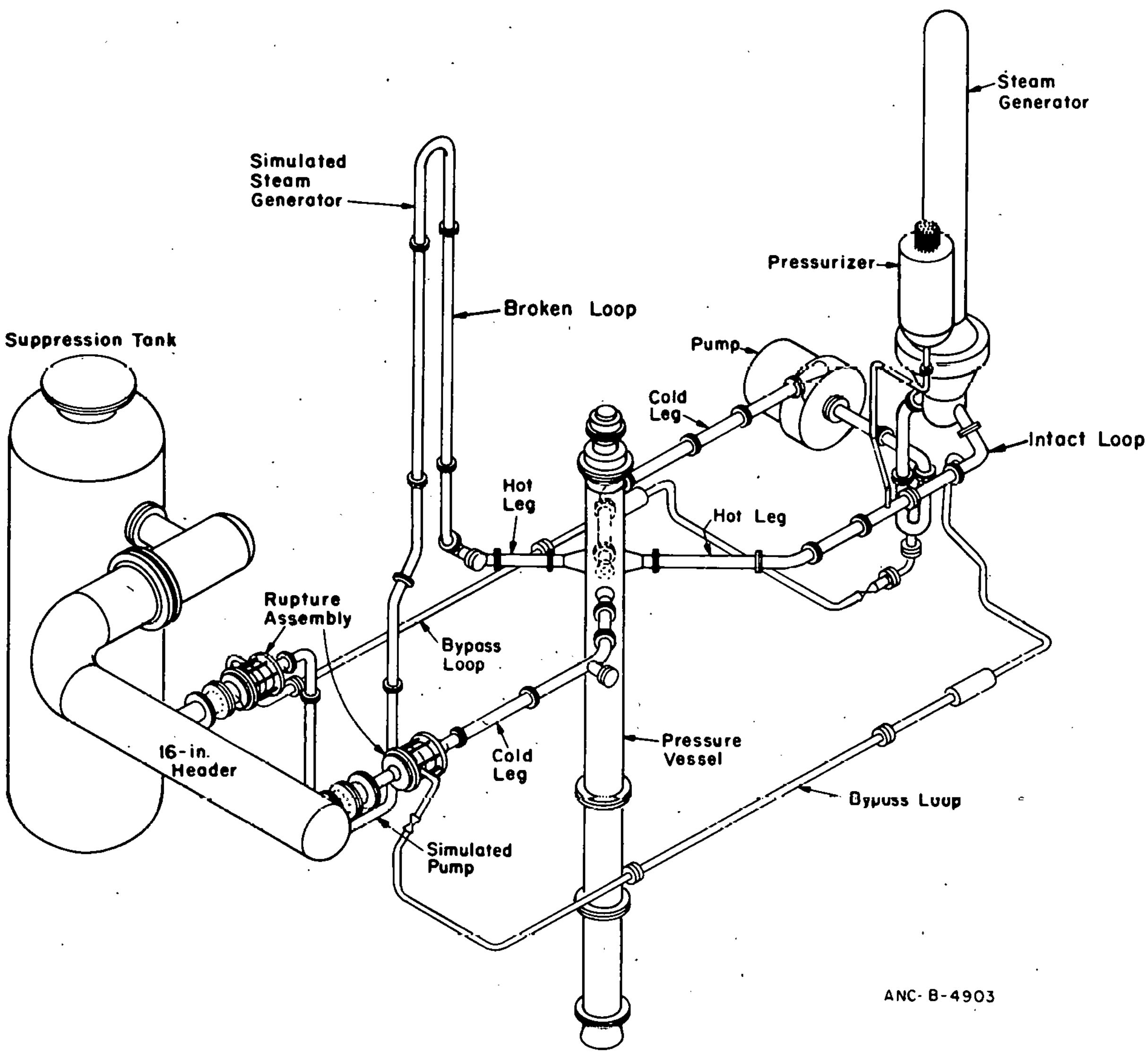

Fig. F-14 Semiscale Facility

7. INPUT LISTING

An input listing for this run is given in Table F-II, which follows.

TABLE F-II

INPUT LISTING

```
=SMBK RUN 2A SEMISCALE SMALL BREAK MODEL; ISER & MOD005 CHECKOUT
010001 -2  9  1  7  16  3  0  20  1  4  2  4  12  3  4  3  0  0
010001 -2  9  1  7  15  3  0  20  1  3  3  4  12  3  4  3  0  0
010002      1.6000           1.00
020000  JW 15,  JH 15,  JC 15,  AP 11,  AP 14, PT 9,  ML 4,  AT 3,  AP 2
020000  JW 15,  JH 15,  JC 15,  AP 11,  ML 2,  ML 3,  ML 4,  AT 3,  AP 2
030003   50   0.0   1000.
030004   50   70.0
030010   1   25   1   0   .2   .001    1000.          *TIME STEP
040010     1   1     0     0   10.      0.00    *  END OF PROBLEM TIME TRIP
040010     1   1     0     0   400.0    0.00    *  END OF PROBLEM TIME TRIP
040020     2   1     0     0     0.00   0.01    *  BREAK OPENING TRIP
040030     3  -4    14     0 1800.00   25.00    *  HPIS START TRIP
040040     4   1     0     0 1000.00    0.00    *  LONG DELAY TRIP(CLOSED VAL)
040050     5  +4    15     0 1200.00    0.00    *  STEAM GENERATOR PRESS TRIP
040060     6   1     0     0   60.00    0.00    *  PRESSURIZER CUTOFF TRIP
040070     7  -4    14     0 1800.00    0.00    *  SCRAM AND PUMP-CUTOFF TRIP
* S.G. SEC. INLET AND OUTLET FLOWS TRIP ON SCRAM WITH BUILT IN 1 SEC. DELAY
*  VOLUME INPUT  DATA
*VOLUME  * BUBBLE * IREAD *  AVERAGE    *   AVERAGE    * AVERAGE * *  COMMENTS
*NUMBER  *  INDEX  *  TDVI *  PRESSURE   * TEMPERATURE * QUALITY * * JUNCT  H.S.
050011      0        0       2272.3246     544.0000      -1.0     *
050021      1        0       2274.4749     544.0000      -0.1     *
050031      1        0       2270.4720     578.777       -0.1     *
050031      1        0       2270.4720     578.394       -0.1     *
050041      1        0       2265.3073     610.59400     -0.1     *
050041      1        0       2265.3073     609.82900     -0.1     *
050051      0        0       2261.750      610.59408     -0.1     *
050051      0        0       2261.750      609.82908     -0.1     *
050061      1        0       2253.8904     595.0710      -0.1     *
050061      1        0       2253.8904     594.4840      -0.1     *
050071      1        0       2252.1380     561.5060      -0.1     *
050071      1        0       2252.1380     561.3030      -0.1     *
050081      1        0       2249.3460     543.7360      -0.1     *
050091      1        0       2262.9930     543.7360      -0.1     *
050101      0        0       2274.9659     544.0000      -0.1     *
050111      0        0       2270.2104     544.0000      -0.1     *
050121      2        0        612.000       85.           0.0     *
050131      2        0        612.000       85.           0.0     *
050141      1        0       2261.5192      -1.0          0.0     *
050151      3        0         00.000      519.644        0.170   *
*  VOLUME  DATA  CARD NUMBER  TWO (2)    SEMISCALE ISER SMALL BREAK MODEL
*VOLUME * VOLUME *  VOLUME  * MIXTURE *FRIC* FLOW *  EQUIV.  * BOTTOM    *VOLUME
*NUMBER * CU.FT. *HEIGHT FT *LEVEL FT *INDX* AREA * DIAMETER * ELEVATION *BELOW
050012    0.9460  1.41210+1  1.41210+1  0  0.0574   0.09217    -1.3610+1    0
050022    0.763   2.408      2.408      0  0.2383   0.5508     -16.008      3
050032    0.3875  7.2973     7.2973     0  0.0557   0.0403     -13.600      4
050042    0.8672  9.65270    9.65270    0  0.0612   0.0489     -6.3027      0
050052    0.4130  0.69770    0.69770    0  0.0376   0.2188      0.5990      0
050062    0.72095 1.01983+1  1.01983+1  0  0.0476   0.0386      1.2967      0
050072    0.72095 1.01983+1  1.01983+1  0  0.0476   0.0386      1.2967      0
050082    0.366   9.472      9.472      0  0.0376   8.2185     -8.175       7
050092    0.491   8.4455     8.4455     0  0.0468   0.01979    -8.1755      0
050102    0.3322  0.43780    0.43780    0  0.0378   0.2188      0.1094      0
050112    0.211   0.2188     0.2188     0  0.02423  0.15001    -0.2188      0*C2
050122    2.9630  3.3380     2.1300     0  1.0000   1.0000      0.0000      0
050132    0.9880  2.9650     1.8310     0  1.0000   1.0000      0.0000      0
050142    0.9780  3.83330    2.12       0  0.2551   0.11456     0.5000      0
050152    7.0000  1.55200+1  9.66000    0  0.0400   0.0420      2.4950      0
060011  0.0  3.0
060021  0.0  1.0+6
060031  0.0   40.0
```

TABLE F-II (contd.)

```
*      JUNCTION    INPUT    DATA    CARD    (ONE)
*JUNC *VOL.*VOL.*PUMP *VALVE* FLOW   * FLOW   *JUNCT. * JUNCTION *FORWARD*REVERSE*
*TION *FROM* TO *INDEX*INDEX* RATE   * AREA   *ELEVAT.* INERTIA  *LOSCOEF*LOSCOEF*
*NUMB.* IW1* IW2*IPUMP*IVALVE*  WP    * AJUN   *ZJUN   * INERTA   * FJUNF * FJUNR *
080011   1    2    0     0    17.25    .04684 -13.61     0.0      1.026971 .69551
080021   2    3    0     0    17.25    .03142 -13.600    0.0        3.15134 3.15134
080031   3    4    0     0    17.25    .0514    -6.3027  0.0      6.91625 6.91625
080041   4    5    0     0    17.25    .0205      .599   0.0        1.25644 1.6064
080051   5    6    0     0    17.25    .03755    1.2967  0.0      9.53112 10.32821
080061   6    7    0     0    17.25    .0476    11.372   0.0      .002727 .002727
080071   7    8    0     0    17.25    .0376     1.2967  0.0      10.32821 9.53112
080081   8    9   -1     0    17.25    .03766   -8.0663  0.0        .11091 .11091
080091   9   10    1     0    17.25    .0376      .2188  0.0        .11334 .11334
080101  10    1    0     0    17.25    .0378      .2188  0.0      9.58567 9.58567
080111   1   11    0     0     0.00    .01964   -.1094   0.0      9.5857  9.5857
080121  12   10    0     2     0.00    .00499    .1094   8000.  211.      211.
080131  13   11    0     3     0.00   .003      0.0000   8000. 686.     686.
080141  14    5    0     4     0.00    .00046     .6     38.5      8.8      8.8
080141  14    5    0     1     0.00    .00046     .6     38.5      8.8      8.8
080151  11   16    0     1     0.00    .000156  -.1000   0.0       0.0      0.0
080151  11  0   3   0   0.   .000156    -.1    182.5   1.446    1.446
080161   0   10    1     0     0.00    .00499    .1094   0.0       0.752    0.39
080171   0   11    2     0     0.00    .005      0.000   0.0       0.752    0.39
080181   0   15    3     0     1.466   .012       2.5    0.0       0.752    0.39
080191  15    0    1     0     1.466   .021     15.4000  0.0    1554.9   1564.9
080201   0   15   4   0    0.    .021     15.4    0   0.    0.
080012   0    5   2   3   0.0   0.0   0   0   1.0   0
080022   0    5   2   3   0.0   0.0   0   2   1.0   0
080032   0    5   2   3   0.0   0.0   0   1   1.0   0
080042   1    5   2   3   0.0   0.0   0   0   1.0   0
080052   1    5   2   3   0.0   0.0   0   2   0.0   0
080062   1    5   2   3   0.0   0.0   0   3   0.0   0
080072   1    5   2   3   0.0   0.0   0   1   1.0   0
080082   1    5   2   3   0.0   0.0   0   0   0.0   0
080092   1    5   2   3   0.0   0.0   0   0   0.0   0
080102   1    5   2   3   0.0   0.0   0   0   0.0   0
080112   1    5   2   3   0.0   0.0   0   0   0.0   0
080122   1    5   0   3   0.0   0.0   0   0   0.0   0
080132   1    5   0   3   0.0   0.0   0   0   0.0   0
080142   0    5   0   3   0.0   0.0   0   0   0.0   0
080152   1    5   3   0   0.0   0.0   0   0   0.0   0
080152   1    5   0   0   0.0   0.0   0   0   0.0   0
080162   0    5   2   3   0.0   0.0   0   0   0.0   0
080172   0    5   2   3   0.0   0.0   0   0   0.0   0
080182   0    5   2   3   0.0   0.0   0   0   0.0   0
080192   0    5   2   3   0.0   0.0   0   0   0.0   0
080202   0    0   2   0   0.    0.    0   0   0.    0
082000   0
082003   1.0   0.9   0.9   0.01
090011   1  7  1  1  0   3560.   .73835 180. 192. 34.8  38.3   62.3  0. 0. 6.7
091001 -11 0. 0. .1 0. .15 .05 .24 .8 .3 .96 .4 .98 .6 .97 .8 .9 .9 .8 .96 .5
091002 1. 0.
092001 -9 0. -.17 .0001 -.17 .006 0. .1 0. .15 .05 .24 .56 .8 .56 .96 .45 1. 0.
100000  16  0  0  16
*               PUMP HEAD AND TORQUE MULTIPLIER CURVES
101011 1 1 -2 0. 1.2 1. 1.
101021 1 2 -5 0. -0.35 0.3 -0.2 0.5 0.0 0.8 0.545 1.0 1.0
101031 1 3 -5 -1. 1.5 -.8 1.275 -.6 1.375 -.4 1.375 0. 1.2
101041 1 4 -6 -1. 1.5 -.8 1.15 -0.6 0.95 -0.4 0.83 -0.2 0.775 0.0 0.725
101051 1 5 -3 0. .975  0.5 1.35 1. 1.95
```

TABLE F-II (contd.)

```
101061 1 6 -5  0. .725  0.2 .725  .4  .8  .6 1.025 1. 1.95
101071 1 7 -3 -1.0 0.175 -0.50 0.65 0.0 .975
101081 1 8 -5 -1.0 0.175  -0.75 -.15 -.55 -0.3 -.275 -.4 0. -0.35
101090   2 1 -8       0. 0.54  0.2 0.59  0.4 0.65  0.6 0.77  0.8 0.95
101091                0.9 0.98  0.95 0.96  1.0 0.87
101100   2 2 -8       0. -0.15  0.2 0.02  0.4 0.22  0.6 0.46  0.8 0.71
101101                0.9 0.81  0.95 0.85  1.0 0.87
101110   2 3 -6       -1.0 0.62  -0.8 0.68  -0.6 0.53  -0.4 0.46
101111                -0.2 0.49  0. 0.54
101120   2 4 -6       -1.0 0.62  -0.8 0.53  -0.6 0.46  -0.4 0.42
101121                -0.2 0.39  0. 0.36
101130   2 5 -7       0. -0.63  0.2 -0.51  0.4 -0.39  0.6 -0.29
101131                0.8 -0.20  0.9 -0.16  1.0 -0.13
101140   2 6 -6       0. 0.36  0.2 0.32  0.4 0.27  0.6 0.18
101141                0.8 0.05  1.0 -0.13
101150   2 7 -6       -1.0 -1.44  -0.8 -1.25  -0.6 -1.08
101151                -0.4 -0.92  -0.2 -0.77  0. -0.63
101160   2 8 -6       -1.0 -1.44  -0.8 -1.12  -0.6 -0.79
101161                -0.4 -0.52  -0.2 -0.31  0. -0.15
104011 1 1 7 0. 0. .1 .83 .2 1.09 .5 1.02 .7 1.01 .9 .94 1. 1.
104021 1 2 8 0. 0. .1 -.04 .2 0. .3 .1 .4 .21 .8 .67 .9 .8 1. 1.
104031 1 3 10 -1. -1.16 -.9 -1.24 -.8 -1.77 -.7 -2.36 -.6 -2.79 -.5 -2.91
104032  -.4 -2.67 -.25 -1.69 -.1 -.5 0. 0.
104041 1 4 10 -1. -1.16 -.9 -.78 -.8 -.5 -.7 -.31 -.6 -.17 -.5 -.08 -.35 0.
104042     -.2 .05 -.1 .08 0. .11
104051 1 5 6 0. 0. .2 -.34 .4 -.65 .6 -.93 .8 -1.19 1. -1.47
104061 1 6 10 0. .11 .1 .13 .25 .15 .4 .13 .5 .07 .6 -.04 .7 -.23 .8 -.51
104062   .9 -.91 1. -1.47
104071 1 7 2 -1. 0. 0. 0.
104081 1 8 2 -1. 0. 0. 0.
104090   2 1 -8       0. 0.54  0.2 0.59  0.4 0.65  0.6 0.77  0.8 0.95
104091                0.9 0.98  0.95 0.96  1.0 0.87
104100   2 2 -8       0. -0.15  0.2 0.02  0.4 0.22  0.6 0.46  0.8 0.71
104101                0.9 0.81  0.95 0.85  1.0 0.87
104110   2 3 -6       -1.0 0.62  -0.8 0.68  -0.6 0.53  -0.4 0.46
104111                -0.2 0.49  0. 0.54
104120   2 4 -6       -1.0 0.62  -0.8 0.53  -0.6 0.46  -0.4 0.42
104121                -0.2 0.39  0. 0.36
104130   2 5 -7       0. -0.63  0.2 -0.51  0.4 -0.39  0.6 -0.29
104131                0.8 -0.20  0.9 -0.16  1.0 -0.13
104140   2 6 -6       0. 0.36  0.2 0.32  0.4 0.27  0.6 0.18
104141                0.8 0.05  1.0 -0.13
104150   2 7 -6       -1.0 -1.44  -0.8 -1.25  -0.6 -1.08
104151                -0.4 -0.92  -0.2 -0.77  0. -0.63
104160   2 8 -6       -1.0 -1.44  -0.8 -1.12  -0.6 -0.79
104161                -0.4 -0.52  -0.2 -0.31  0. -0.15
110010  -2   0   1   0.   0.   0.   0.            *BREAK VALVE
110010  6    2      0.0    0.0    0.0    0.0    0.0  *PRESSURIZER CUT-OFF VALVE
110020   21  0   0   0.   0.     1.0+20   1.0+20  *ACCUM CHECK VALVE (ACTIVE)
110030   21  0   0   0.   0.     1.0+20   1.0+20  *ACCUM CHECK VALVE (INACTIVE)
120101  -4   2   0.   0.   1.   10.  1.   11.  0.0     600.   0.0 *S G SEC LEAK
120201  -3   6   0.0   0.0  1.0   .1  0.0  10.0+4  0.0 *PRESS VALVE LEAK TABLE
120301  -4   2   40.   0.   0.   .001   0.   .002   1.0   1000.  1.
130100   3    1    2    3   GAL/MIN    85.0    0.0  * HPIS INJECTION TABLE-FILL
130101  0.0  101.803  1.0+4  101.803              * HPIS INJECTION TABLE-FILL
130200   3    1    2    3   GAL/MIN    85.0    0.0  * HPIS INJECTION TABLE-FILL
130201  0.0  33.93 1.0+4  33.93
130300  2  1  4  4  LBS/SEC  900.0  440.0   0.0  *S.G.SEC. INLET-FILL
130301  0.0  162.25  10.  162.25  11.  0.0  1.0+3  0.0
130400    5 2 15 4 LBS/SEC 50. 250.
```

TABLE F-II (contd.)

```
                                                                       * ST GEN RLF - FILL
130401 1000. 0.  1200. 0. 1210. -5.714 1220. -17.143 1230. -34.286 1236. -48.0 5
130402 1246.3 -65.714 1250. -69.524 1256.6 -80.952 1264. -89.048 1265. -91.905
130403 1266.9 -92.381 1270. -93.810 1287.5 -103.810 1500. -171.905
140000  0  0.0   0.0   0.0   0.0
141001  -19  7      0.0  1.0    1.0  .96    2.0  .928    3.0  .86    4.0   .81
141002   6.0     .70      7.0   .625    9.0   .5  10.0  .44  11.0  .39
141003  12.0  .36  14.0  .25   15.0  .23  16.0  .2  18.0  .16
141004   20.0  .13  24.0  .1   34.0  .075  500.0  .038
* HEAT SLAB DATA CARDS      CARD #1
* HEAT * VOL *PHYSICAL* HEAT TRANSFER INFO.   * VOLUME *
*SLAB *IV*IL*IG*IS*IX*IM*IM*  ASUL  *  ASUR  *  VOLS  *HDML*HDMR*DHEL*DHER*
*NUMBER*SL*SR*OM*B *LO*CL*CR*SQ. FEET*SQ. FEET*CU. FEET*    *    *    *    *
150011   0  3  1  0  2  0  0  0.0        8.1317 0.071448  0.0 .0361 0.0  0.0465
150021   0  3  1  1  2  0  0  0.0        8.1317 0.071448  0.0 .0361 0.0  0.0465
150031   0  3  1  1  2  0  0  0.0        8.1317 0.071448  0.0 .0361 0.0  0.0465
150041   0  4  1  1  2  0  0  0.0       38.3920 0.337500  0.0 .0361 0.0  0.0
150051   5  0  2  0  0  0  0  7.5700     0.0    0.643600  0.0  0.0  0.0  0.0
150061   6 15  2  0  3  0  0 47.8805    59.5528 0.219340  0.0  0.0  0.0  0.0
150071   7 15  2  0  3  0  0 47.8805    59.5528 0.219340  0.0  0.0  0.0  0.0
150081   8  0  2  0  1  0  0  12.330     0.0    1.040800  0.0  0.0  0.0  0.0
150091  10  0  2  0  1  0  0  5.4400     0.0    0.463000  0.0  0.0  0.0  0.0
150101   1  0  3  0  1  0  0 10.8750     0.0    1.464000  0.0  0.0  0.0  0.0
150111   2  0  3  0  1  0  0 10.8750     0.0    1.464000  0.0  0.0  0.0  0.0
150121  11  0  2  0  1  0  0  6.9110     0.0    0.475200  0.0  0.0  0.0  0.0
*HEAT SLAB DATA CARDS      CARD #2
*HEAT   * LEFT   * RIGHT * BOTTOM*  TOP   *
*SLAB   * LENGTH* LENGTH*ELEVAT.*ELEVAT.*
*NUMBER* 'CHNL *  CHNR * ZBOT   * ZTOP   *
150012   0.0      5.5202  1.7773  3.6173
150022   0.0      5.5202  3.6173  5.4573
150032   0.0      5.5202  5.4573  7.2972
150042   0.0      0.0     0.0     0.0
150052   8.0      0.0     0.0     0.0
*   JUNCTION OVER LAP OF 0.001 FEET  SLAB CAM NOT BE IN JUNCTION
150062   8.998    8.998   0.001    8.998
150072   8.998    8.998   0.001    8.998
150082   0.0      0.0     0.0     0.0
150092   7.0      0.0     0.0     0.0
150102   0.0      0.0     0.0     0.0
150112   0.0      0.0     0.0     0.0
150122   0.0      0.0     0.0     0.0
* CORE   *     *NODE NUMBERS* CLAD * POWER    * MODERATOR *
*SECTION*      *FOR TEMP CAL*THICK * FRACTION*  HEATING   *
* DATA   *ISLB*    NODT     * CLTI * QFRAC    *QPMOD*QDMOD*
160010     1       2   6      10    0.0  0.36636   0.0    0.0          * LOWER CORE
160020     2       2   6      10    0.0  0.47254   0.0    0.0          * MID CORE
160030     3       2   6      10    0.0  0.16110   0.0    0.0          * UPPER CORE
* CORE SLABS: GEOM=1, MTRL=1,2,3
170101 2 4 1 1 0. .002917 0.
170102 0 3 4 .007167 1.
170103 0 1 4 .00425 0.
170104 0 2 8 .00325 0.
* SG SLABS: GEOM=2, MTRL=2
170201 2 1 2 5 .01675 .004 0.
170301  2  3  2  3  0.2750  0.0104  0.0
170302  0  4  2  0.004  0.0
170303  0  2  3  0.094  0.0
180101     -7          500. 16.6  1000. 15.9  1500. 15.3  2000. 14.7
180102                 2500. 14.1  3000. 13.5  3500. 12.8      *BORON NITRATE
180201     -3          100. 7.75  800. 11.0  1600. 14.3        *316L STAINLESS
```

TABLE F-II (contd.)

```
180301    -2        0. 14.0  3000. 14.0                          *CONSTANTAN
180401  -2  0.0  0.013  2000.0  0.05
190101    -7        400. 37.5  800. 48.3  1200. 54.6  1600. 58.3
190102              2000. 60.5  2400. 61.4  3400. 62.5     * BORON NITRATE
190201    -4        400. 61.3  600. 64.6  800. 67.1  2200.  82.9  * 316L SS
190301    -7        212. 56.  572. 61.  932. 67.  1472. 73.
190302              2192. 78.  2552. 84.  3000. 90.          *CONSTANTAN
190401  -2  0.0  0.2  2000.0  0.2
080152   1   4   0   0   0.0   0.0   1   0   0.0   0
```

REFERENCE

F-1. System Design Description for the 1-1/2 Loop Mod-1 Semiscale System, Revision M, ANC SDD1, Aerojet Nuclear Company (June 1975) p II-231.

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APPENDIX G

LARGE COLD LEG BREAK - INEL LOFT

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APPENDIX G

LARGE COLD LEG BREAK - INEL LOFT

1. INTRODUCTION

The LOFT system was modeled to represent a 200% offset shear break in the blowdown loop cold leg piping between the pump simulator and the reactor vessel inlet. While the initial conditions chosen for the model were typical of planned LOFT test conditions, the model was not intended to represent any specific LOFT test. The system model and assumptions used, the calculated results, and the conclusions drawn from this run are presented. Some interpretation of the results is based on digital data and plots which were too voluminous to be included in this appendix. The model presented was used for program checkout and should not be considered a comprehensive study of the LOCA response of the LOFT plant.

2. SYSTEM MODEL AND ASSUMPTIONS

The RELAP4/MOD5 model used to describe the LOFT system is shown in Figure G-1. It consisted of 34 volumes, 40 junctions, and 19 heat slabs. The volumes and fill junctions shown in Figure G-1 are identified in Table G-I. The heat slabs shown in Figure G-2 are in turn identified in Table G-II.

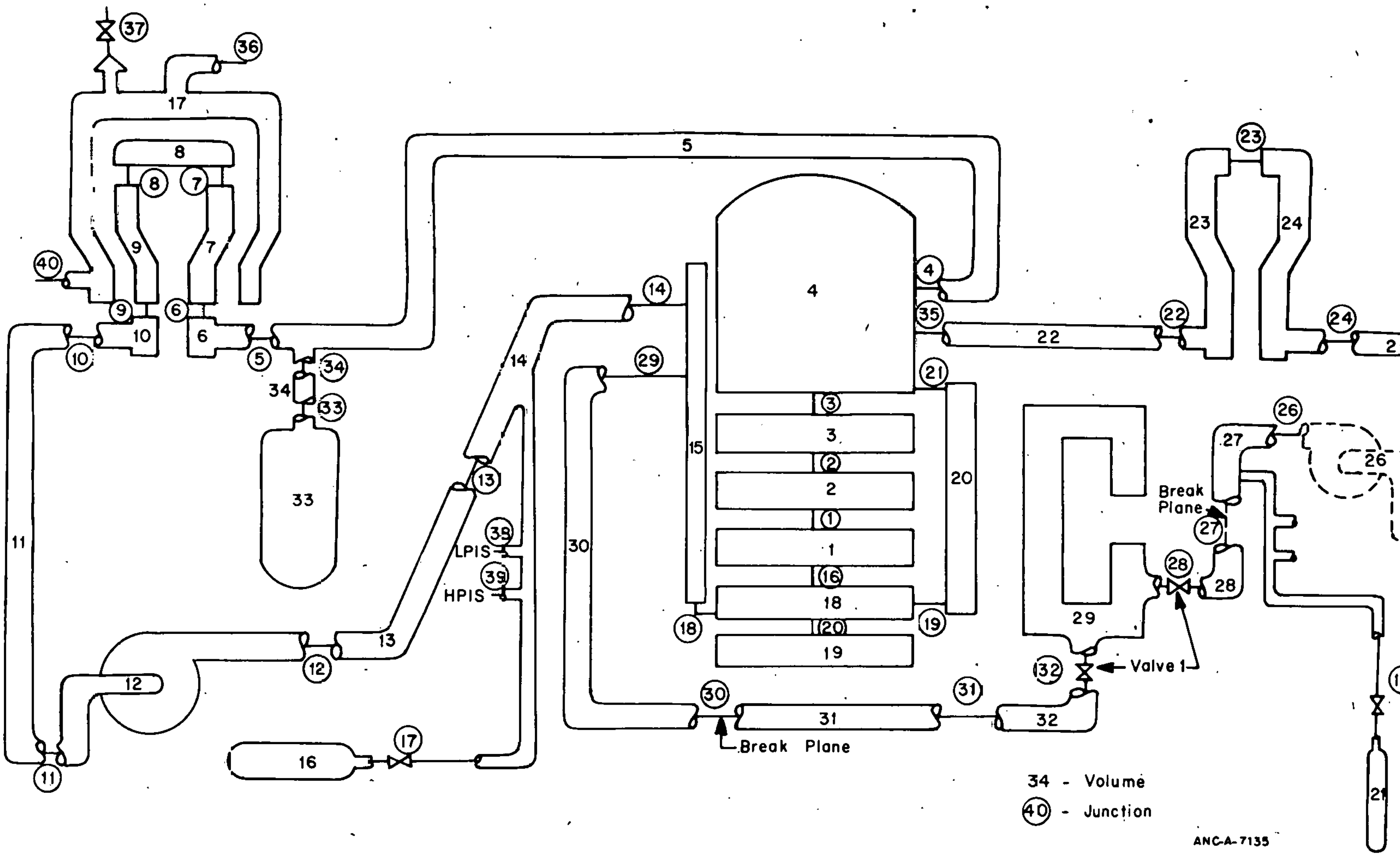

Fig. G-1 Nodalization for 200% cold leg break - LOFT.

TABLE C-I

VOLUME AND FILL JUNCTION IDENTIFICATION FOR 200% BREAK - LOFT

Volume No.	Description
1	Lower Section of Core
2	Middle Section of Core
3	Top Section of Core
4	Upper Plenum
5,11,13,14	Intact Loop Piping
6	Steam Generator Inlet Plenum
7,8,9	Steam Generator Primary
10	Steam Generator Outlet Plenum
12	Pump Volume
15	Upper Annulus and Downcomer
16	Intact Loop Accumulator
17	Steam Generator Secondary
18	Top Section of Lower Plenum
19	Bottom Section of Lower Plenum
20	Core Bypass
21	Inactive Accumulator (Outlet Valve Closed)
22,25,27,30,31	Blowdown Loop Piping
23,24	Steam Generator Simulator
26	Pump Simulator
28,32	Suppression Tank Inlet Piping
29	Suppression Tank
33	Pressurizer
34	Pressurizer Line

Junction No.	Description
38	Low Pressure Injection System
39	High Pressure Injection System
40	Steam Generator Secondary Inlet
36	Steam Generator Secondary Outlet (Negative Fill)
37	Steam Generator Secondary Relief Valve (Negative Fill)

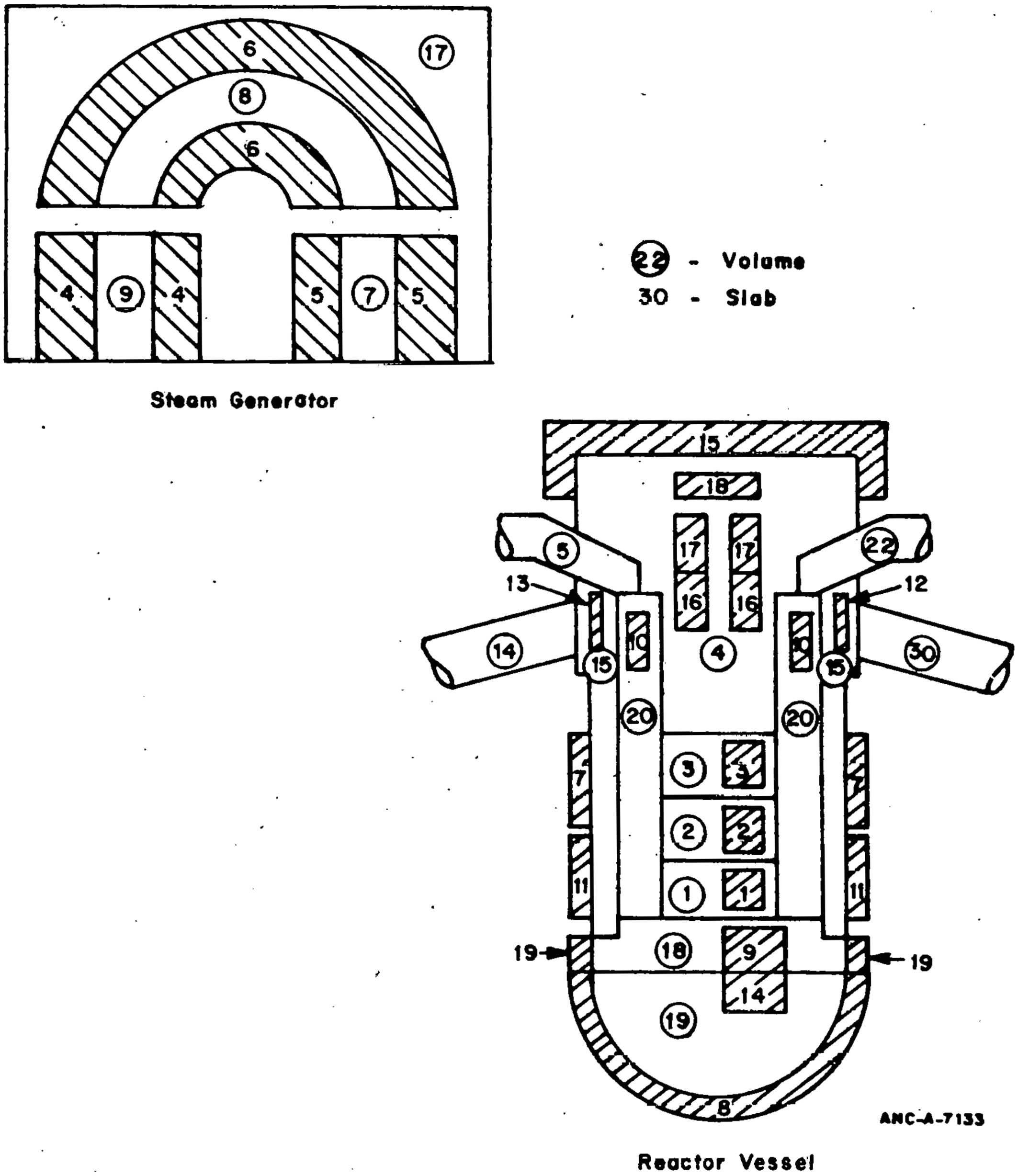

Fig. G-2 Heat slabs for 200% break - LOFT.

TABLE G-II

HEAT SLAB IDENTIFICATION FOR 200% COLD LEG BREAK - LOFT

Heat Slab No.	Adjacent Volume[a] Left	Right	Heat Slab Identification
1	0[b]	1	Fuel Rods (lower 1/3)
2	0	2	Fuel Rods (middle 1/3)
3	0	3	Fuel Rods (top 1/3)
4	9	17	Steam Generator Tubes (outlet)
5	7	17	Steam Generator Tubes (inlet)
6	8	17	Steam Generator Tubes (middle)
7	15	0	Downcomer Inside Barrel
8	19	0	Reactor Filler
9	0	18	End Box
10	20	0	Core Bypass
11	0	15	Downcomer Outside Barrel
12	0	15	Reactor Filler
13	15	0	Reactor Filler
14	0	19	Core Support Structure
15	4	0	Upper Plenum Top and Sides
16	4	0	Flow Skirt and Core Filler
17	4	0	Shell and Outlet Region
18	4	0	Supports and Control Rods
19	0	18	Reactor Vessel

[a] For cylindrical geometry, left is the inside surface and right is the outside surface.

[b] Zero represents the surface of Zero Heat Flux, e.g., insulated surface or center of slabs.

Fill junctions were used for the high and low pressure injection systems and steam generator secondary side flows. Initial power was specified at 100% of nominal power, or 55.7 MW(t). The major MOD5 options used in the run are summarized as follows:

(1) Downcomer Penetration Model Based on Battelle-Columbus Data: This model was turned on just prior to the accumulator valve opening. The downcomer and upper annulus were modeled as one volume to correspond to the noding required by the downcomer penetration model.

(2) Vertical Slip: This model was specified at Junctions 18 and 20 (between the downcomer and lower plenum and between the two sections of the lower plenum).

(3) Vertical Stacking: This slip flow and vertical stack index option was used at Junction 20 only, to insure that liquid descended to the lowest volume.

(4) Henry-Fauske/HEM Critical Flow Model: This option was used with multipliers of 0.9 for Henry-Fauske and 1.0 for Homogeneous Equilibrium Models (HEM), along with a transition quality of 0.01. The stagnation property option was not used.

(5) Bubble Rise: The RELAP4 bubble rise model with a bubble rise velocity of 3 ft/sec was used in Volumes 4, 17, 18, 19, and 33. A bubble rise velocity of 10^6 ft/sec was used in the accumulator (Volume 16), inactive accumulator (Volume 21), and suppression tank (Volume 29) in order to maintain continuous phase separation.

3. RESULTS

RELAP4/MOD5 ran quite smoothly and had a reasonable processing time. The transient time from break initiation to lower plenum refill was 35 sec and required 50 min of CPU time on the CDC 7600 at Brookhaven National Laboratory. Although the lower plenum was refilled at 35 sec, the problem was run for an additional 5 sec to verify that the lower plenum remained full. An additional 11.8 min (61.8 min total) of CPU time was required to extend the transient from 35 to 40 sec.

The major events that occurred during the course of the transient are given in Table G-III. The data output traces for this problem run are shown as Figures G-3 through G-12 in Section 5 of this appendix. A summary discussion of the transient is as follows.

The break plane junction (sizing orifices) and their downstream junctions choked immediately after the initiation of blowdown at 0.010 sec. All system volumes underwent a very rapid subcooled depressurization immediately after the opening of the break. The lower plenum depressurized from 2,260 psia to 1,600 psia in less than 0.2 sec as shown in Figure G-3. The system volumes experienced a gradual, saturated depressurization after this rapid, subcooled depressurization.

The digital data output showed that the pressurizer line flow choked at 3 sec and remained choked until 9 sec. The accumulator flow started at 14 sec. This injected 90°F water into the intact-loop volumes, having an initial temperature of 488°F and a pressure of 612 psia. The injection of this subcooled water caused condensation of the saturated vapor in the intact loop. This injection of subcooled water into volumes containing a saturated mixture, introduced transient effects noted in the digital output and which led to smaller time step requirements. These caused a marked increase in computer running time.

TABLE G-III

MAJOR EVENTS SUMMARY FOR 200% BREAK - LOFT

Time (sec)	Event
0.0	Start of run
0.01	Blowdown started, valves to suppression tank opened, scram began, and valves in steam generator secondary line began to close
0.06	Pump power shut off and pump began coastdown
10.29	Valves in steam generator secondary line closed completely
13.0	Peak cladding temperature of 1,185°F reached in mid-core cladding
14.0	Accumulator valve opened and accumulator flow began
25.01	High Pressure Injection System (HPIS) and Low Pressure Injection System (LPIS) started injection into intact loop cold leg
35.0	Lower plenum full of water and refill completed
40.0	End of problem run

The digital data output showed that flow from the pump and vessel sides of the break unchoked at 19 and 28 sec, respectively, and remained unchoked for the duration of the transient. Break flow rates are shown in Figures G-4 and G-5. The pump side of the break unchoked first, due to lower pressures on the pump side than on the vessel side of the break. These lower pressures on the pump side were caused by the pressure drop associated with the flow resistance of the steam generator simulator and pump simulator in the hot leg of the blowdown loop. The pressure in the suppression tank reached a maximum value of 65 psia at 28 sec when the vessel side of the break unchoked.

LPIS and HPIS began injecting water into the intact loop cold leg 25 sec after the initiation of blowdown. This delay time of 25 sec corresponds to the time required for a typical plant standby electrical generator to come on-line in the event that loss of electrical power were concurrent with initiation of the break.

Core inlet and outlet mass flow rates are shown in Figures G-6 and G-7, respectively. These figures show the immediate core flow reversal at break initiation which is characteristic of large cold leg breaks. This was followed by the expected rise to a relatively small positive core flow as the pumps took over. Accumulator ECC injection occurred at 14 sec and led to oscillations in core flow, particularly in the inlet flow which began at approximately 15 sec elapsed time. These oscillations persisted for the duration of the transient.

Figures G-8, G-9, and G-10 show cladding temperature in the three core volumes. Peak cladding temperatures reached in the lower, middle, and upper core regions were 985°F, 1,185°F, and 640°F, respectively. The shapes of the cladding temperature plots, particularly that of the lower core volume, can be correlated with the core flow behavior shown in Figures G-6 and G-7. The increased flows noted in G-6 and G-7 have corresponding decreased temperatures in G-8.

Figures G-11 and G-12, respectively, show the mass quantity in the upper and lower sections of the lower plenum. Large oscillations in total mass were seen to occur after 14 sec when accumulator injection began. The lower volume remained filled with water after 33 sec elapsed time and filling of the upper volume followed at 34 sec. This terminated the refill phase of the transient and met the program criterion for completion of the problem run. The calculation was continued to 40 sec elapsed time, however, to verify that the lower plenum remained full after 34 sec elapsed time. A further perturbation at 39 sec is shown in Figures G-4 and G-12. The increased flow and mass loss is attributed to bubble formation and collapse. The mass in the upper section of the lower plenum (Figure G-11) was only slightly affected by this.

4. CONCLUSIONS

The LOFT large break was run to completion without any major difficulty and within the established time limit of one hour on the CDC-7600 computer. The completion criteria for the MOD 5 checkout runs listed in Volume III, Section 7.2 were satisfied.

5. OUTPUT DATA

The output data traces are shown as Figures G-3 through G-12 in this section.

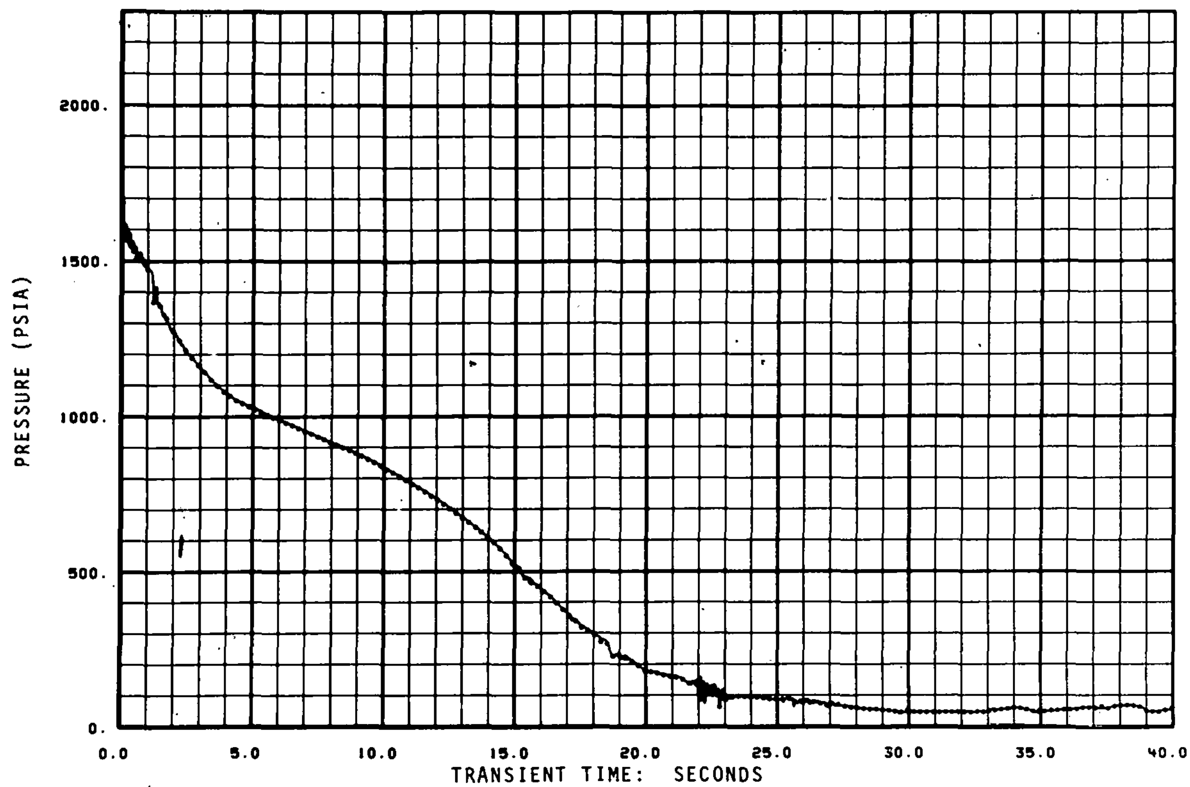

Fig. G-3 Lower Plenum pressure - LOFT (200% break).

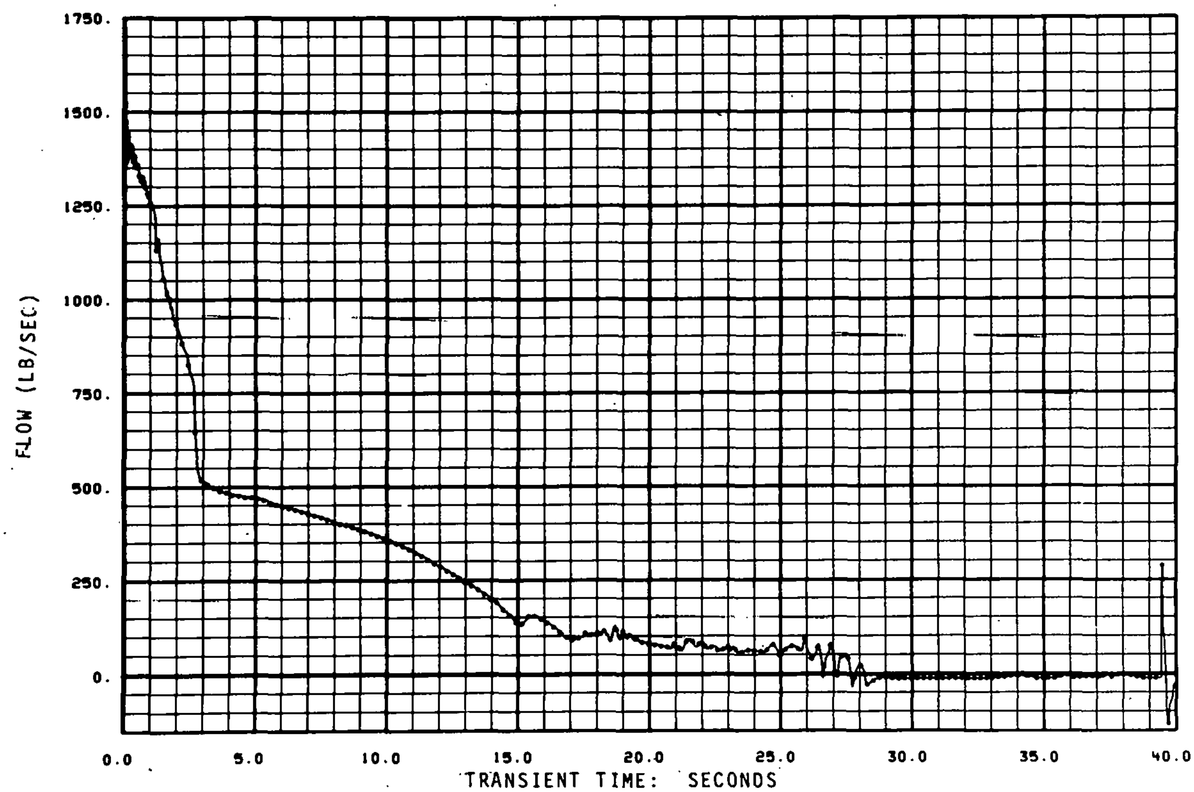

Fig. G-4 Vessel side break mass flow rate - LOFT (200% break).

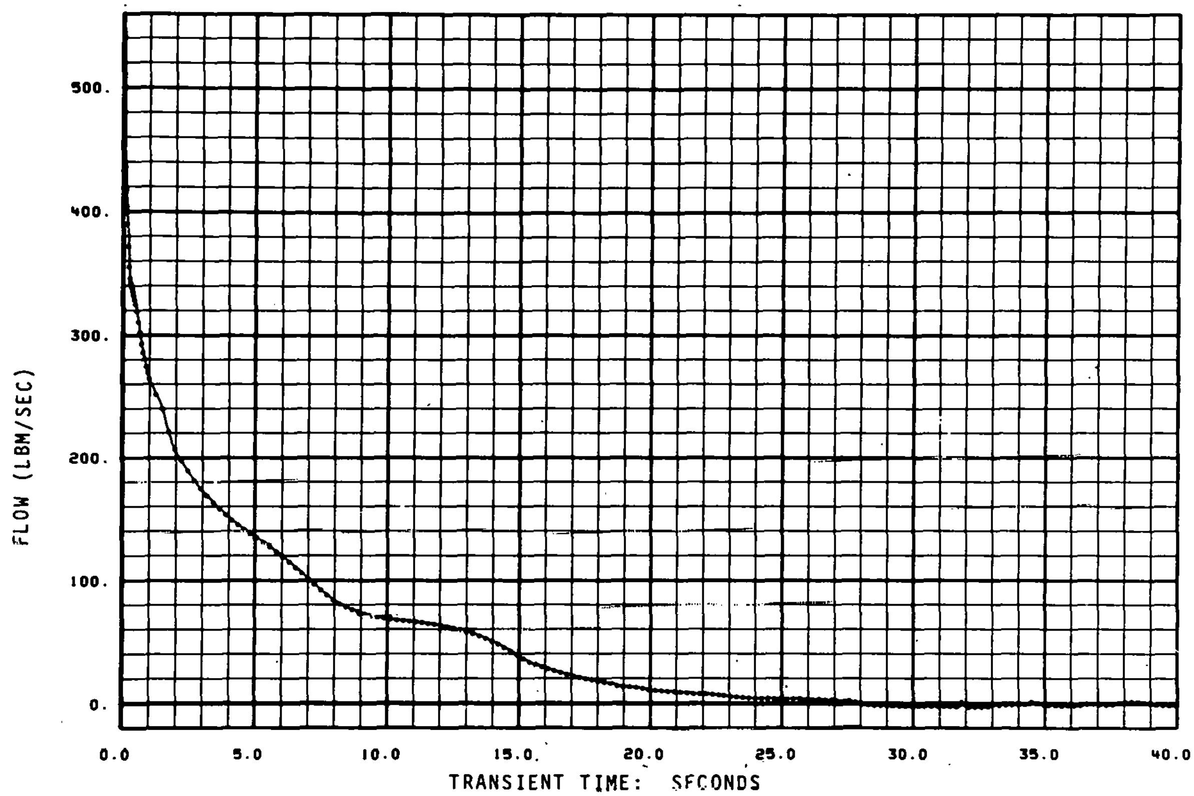

Fig. G-5 Pump side break mass flow rate - LOFT (200% break).

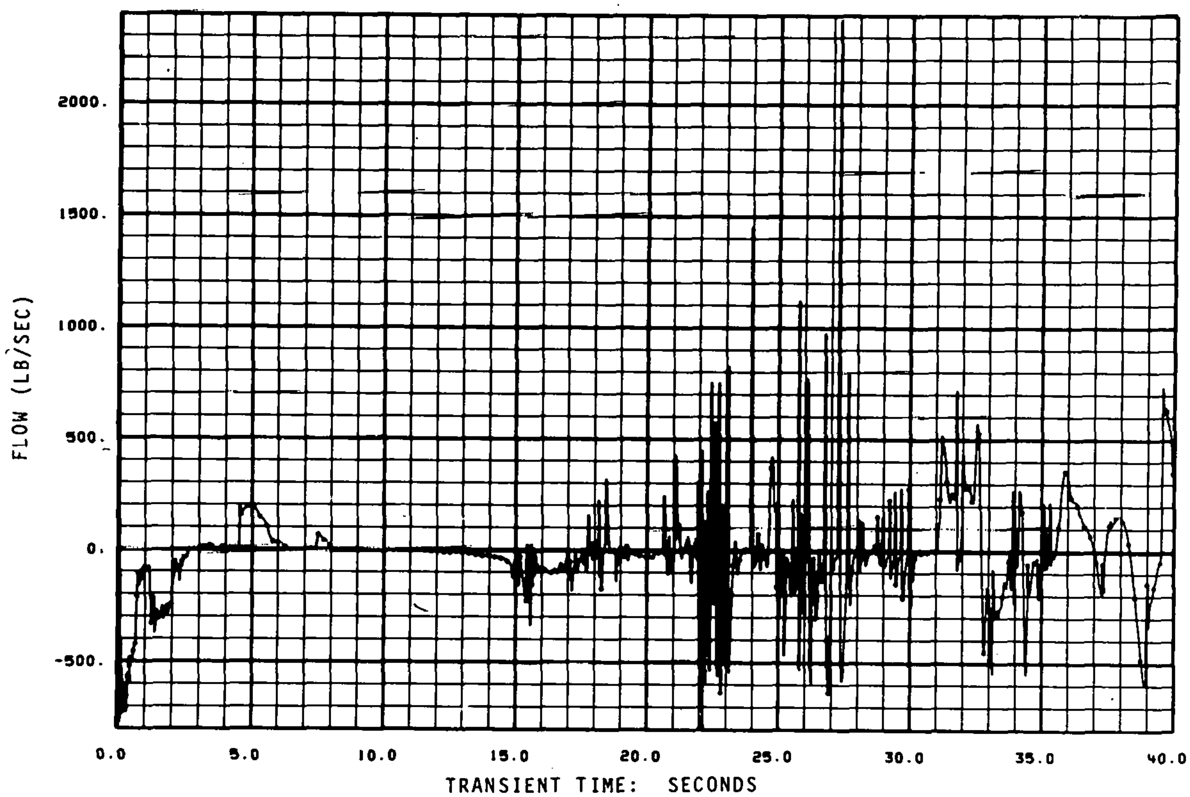

Fig. G-6 Core inlet mass flow rate - LOFT (200% break).

Fig. G-7 Core outlet mass flow rate - LOFT (200% break).

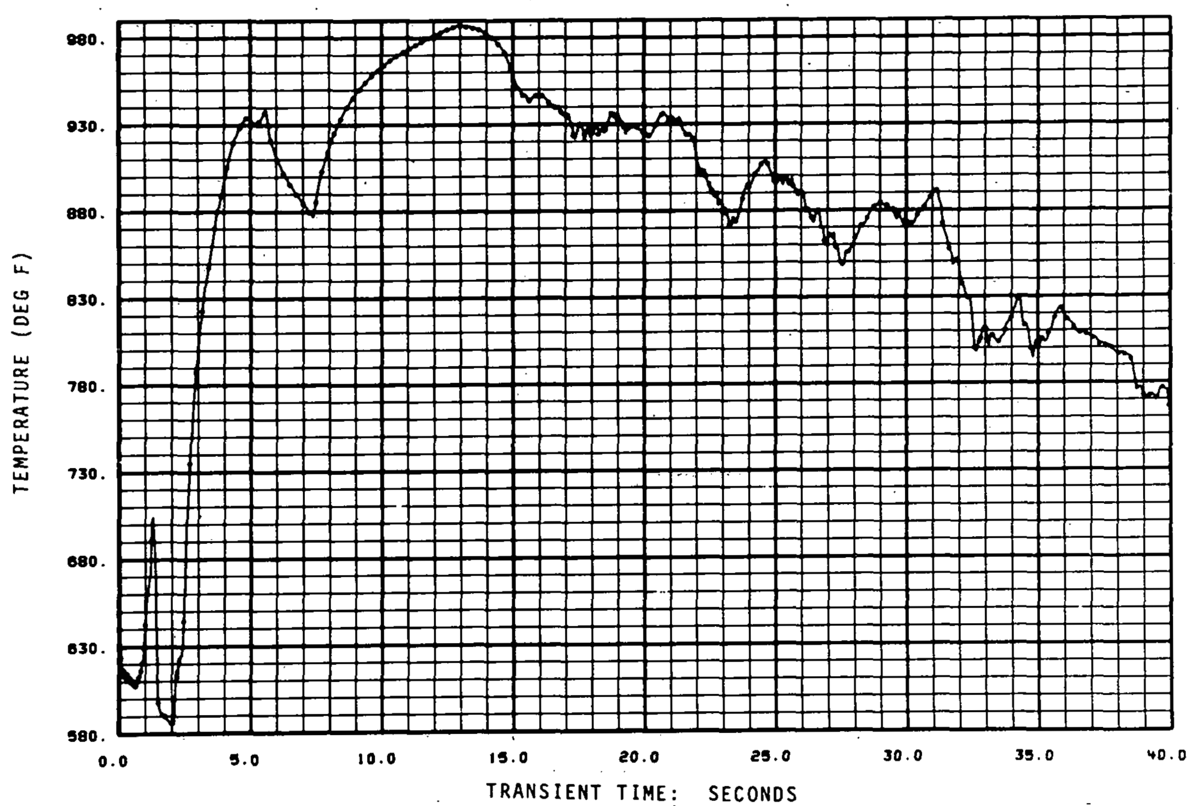

Fig. G-8 Lower core cladding temperature - LOFT (200% break).

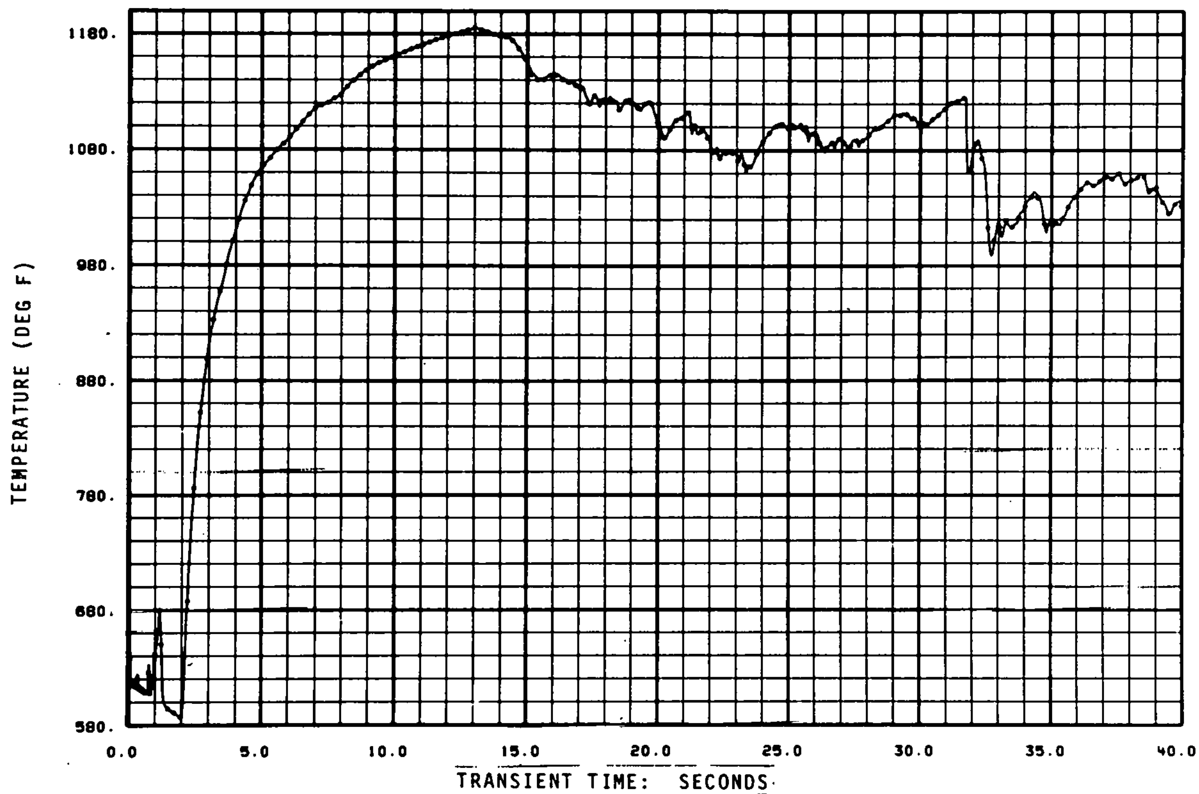

Fig. G-9 Mid core cladding temperature - LOFT (200% break).

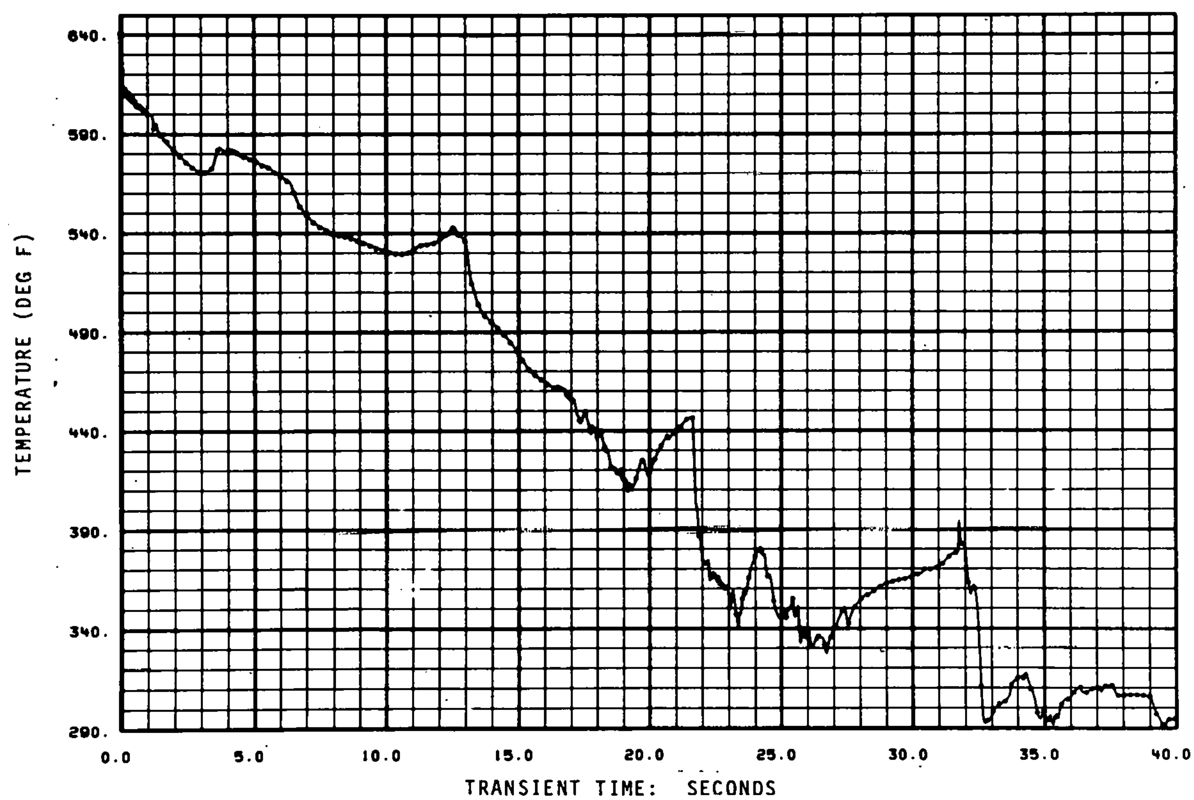

Fig. G-10 Upper core cladding temperature - LOFT (200% break).

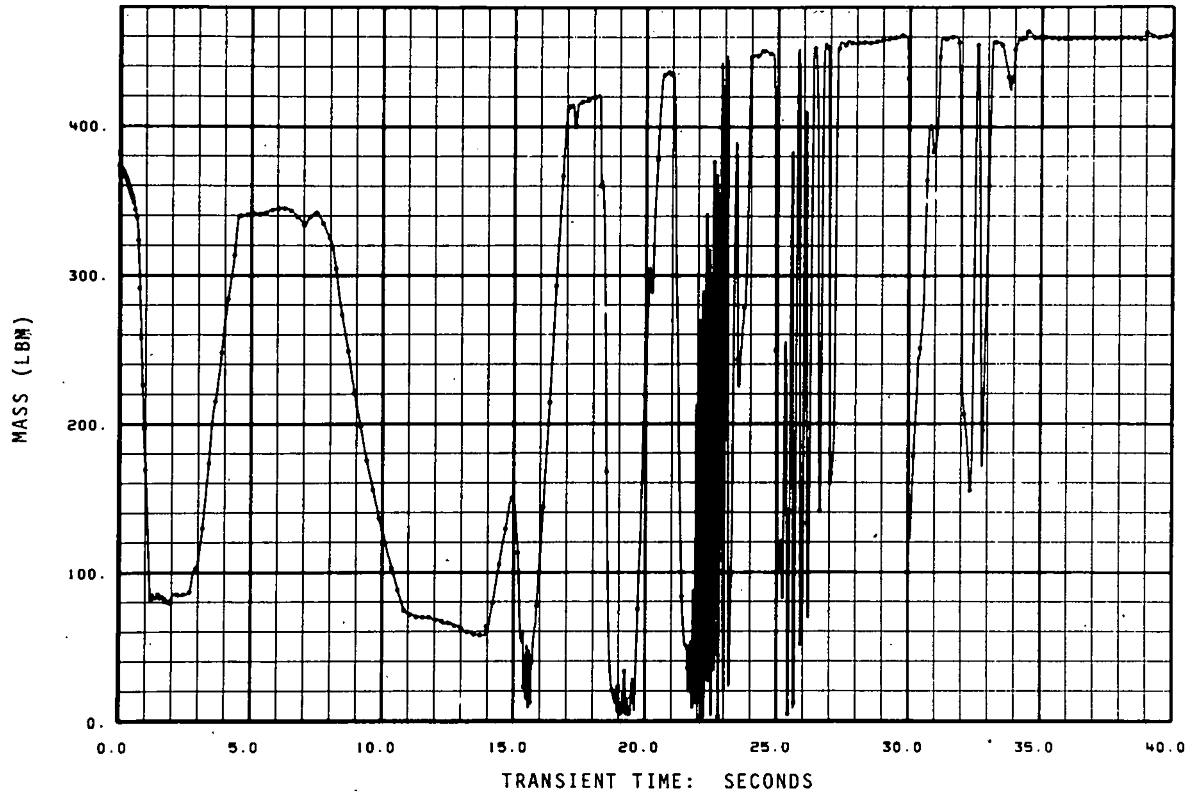

Fig. G-11 Top of lower plenum total mass - LOFT (200% break).

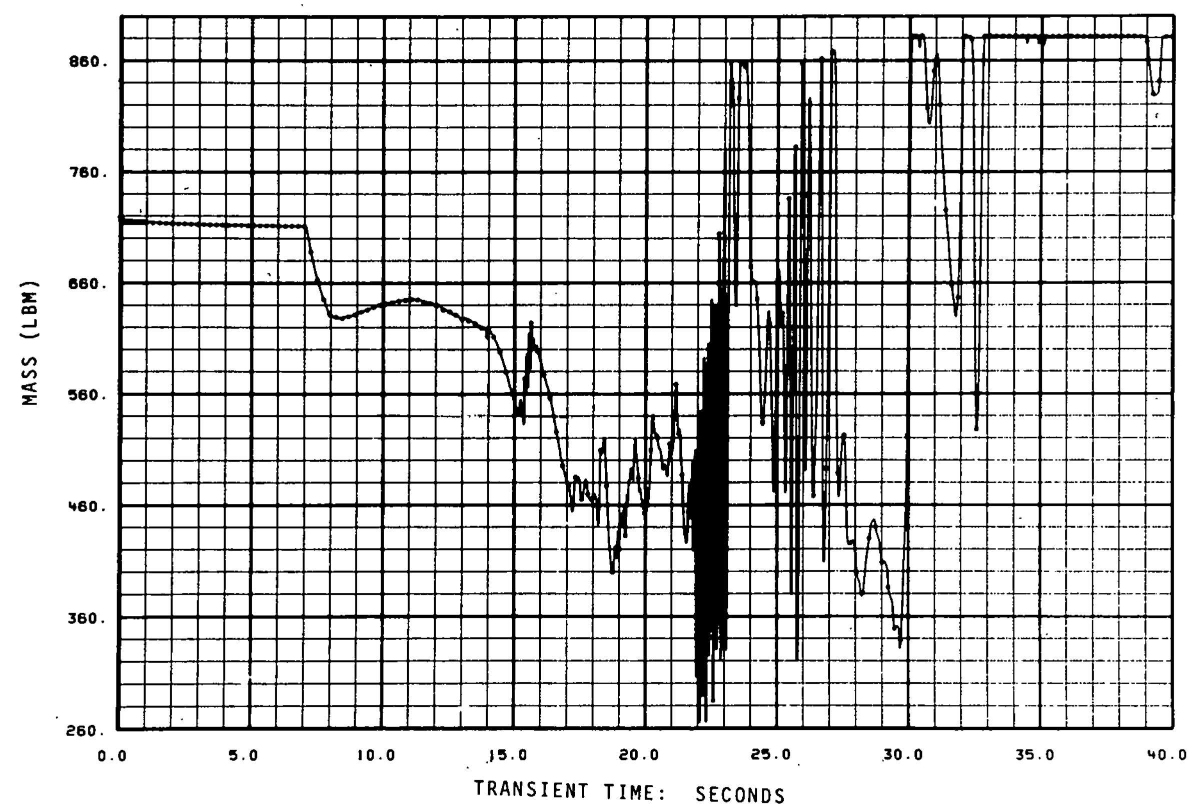

Fig. G-12 Bottom of lower plenum total mass - LOFT (200% break).

6. <u>INPUT LISTING</u>

An input listing for this run is given in Table G-IV which follows.

TABLE G-IV

INPUT LISTING

```
=ISERLOFT 200% COLD LEG BREAK
*  THIS MODEL HAS A COMBINED UPPER ANNULUS AND DOWNCOMER
***   THIS DECK MODELS LOW RESISTANCE IN THE INTACT LOOP STEAM GENERATOR ****
010001 -2  9  4  7  34  2  0  40  1  3  0  5  19  13  4  3  0  0
010002  55.7  1.0
020000  SR 1 SR 2 SR 3 JW 16 JW 3 JW 28 JW 32 JW 40 JW 36
* # WATER PACKING EDITS  START OF W P   START OF CHOKING-SMOOTHING OPTION
030003      50                 0.0                              0.0
030004  50  0.001  * MIXTURE LEVEL CROSSING FROM ABOVE CARD
030010  10  50   1  0  .0005 .00001  0.5
030020  1  25  1  0  0.010  0.001  1.0
030030  4  50  1  0  0.010  .0005  17.
030040  20  50  1  0  0.002  0.0001  90.
040010  1  1  0  0  40.     0.      *TRIP--END OF PROBLEM
040020  2  1  0  0  .01001   0      *TRIP--SCRAM   AND BLOWDOWN
040030  3  1  0  0  .01001 0.050     *TRIP--PUMP SHUTOFF
040040  4  1  0  0  .01001 25.0    *TRIP--LPIS AND HPIS FILL
040050  5 -4  14 0  612.  0         *TRIP--ACCUMULATOR VALVE
040060  6  1  0  0  20000.  0.      * TRIP-ACCUMULATOR B VALVE
040070   7 1 0 0  0.   0.  *TRIP - FILLS 3,4, AND 5 (S.G. INLET,R.VALVE,OUTLET)
*        BUB      PRESSURE        TEMP.       QUAL    VOLUME          VOL HT      MIX HT
050011  0  0  2259.6530      558.72       -1.    3.426791323  1.833250000 1.833250000
050021  0  0  2258.4850      589.26       -1.    3.426791323  1.833250000 1.833250000
050031  0  0  2257.4160      609.503      -1.    3.426791323  1.833250000 1.833250000
050041  1  0  2253.5910      610.12       -1.    19.92535578  11.60240000 11.60240000
050051  0  0  2251.4806      610.12       -1.    14.21976010  2.421562792 2.421562792
050061  0  0  2249.0637      610.12       -1.    11.18238868  2.500000000 2.500000000
050071  0  0  2246.7341      591.444      -1.    10.97690000  6.750200000 6.750200000
050081  0  0  2244.6652      568.288      -1.    5.447800000  2.005208333 2.005208333
050091  0  0  2245.3506      554.995      -1.    10.97689826  6.750000000 6.750000000
050101  0  0  2246.4774      544.4        -1.    11.18238868  2.500000000 2.500000000
050111  0  0  2243.2786      544.4        -1.    6.495269620  5.806213563 5.806213563
050121  0  0  2254.3169      544.4        -1.    12.06467722  4.650220200 4.650220200
050131  0  0  2264.3022      544.4        -1.    8.877680774  0.932337333 0.932337333
050141  0  0  2263.5772      544.4        -1.    3.228619939  0.932333333 0.932333333
050151  0  0  2261.63        544.4        -1.    24.51627458  15.04691    15.04691
050161  2  0   610.5         90.4         0.0    108.5        9.3054      5.9606
050171  1  0   742.7000      -1.0         0.0    281.6000000  16.46390000 5.404000000
050181  1  0  2262.9487      544.4        -1.    7.912700780  2.113833310 2.113833310
050191  1  0  2264.2486      544.4        -1.    15.22925692  2.031266690 2.031266690
050201  0  0  2258.740       544.400      -1.    1.772410000  11.78980000 11.78980000
050211  2  0   612.5         90.0         0.0    145.700      10.53450000 7.93160
050221  0  0  2254.9200      609.990      -1.    11.37971608  2.997416667 2.997416667
050231  0  0  2253.6500      605.000      -1.    9.890080000  11.06970833 11.06970833
050241  0  0  2253.2900      602.0        -1.    9.600427300  8.629583333 8.629583333
050251  0  0  2254.8508      544.383      -1.    0.408918058  4.541666667 4.541666667
050261  0  0  2255.9524      544.388      -1.    1.709604034  2.174500000 2.174500000
050271  0  0  2255.5035      544.386      -1.    0.578667409  4.31775000  4.31775000
050281  0  0  2254.8443      544.384      -1.    3.276254839  0.841145833 0.841145833
050291  2  0  43.000000      271.600      0.0    3693.454946  16.09374999 9.420000000
050301  0  0  2260.8300      544.400      -1.    14.04450000  2.997416667 2.997416667
050311  0  0  2261.1754      544.400      -1.    0.817513000  0.567750000 0.567750000
050321  0  0  2261.17        544.400      -1.    3.276254800  .8411458333 .8411458333
050331  1  0  2253.34954     -1.0     .1026779 34.75215344  6.713541667 6.713541667
050341  0  0  2254.5566      610.500      -1.    0.362365918  4.035000000 4.035000000
*      FRIC       AREA            EQ DIAM      ELEVATION       IAMBLO
050012  0         1.765600000     1.51798      -12.25600       0
050022  0         1.765600000     1.51798      -10.42275       0
050032  0         1.765600000     1.51798      -8.589500       0
050042  0         2.191870000     1.13960      -6.756250       0
050052  0         0.725780000     0.87590      -0.533917       0
050062  0         7.941248101     1.4615       0.3121933633    0
050072  0         1.626207149     0.0335       2.812193363     0
050082  0         1.626207149     0.0335       9.562193363     0
050092  0         1.626207149     0.0335       2.812193363     0
050102  0         7.941248101     1.4615       0.3121933630    0
050112  0         0.781772939     0.9976894    -4.296103533    0
050122  0         1.167714621     0.8622008    -4.296103533    0
050132  0         0.682703776     0.83907886   -0.4661667      0
050142  0         0.682703776     0.932333     -0.466166667    0
050152  0         1.527163095     0.33333      -13.9636        0
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TABLE G-IV (contd.)

```
050162  0    11.661          3.8532      0.46617        0
050172  0    17.1042         4.6667      1.99           0
050182  0    3.743294584     2.183142    -14.36983331   0
050192  0    7.497480256     3.089674    -16.4011       18
050202  0    1.214           0.0312      -12.2560       0
050212  0    13.8307         4.1964      -.0089         0
050222  0    0.6827037757    1.1284      -0.46617       0
050232  0    1.08321         0.00661    -0.169292       0
050242  0    1.11317         1.2011      2.27083        0
050252  0    9.00370037D-02  0.33858     -2.270833330   0
050262  1    0.6827037757    0.932333    -4.445333330   0
050272  0    9.00370037D-02  0.33858     -4.148458      0
050282  0    0.5556898667    0.84114     -.400572917    0
050292  0    9.621127503     3.500000    -13.5104       0
050302  0    0.6827037757    1.1284      -0.46617       0
050312  0    0.2531653       0.56775    -0.283875       0
050322  0    0.55569         0.932333    -0.42057       0
050332  0    6.007260513     2.7656      4.501167       0
050342  0    0.15559179D-01  0.14075     0.466167       0
*         DOWNCOMER PENETRATION MODEL    (BATTELLE COLUMBUS) REF: SRF-8-75
060004  14  18  1   15  16  18  14  2   614.0  0.3333  *CCF DEFAULT
        *CARD 060005 NOT USED --- ALL DEFAULT.
060011  0.8    3.0
060021  0.     1.E6
*   VOL-IN  OUT PMP VAL FLOW (LB/SEC)     JUN FLOW AREA     ELEVATION
080011   1   2   0   0  565.996           1.055973311       -10.42275
080021   2   3   0   0  565.996           1.055973311       -8.58950
080031   3   4   0   0  565.996           1.055973311       -6.756250000
080041   4   5   0   0  597.2222222       0.6827037757      0.0
080051   5   6   0   0  597.2222222       0.6385            1.510110030
080061   6   7   0   0  597.2222222       1.626207149       2.812193363
080071   7   8   0   0  597.2222222       1.626207149       9.562193363
080081   8   9   0   0  597.2222222       1.626207149       9.562193363
080091   9  10   0   0  597.2222222       1.626207149       2.812193363
080101  10  11   0   0  597.2222222       0.6385            1.510110030
080111  11  12  -1   0  597.2222222       0.682703776       -3.82993687
080121  12  13   1   0  597.2222222       0.788126          0.0
080131  13  14   0   0  597.2222222       0.6608871601      0.0
080141  14  15   0   0  597.2222222       0.6827037757      0.0
080151  21  27   0   3  0.0               0.64470000D-01    -.0088
080161  18   1   0   0  565.996           1.05597331        -12.256
080171  16  14   0   2  0.0               0.64470000D-01    0.4661666667
080181  15  10   0   0  597.2222222       1.304940872       -13.96358330
080191  18  20   0   0  31.2261           0.1214            -12.2560000
080201  19  18   0   0  0.0               7.466736705       -14.36983331
080211  20   4   0   0  31.2261           0.1098960738      -.4663
080221  22  23   0   0  0.0               0.90037003 7D-01  0.0
080231  23  24   0   0  0.0               0.2060339789      6.85
080241  24  25   0   0  0.0               0.90037003 7D-01  2.270833333
080251  25  26   0   0  0.0               0.90037003 7D-01  -2.27083333
080261  26  27   0   0  0.0               0.90037003 7D-01  -3.97916667
080271  27  28   0   0  0.0               0.90037003 7D-01  0.0
080281  28  29   0   1  0.0               0.5556898667      0.0
080291  15  30   0   0  0.0               0.6827037757      0.0
080301  30  31   0   0  0.0               0.90037003 7D-01  0.0
080311  31  32   0   0  0.0               0.2531653         0.0
080321  32  29   0   1  0.0               0.5556898667      0.0
080331  33  34   0   0  0.0               0.15559179D-01    4.501166667
080341  34   5   0   0  0.0               0.15559179D-01    0.4661666667
080351   4  22   0   0  0.0               0.6827037757      0.0
080361   0  17   4   0  -64.5             0.540876          16.0671
080371   0  17   5   0  0.                0.229765757       16.0671
080381   0  14   1   0  0.0               0.64470000D-01    0.4661666667
080391   0  14   2   0  0.0               0.64470000D-01    0.4661666667
080401   0  17   3   0  64.5              0.087266463       12.72916667
*        INERTA              FORM LOSS-FOR   FORM LOSS-REV   VJUN  JCH  JCAL  MVMIX
080012 1.013                 0.8422          0.8422            0    5    0     0
080022 1.013                 0.7217          0.7217            0    5    0     0
080032 4.911                 2.505           2.446             0    5    0     3
080042 21.12478              0.7529580722    1.9666            1    5    0     3
080052 7.0993                1.6648          1.6428            1    5    0     0
080062 2.164041222           0.357           0.6312            0    5    0     0
080072 3.105385439           0.0             0.0               0    5    0     0
080082 3.105385439           0.056           0.056             0    5    0     0
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TABLE G-IV (contd.)

080092	2.164041222	0.6312	0.357	0	5	0	0
080102	0.	1.402	1.424	1	5	2	0
080112	18.29256484	2.1986	1.7002	1	5	0	0
080122	8.027384985	1.6093	0.985	0	5	0	0
080132	0.	0.3109	0.3109	1	5	2	0
080142	0.	2.2	2.0	1	5	2	3
080152	810.4	11.70	11.70	0	5	0	3
080162	0.	3.7673	3.7673	0	5	2	0
080172	3079.6	29.9	29.9	0	5	0	3
080182	0.	1.717	1.719	0	5	2	3
080192	0.	9.641	9.641	0	5	2	3
080202	0.	0.0	0.0	0	5	2	3
080212	55.84	14.105	14.105	0	5	0	3
080222	40.257	1.3587	1.4315	1	5	0	0
080232	11.518	14.4669	14.4669	1	5	0	0
080242	0.	1.2414	1.1687	0	5	2	0
080252	27.05511851	7.856	8.369	0	5	0	0
080262	37.52486243	7.465	7.615	1	5	0	0
080272	40.99582315	1.5445	1.4815	1	5	0	0
080282	25.25554003	1.037	0.537	1	5	0	0
080292	0.	0.9055	1.4317	1	5	2	3
080302	8.8497	0.80584	1.04358	1	5	0	0
080312	11.682553	0.8379	0.4119	1	5	0	0
080322	25.256	1.037	0.537	1	5	0	0
080332	748.8990673	0.5	1.0	0	5	0	0
080342	753.2990961	2.1	2.6	0	5	0	0
080352	9.57	0.41	0.5737	1	5	0	3
080362	0.	468.585	468.585	0	5	0	-2
080372	0.	0.	0.	0	5	0	-2
080382	3.464	1.0	1.0	0	5	0	3
080392	3.464	1.0	1.0	0	5	0	3
C80402	0.	0.	0.	1	5	0	0

*	DIAMJ	LEAK CON CO	ICHOKE	IHQ	SRCOS	IADJUN
080013	1.51799	0.0	0	3	0.0	0
080023	1.51799	0.0	0	3	0.0	0
080033	1.51799	0.0	0	1	0.0	0
080043	0.9323333333	0.0	0	0	0.0	0
080053	0.755072	0.0	0	0	0.0	0
080063	1.438941017	0.0	0	2	0.0	0
080073	1.438941017	0.0	0	3	0.0	0
080083	1.438941017	0.0	0	3	0.0	0
080093	1.438941017	0.0	0	1	0.0	0
080103	0.932333333	0.0	0	0	0.0	0
080113	0.9323333333	0.0	0	0	0.0	0
080123	1.001734607	0.0	0	0	0.0	0
080133	0.9323333333	0.0	0	0	0.0	0
080143	0.932333333	0.0	0	0	0.0	0
080153	0.2865061141	0.0	0	0	0.0	0
080163	1.26557	0.0	0	2	0.0	0
080173	0.2865061141	0.0	0	0	0.0	0
080183	1.288992755	0.0	0	0	1.0	0
080193	0.5511	0.0	0	0	0.0	0
080203	3.0833333333	0.0	0	0	1.0	0
080213	0.43	0.0	0	0	0.0	0
080223	0.359417	0.0	0	0	0.0	0
080233	0.527319	0.0	0	0	0.0	0
080243	0.359417	0.0	0	0	0.0	0
080253	0.3594166667	0.0	0	0	0.0	0
080263	0.3594166667	0.0	0	0	0.0	0
080273	0.3594166667	0.0	0	0	0.0	0
080283	0.843833333	0.0	0	0	0.0	0
080293	0.932333333	0.0	0	0	0.0	0
080303	0.359417	0.0	0	0	0.0	0
080313	0.56775	0.0	0	0	0.0	0
080323	0.843833333	0.0	0	0	0.0	0
080333	0.140750000	0.0	0	0	0.0	0
080343	0.140750000	0.0	0	0	0.0	0
080353	0.932333333	0.0	0	0	0.0	0
080363	0.829858	0.0	0	0	0.0	0
080373	0.540876	0.0	0	0	0.0	0
080383	0.2865061141	0.0	0	0	0.0	0
080393	0.2865061141	0.0	0	0	0.0	0
C80403	0.3333333333	0.0	0	0	0.0	0

TABLE G-IV (contd.)

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*         STAGNATION PROPERTIES            0=NON-USE;  1=USE FOR MACH.GT. 0.3
082000    0
*         CRITICAL FLOW MODEL  --  HENRY-FAUSKE--HEM    REF: KAT-18-75
082003    1.   0.9   0.9   0.01             ****REQUIRES JCHOKE=5; ICHOKE=ANY
090011  1 3 0 1 0 3530. 0.526  10000. 330. 930. 768. 38.75 0 0 0.  *PUMP 1
095011   0.0    0.0    0.0
100000 16  0   0  16
*                PUMP HEAD AND TORQUE MULTIPLIER CURVES
091001 -11 0. 0. .1 0. .15 .05 .24 .8 .3 .96 .4 .98 .6 .97 .8 .9 .9 .8 .96 .5
091002 1. 0.
092001 -9 0. -.17 .0001 -.17 .006 0. .1 0. .15 .05 .24 .56 .8 .56 .96 .45 1. 0.
101011   1  1  6 0.        1.4036   .19061   1.3636   .38963   1.3185   * PUMP-HD
101012           .59396    1.2328   .7902    1.1336   1.       1.0078   * PUMP-HD
101021   1  2  8 0.        -.67     .2       -.5      .4       -.25     * PUMP-HD
101022           .57554    0.       .74432   .2583    .77348   .3778    * PUMP-HD
101023           .86313    .6326    1.       1.0078                     * PUMP-HD
101031   1  3  6 -1.       2.4722   -.80574  2.0474   -.6069   1.831    * PUMP-HD
101032           -.40683   1.624    -.200171 1.4705   0.       1.4036   * PUMP-HD
101041   1  4  8 -1.       2.4722   -.82297  1.9968   -.63332  1.5897   * PUMP-HD
101042           -.45534   1.3279   -.27109  1.1949   1.17716  1.0605   * PUMP-HD
101043           -.09073   1.0156   0.       .934279                    * PUMP-HD
101051   1  5  7 0.        .25      .2       .28      .4       .34      * PUMP-HD
101052           .4118     .2768    .59763   .4584    .793467  .6992    * PUMP-HD
101053           1.        .9465                                        * PUMP-HD
101061   1  6 10 0.        .934279  .091099  .9229    .186509  .8963    * PUMP-HD
101062           .271762   .875     .455872  .8433    .574406  .8355    * PUMP-HD
101063           .740576   .8466    .766619  .8469    .871471  .8838    * PUMP-HD
101064           .1        .9465                                        * PUMP-HD
101071   1  7  6 -1.       -1.      -.8      -.63     -.6      -.3      * PUMP-HD
101072           -.4       -.05     -.2      .15      0.       .25      * PUMP-HD
101081   1  8  6 -1.       -1.      -.8      -.97     -.6      -.95     * PUMP-HD
101082           -.4       -.88     -.2      -.8      0.       -.67     * PUMP-HD
101091   2  1  6 0.        .6032    .1930    .6325    .393     .7369    * PUMP-TQ
101092           .59552    .8331    .79782   .9229    1.       .9672    * PUMP-TQ
101101   2  2  7 0.        -.67     .4       -.25     .5       .15      * PUMP-TQ
101102           .737255   .526586  .768049  .606594  .86723   .74366   * PUMP-TQ
101103           1.        .9672                                        * PUMP-TQ
101111   2  3  6 -1.       1.9843   -.80096  1.394    -.60638  1.0975   * PUMP-TQ
101112           -.40686   .822     -.19928  .6648    0.       .6032    * PUMP-TQ
101121   2  4  8 -1.       1.9843   -.82234  1.8308   -.63371  1.6824   * PUMP-TQ
101122           -.45853   1.557    -.267023 1.4362   -.176107 1.3879   * PUMP-TQ
101123           -.08931   1.3481   0.       1.23361                    * PUMP-TQ
101131   2  5  4 0.        -.45     .4       -.25     .5       0.       * PUMP-TQ
101132           1.        .3569                                        * PUMP-TQ
101141   2  6 10 0.        1.23361  .090643  1.1965   .138569  1.1096   * PUMP-TQ
101142           .27347    1.0416   .458669  .8958    .57448   .7807    * PUMP-TQ
101143           .73816    .6134    .76852   .5849    .870057  .4877    * PUMP-TQ
101144           1.        .3569                                        * PUMP-TQ
101151   2  7  4 -1.       -1.      -.3      -.9      -.1      -.5      * PUMP-TQ
101152           0.        -.45                                         * PUMP-TQ
101161   2  8  4 -1.       -1.      -.25     -.9      -.08     -.8      * PUMP-TQ
101162           0.        -.67                                         * PUMP-TQ
104011 1 1 7 0. 0. .1 .83 .2 1.09 .5 1.02 .7 1.01 .9 .94 1. 1.
104021 1 2 8 0. 0. .1 -.04 .2 0. .3 .1 .4 .21 .8 .67 .9 .8 1. 1.
104031 1 3 10 -1. -1.16 -.9 -1.24 -.8 -1.77 -.7 -2.36 -.6 -2.79 -.5 -2.91
104032  -.4 -2.67 -.25 -1.69 -.1 -.5 0. 0.
104041 1 4 10 -1. -1.16 -.9 -.78 -.8 -.5 -.7 -.31 -.6 -.17 -.5 -.08 -.35 0.
104042      -.2 .05 -.1 .08 0. .11
104051 1 5 6 0. 0. .2 -.34 .4 -.65 .6 -.93 .8 -1.19 1. -1.47
104061 1 6 10 0. .11 .1 .13 .25 .15 .4 .13 .5 .07 .6 -.04 .7 -.23 .8 -.51
104062   .9 -.91 1. -1.47
104071 1 7 2 -1. 0. 0. 0.
104081 1 8 2 -1. 0. 0. 0.
104091   2  1  6 0.        .6032    .1930    .6325    .393     .7369    * PUMP-TQ
104092           .59552    .8331    .79782   .9229    1.       .9672    * PUMP-TQ
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TABLE G-IV (contd.)

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104101  2  2  7 0.        -.67      .4        -.25      .5        .15       * PUMP-TQ
104102           .737255  .526586   .768049   .606594   .86723    .74366    * PUMP-TQ
104103           1.       .9672                                             * PUMP-TQ
104111  2  3  6 -1.       1.9843    -.80096   1.394     -.60638   1.0975    * PUMP-TQ
104112           -.40686  .822      -.19928   .6648     0.        .6032     * PUMP-TQ
104121  2  4  8 -1.       1.9843    -.82234   1.8308    -.63371   1.6824    * PUMP-TQ
104122           -.45853  1.557     -.267023 1.4362     -.176107 1.3879     * PUMP-TQ
104123           -.08931  1.3481    0.        1.23361                       * PUMP-TQ
104131  2  5  4  0.       -.45      .4        -.25      .5        0.        * PUMP-TQ
104132           1.       .3569                                             * PUMP-TQ
104141  2  6 10 0.        1.23361   .090643   1.1965    .188569   1.1096    * PUMP-TQ
104142           .27347   1.0416    .458669   .8958     .57448    .7807     * PUMP-TQ
104143           .73816   .6134     .76852    .5849     .870057   .4877     * PUMP-TQ
104144           1.       .3569                                             * PUMP-TQ
104151  2  7  4 -1.       -1.       -.3       -.9       -.1       -.5       * PUMP-TQ
104152           0.       -.45                                              * PUMP-TQ
104161  2  8  4 -1.       -1.       -.25      -.9       -.08      -.8       * PUMP-TQ
104162           0.       -.67                                              * PUMP-TQ
110010  -2 0 0 0 0 0 0 * BLOWDOWN
110020  -5 0 0 0 0 0 0 * ACCUMULATOR
110030  -6 0 0 0 0 0 0*ACCUMULATOR B VALVE
130100  4  2  12  4  'GAL/MIN' 12. 90.        *LPIS FILL
130101  0.1  1971.220    12.7      1774.098
130102  50.5 1576.976    86.0      1379.854    116.0     1182.732
130103 141.0 985.61      160.0     788.488     173.0     591.366
130104 184.0 394.244     191.5     197.122     194.0     0.0     2000.   0.0
130200  4  2  2  4  'GAL/MIN' 12. 90.         *HPIS FILL
130201  0.1  266.0  2000.1  266.0
* STEAM GENERATOR FILLS 3 AND 4 ASSUME BLOWDOWN AT .01001 SECONDS - IF OTHERWISE
* CHANGE THE FILL TABLES. THE CLOSURE RATE FOR THE S.G. SECONDARY IS A 10.2796
* SECOND RAMP TO ZERO AFTER START OF BLOWDOWN.
130300 7 1 4 4  'LBS/SEC' 300.  407.
130301  0. 739.116  0.01001  739.116  10.2897  0.  10000. 0.
130400 7 1 4 4 'LBS/SEC'  300. 510.
130401  0. -119.251 0.01001 -119.251  10.2897  0.  10000.  0.
130500  7  2  6  1  'LBS/SEC'   742.7    544.656
130501  0.  0.  1060.  0.  1080. -54.40323294  1100. -163.2096988
130502  1120. -217.6129318  4000. -217.6129318
140000 2 0 371.875  0.  1.0  0.93001 0. 0.      *REACTOR KINETICS
140010  .3948351237 .3948351237 0  0.0          * CORE REG#1 WT FACTORS (VOL#1)
140020  .533075938  .533075938  0  0.0          * CORE REG#2 WT FACTORS (VOL#2)
140030  .0720889382 .0720889382 0  0.0             * CORE REG#3 WT FACTORS(V#3)
141001 20 2        0.       0.          0.1     -.110        0.2     -.248   * SCRAM
141002             0.3      -.551       0.4     -.964        0.5     -1.722  *SCRAM
141003             0.6      -3.582      0.7     -5.373       0.8     -8.266  * SCRAM
141004             0.9      -10.594     1.0     -13.363      1.1     -15.980 * SCRAM
141005             1.2      -18.047     1.3     -19.080      1.4     -19.907 *SCRAM
141006             1.5      -20.388     2.0     -21.008      2.5     -21.077 *SCRAM
141007                2.6       -21.3699     10000.   -21.37
142000 -12 0.398763   -48.1334    0.498455    -31.8630    0.612286    * $,DENS
142001     -20.8844   0.697836    -13.2112    0.797528    -7.6732     * $,DENS
142002     0.897218   -3.6369     0.996909    -.6475      1.100612    * $,DENS
142003     -.4234     1.07460     1.2920      1.27074     8.6140      *$,DENS
142004     1.36463    16.9147     1.41978     24.8556                 * $,DENS
143000 -8 400.        2.673       700.        2.149       1100.       * $,FTEMP
143001     1.515      1500.       .964        1900.       .441        * $,FTEMP
143002     2300.      -.041       2800.       -.579       3300.       * $,FTEMP
143003     -1.130                                                     * $,FTEMP
150011 0  1  1 0 0 0 0   0.       263.31   2.315       0.        0.04529
150012    0.             0.0521   0.       5.5     0.        1.83325
150021 0  2  1 1 0 0 0   0.       263.31   2.315       0.        0.04529
150022    0.             0.0521   0.       5.5     0.        1.83325
150031 0  3  1 1 0 0 0   0.       263.31   2.315       0.        0.04529
150032    0.             0.0521   0.       5.5     0.        1.83325
150041 9  17 2 0 3 2 2   882.306 1097.404 4.041527    0.0335  0.041667
150042    0.             0.       6.747    6.747   0.823     7.570000000
150051 7  17 2 0 3 2 2   882.306 1097.404 4.41527     0.0335  0.041667
150052    0.             0.       6.747    6.747   0.823     7.570000000
150061 8  17 2 0 3 2 2   437.885 544.6376 2.00579     0.0335  0.041667
```

TABLE G-IV (contd.)

```
150062     0.              0.              3.35       3.35      7.572193370 9.5774000
150071 15 0   4 0 0 2 2    112.4798 0.0         118.1764      3.08333 0.
150072     0.              0.              11.612   0.0       0.          11.611
150081 19 0   5 0 0 2 2    25.1284 0.0         12.4400636    4.07306 0.0
150082     0.              0.              2.40142  0.0       0.          2.03125002
150091 0   18 6 1 2 2 2    0.        35.       1.363755      0.       1.74358
150092     0.              0.              0.       1.74358 0.         0.87179
150101 20 0   7 0 0 2 2    111.565   0.0       6.86351       2.48042 0.0
150102     0.              0.              14.3170 0.        0.          11.7898
150111 0   15 8 0 0 2 2    0.0       100.3197 2.78365       0.0       2.75
150112     0.              0.              0.       11.612   0.          11.611
150121 0 15 10 0 0 2 2     0.        29.6763   0.864152      0.0       2.75
150122     0.              0.              0.       3.435     11.612     15.046
150131 15 0   9 0 0 2 2    35.1335   0.0       34.95857      3.2557    0.0
150132     0.              0.              3.435    0.        11.612     15.046
150141 0  19 6 0 2 2 2     0.        35.       1.363755      0.        1.74358
150142     0.              0.              0.       1.74358 1.15946    2.03125
150151 4   0 11 0 0 2 2    35.1674   0.0       53.5556       2.55108 0.0
150152     0.              0.              4.388    0.0       7.2144     11.6024
150161 4   0 12 0 0 2 2    44.6609   0.0       .90879        2.26006 0.0
150162     0.              0.              6.2901   0.0       0.         6.282067
150171 4   0 13 0 0 2 2    6.83192   0.0       0.256867      2.3325    0.0
150172     0.              0.              0.932333 0.        6.282067  7.2144
150181 4   0  3 0 0 2 2    950.4525 0.0        9.90054       2.9026    0.0
150182     0.              0.              11.61    0.0       0.          11.6
150191 0 18 5 1 0 2 2 0. 5.59984   2.77225539   0.   4.07306
150192  0. 0. 0.   2.40142   0.   0.37016998
160010 1 7 9 0              0                .3826537428          * CORE SECTION#1 (V#1)
160020 2 7 9 0              0                .47766777            * CORE SECTION#2 (V#2)
160030 3 7 9 0              0                .1396784872          * CORE SECTION#3 (V#3)
170101   2   4   1   6   0   .01524585   1.0    * CORE HEAT SLAB GEOMETRY, FUEL PIN
170102   1     2   2       .00031250 0        * CORE HEAT SLAB GEOMETRY, GAP
170103   0     3   5       .00135     0       * CORE HEAT SLAB GEOMETRY, CLAD
170104   0     3   5       .000675    0       * CORE HEAT SLAB GEOMETRY, CLAD
170201   2   1   4   6   .01675 .0040833   0.0   * ST GEN HT SLAB GEOM
170301   1   2   4   6   0.0  0.0052083      0.0
170302    0      4   6             0.0052083  0.0
170401   2   2   4    6     1.541667 0.414096     0.0
170402   0       4    6               0.414096    0.0
170501   2   2   4   6   2.036528   .22091    0.0
170502    0      4   6              0.22091    0.0
170601   1   2   4   6   0.0   0.0194822      0.0
170602    0      4   6              0.0194822 0.0
170701    2   2   4   6   1.240208   .030033   0.0
170702    0       4   6              .030033   0.0
170801   2   2   4    6     1.375 0.014016        0.0
170802   0   4   6                0.014016        0.0
170901    2   2   4   6   1.627851   .39948     0.0
170902    0       4   6              .39948     0.0
171001    2   2   4   6   1.375    .01472    0.0
171002    0       4   6            .01472    0.0
171101    2   2   4   6   1.275539   .53611    0.0
171102    0       4   6              .53611    0.0
171201    2   2   4   6   1.130032   .0100843   0.0
171202    0       4   6              .0100843   0.0
171301    2   2   4   6   1.16625   .018505   0.0
171302    0       4   6             .018505   0.0
180101   18           32.    5.598            212.   4.302          392.   3.636   *   UO2   K
180102               572.    3.15             752.   2.7612         932.   2.4624
180103              1112.    2.2212          1292.   2.0304        1472.   1.872
180104              1832.    1.6344          2192.   1.4688        2552.   1.3572
180105              2912.    1.2852          3272.   1.2492        3632.   1.2456
180106              3992.    1.26727         4532.   1.3500        5144.   1.5156
180200   2      32.          .46872        5400.        .46872                       *   GAP   K
180301   18     32.          7.812         212.         7.992       392.      8.208   *  CLAD  K
180302          572.         8.784         752.         9.540       932.      10.404
180303          1112.        11.268        1292.        12.492      1472.     13.176
180304          1652.        13.968        1832.        14.796      2012.     16.128
180305          2192.        17.784        2372.        19.656      2552.     21.780
180306          2732.        24.048        3092.        28.908      3360.     33.120
180401   -2                           * SS304 THERMAL CONDUCTIVITY
180402         212.   9.574     2372.     19.294
```

TABLE G-IV (contd.)

```
190101  15   32.   34.45        122.  38.35       212.   40.95        392.  43.55 *  UO2  C
190102      752.   46.80       2012.  51.35      2732.   52.65       3092.  56.55
190103     3452.   63.05       3812.  72.80      4352.   89.70       4532.  94.25
190104     4712.   98.15       4892. 100.10      5144.  101.40
190200  2   32.   .000075     5400.  .000075                                   *  GAP  C
190301  9   32.   25.92        212.  28.755       392.   30.375       572.  31.59 * CLAD C
190302      932.   33.615     1292.  35.235      1742.   36.855      1743.  35.235
190303     3360.   35.235
190401    -13                        * SS304 HEAT CAPACITY
190402      170.      44.46081    250.      44.32964     400.     44.48722
190403      600.      45.39201    800.      46.90938    1000.     48.84151
190404     1200.      50.99056   1400.      53.15869    1600.     55.14808
190405     1800.      56.76090   2000.      57.79932    2200.     58.06550
190406     2400.      57.36161
*    LINEAR EXPANSION COEFFICIENT DATA
200101   -2                                 *UO2 COEF. OF LINEAR EXPANSION
200102         32.  3.7752-6      6000.  1.4440-5
200201   -2                                 *GAP COEF. OF LINEAR EXPANSION
200202         32.  0.0           6000.  0.0
200301   -4                                 *ZR4 COEF. OF LINEAR EXPANSION
200302         77.  3.1711-6      1472.  4.5051-6     1473.  5.3900-6
200303       5000.  5.3900-6
200401   -2 0. 0. 5000. 0.
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APPENDIX H

LARGE COLD LEG BREAK (TEST S-02-9) - INEL SEMISCALE

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APPENDIX H

LARGE COLD LEG BREAK (TEST S-02-9) - INEL SEMISCALE

1. INTRODUCTION

The Mod-1 Semiscale System Test S-02-9 was modeled using the RELAP4/MOD5 computer code. This test was a 200% double-ended cold leg break simulation from initial conditions of 100% rated power and 100% rated flow. Emergency core coolant (ECC) injection (accumulator and low pressure injection system) in both the intact loop and broken loop pump discharge legs was included. Thirty-seven electrically heated rods were contained in the Semiscale core. A flat radial power profile was implemented for the heater rods in Test S-02-9. The peak power density for each of the 37 heater rods was 11.84 kW/ft.

This appendix contains a comparison of Test S-02-9 experimental data with results calculated using RELAP4/MOD5. A brief description of the Semiscale facility is provided in Section 6. Some interpretation of the results is based on digital and data trace output which were too voluminous to be included in this appendix. This application of MOD5 differs from the eight other checkout runs, reported in this volume of the RELAP4/MOD5 User's Manual, in that comparisons have been made to actual experimental data.

2. SYSTEM MODEL AND ASSUMPTIONS

The RELAP4 model of the Semiscale facility included 37 control volumes and 43 junctions as shown in Figure H-1. Three control volumes were used to model the simulated core and the lower plenum of the primary vessel. Thirty-seven heater pins in the simulated core were

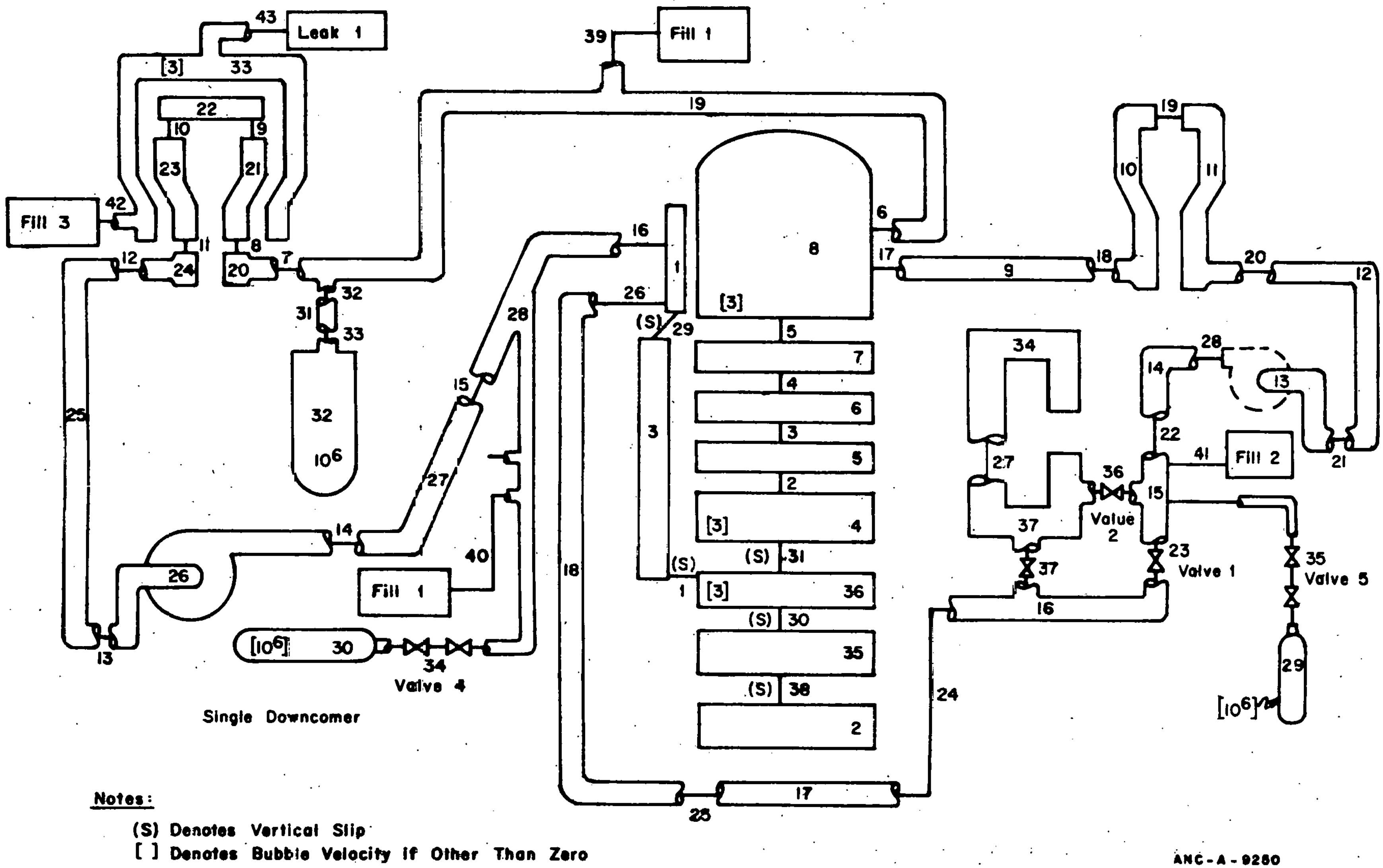

Fig. H-1 Nodalization for 200% break - Semiscale.

TABLE H-I

VOLUME IDENTIFICATION FOR 200% BREAK (TEST S-02-9) - SEMISCALE

Volume No.	Description	Volume No.	Description
1	Upper Annulus	21	Steam Generator Primary - Intact Loop
2	Lower Plenum Bottom Volume	22	Steam Generator Primary - Intact Loop
3	Downcomer	23	Steam Generator Primary - Intact Loop
4	Mixing Box	24	Steam Generator Outlet Plenum - Intact Loop
5	Lower 1/3 of Core	25	Steam Generator Outlet Piping to Low Elevation - Intact Loop
6	Middle 1/3 of Core	26	Coolant Pump - Intact Loop
7	Upper 1/3 of Core	27	Pump Outlet Piping - Intact Loop
8	Upper Plenum	28	Vessel Inlet Piping - Intact Loop
9	Hot Leg - Broken Loop	29	Accumulator - Broken Loop
10	Simulated Steam Generator - Broken Loop	30	Accumulator - Intact Loop
11	Simulated Steam Generator - Broken Loop	31	Surge Line Between Pressurizer and Hot Leg - Intact Loop
12	Loop Closure - Broken Loop	32	Pressurizer
13	Simulated Pump - Broken Loop	33	Steam Generator Secondary Side - Intact Loop
14	Cold Leg Volume Adjacent to Simulated Pump - Broken Loop	34	Pressure Suppression Vessel - Broken Loop Discharge
15	Volume in Cold Leg of Broken Loop - Donor Volume for Hot Leg Break	35	Lower Plenum Middle Volume
16	Donor Volume for Cold Leg Break - Broken Loop	36	Lower Plenum Top Volume
17	Cold Leg Volume - Broken Loop	37	Inlet Header to the Pressure Suppression Vessel - Broken Loop Discharge
18	Cold Leg Volume - Broken Loop Adjacent to Vessel		
19	Hot Leg - Intact Loop		
20	Steam Generator Inlet Plenum - Intact Loop		

modeled. Two of the 39 rods normally used were inoperable for Test S-02-9. One volume represented the combined upper head and upper plenum. The downcomer was represented by a single volume as was the upper annulus. Table H-I lists the volumes used in the model. Homogeneous fluid conditions were assumed in all volumes except in the upper plenum, the two volumes immediately below the simulated core, the accumulators, the pressurizer, and the steam generator secondary. Bubble rise parameters were used for these volumes as shown in Table H-II. Note that the slope (bubble gradient) was zero for all volumes, which eliminated the quality discontinuity in vertically stacked control volumes. A bubble rise velocity of 10^6 was used to simulate complete fluid separation.

Three fill systems were used and are shown in Table H-III. The hot leg fill was modeled but not turned on. Steam generator relief was represented as a leak junction and was modeled with a one-second delay followed by a one-second valve closing time.

A total of 29 heat slabs was used in the model to represent heat transfer in the simulated core, the intact loop steam generator, and the vessel and piping. Three vertically stacked slabs were used to represent the average core, while six slabs were used to simulate a hot channel in the core. Four slabs were used to simulate the steam generator tubes. The remaining 16 slabs were used to simulate heat addition from the piping and reactor vessel. The slabs and adjacent fluid control volumes are defined in Table H-IV. The hot channel heater pins in the RELAP4 model were set at the average axial power distribution used in Test S-02-9.

Vertical slip was used with the default coefficients in the downcomer and lower plenum junctions as denoted by 's' on Figure H-1. Downcomer penetration modeling was attempted, but did not show the ECC bypass indicted by the test data. The downcomer penetration model accordingly was not used for the final RELAP4 model. Critical flow modeling used the Henry-Fauske Model with a multiplier of 0.9 in the subcooled region, transition at a fluid quality of 0.01, and the

TABLE H-II

BUBBLE RISE PARAMETERS FOR 200% BREAK (TEST S-02-9) - SEMISCALE

Volume No.	Description	Gradient	Bubble Velocity
4	Mixing Box	0.0	3.0
8	Upper Plenum	0.0	3.0
29	Accumulator - Broken Loop	0.0	10^6
30	Accumulator - Intact Loop	0.0	10^6
32	Pressurizer	0.0	10^6
33	Steam Generator Secondary - Intact Loop	0.0	3.0
36	Lower Plenum Top Volume	0.0	3.0

TABLE H-III

FILL JUNCTION IDENTIFICATION FOR 200% BREAK (TEST S-02-9) - SEMISCALE

Fill or Leak No.	Junction No.	Description
1	40	Pumped ECC - Intact Loop Cold Leg
1	39	Pumped ECC - Intact Loop Hot Leg (Note that this fill was modeled but not turned on).
1	43	Outlet (Leak) - Intact Loop Steam Generator
2	41	Pumped ECC - Broken Loop Cold Leg
3	42	Feed - Intact Loop Steam Generator

TABLE H-IV

HEAT SLAB IDENTIFICATION FOR 200% BREAK - SEMISCALE

Slab No.	Adjacent Control Volume Left	Adjacent Control Volume Right	Description
1	0	5	Lower 1/3 of Average Core
2	0	6	Middle 1/3 of Average Core
3	0	7	Upper 1/3 of Average Core
4	0	8	Rod Extensions
5	0	5	1/6 of Hot Channel, Bottom-most Slab
6	0	5	1/6 of Hot Channel, above Slab 5
7	0	6	1/6 of Hot Channel, above Slab 6
8	0	6	1/6 of Hot Channel, above Slab 7
9	0	7	1/6 of Hot Channel, above Slab 8
10	0	7	1/6 of Hot Channel, above Slab 9
11	0	8	Rod Extensions
12	21	33	Steam Generator (SG) Tubes, 2/3 of Up Flow Tube Section
13	22	33	SG Tubes, 1/3 of Up Flow and 1/2 of U-bend
14	23	33	SG Tubes, Lower 2/3 of Down Flow Tube Sections
15	22	33	SG Tubes, Upper 1/3 of Down Flow Tubes and 1/2 of U-bend
16	19	0	Hot Leg Piping, Operating Loop
17	25	0	Loop Closure Piping, Operating Loop
18	28	0	Cold Leg Piping, Operating Loop
19	9	0	Hot Leg Piping, Broken Loop
20	10	0	SG Piping, Broken Loop

TABLE H-IV (contd.)

HEAT SLAB IDENTIFICATION FOR 200% BREAK - SEMISCALE

Slab No.	Adjacent Control Volume Left	Adjacent Control Volume Right	Description
21	11	0	SG Piping, Broken Loop
22	12	0	Loop Closure, Broken Loop
23	14	0	Cold Leg Piping, Broken Loop
24	15	0	Cold Leg Piping, Broken Loop
25	16	0	Cold Leg Piping, Broken Loop
26	17	0	Cold Leg Piping, Broken Loop
27	18	0	Cold Leg Piping, Broken Loop
28	3	0	1/2 of Simulated Reactor Vessel Shell
29	3	0	1/2 of Simulated Reactor Vessel Shell

homogeneous equilibrium (HEM) critical flow model beyond this transition. Mixture level crossing smoothing was required beyond 30 sec.

3. RESULTS AND COMPARISON WITH EXPERIMENTAL DATA

Results from the RELAP4 run of the model are shown in Figures H-2 through H-13 in Section 5 of this appendix. Most data compares favorably with the experimental results of Test S-02-9. Experimental data are denoted by 'x' and RELAP data by '•' in the comparison plots. The RELAP4-predicted times of major events shown in Table H-V were equal to or earlier than those experienced during the test with the exception of the time that the pressurizer emptied.

The initial depressurization agrees favorably with the experimental data to about 10 sec, as shown in Figure H-2. This agreement indicates that the fluid energy addition, the break flow, the fluid mass, and the fluid thermodynamic conditions were all reasonably well predicted. The small time deviation of the upper plenum pressure beyond 10 sec was typical of previous semiscale data comparisons. Effects that could possibly explain this deviation, include:

(1) The computed break flow was significantly larger than indicated by the experimental data

(2) The computed energy transferred to the fluid was less than indicated by the experimental data.

Flow from the cold leg side of the break is shown in Figure H-3 to be in good agreement with the experimental result (drag disc measurement) throughout the transient. The calculated flow is within 14% of the measured flow at transition, which was correctly predicted at approximately 3.7 sec. Figure H-4 shows the computed hot leg break flow to be somewhat less than that measured during the experiment. The calculated total break flow is, therefore, somewhat less than the experimental data. The more rapid depressurization noted in Figure H-2 accordingly is not

TABLE H-V

MAJOR EVENTS SUMMARY
FOR 200% COLD LEG BREAK (TEST S-02-9) - SEMISCALE

Time (sec)		Event
RELAP4	TEST S-02-9	
0.0	0.0	Break opened
8.0	8.0	Steam generator heat transfer reversed
16.0	17.5	Intact loop accumulator injection started
5.5	6.0	Broken loop accumulator injection started
14.0	11.0	Pressurizer emptied
42.0	51.0	Refill completed

explained by increased break flow. The large spike in the break flow data occurring between approximately 3.7 and 5.5 sec in Figure H-4 is a direct result of the density spike appearing in Figure H-5. The source of the density spike has not been fully explained.

The deviation in break flow in Figure H-4 is largely caused by the deviation between calculated and measured hot leg fluid densities, as shown in Figure H-5. The good correspondence between calculated and measured cold leg densities in the broken loop (Figure H-6) is worthy of note.

The large oscillations in measured cold leg density in the broken loop (Figure H-6) beyond about 25 sec should be also noted. These oscillations are a part of the condensation dynamics resulting from ECC injection.

Energy transferred to and from the secondary fluid of the operating steam generator is compared in Figure H-7 (hand plotted from digital data) with that calculated from experimental data. This comparison indicates that the predicted energy transfer is in acceptable agreement up to 8 sec into the transient. Beyond 8 sec, the computed result is nearly 100% low. The discrepancy noted is believed to have been caused by the heat transfer modeling within RELAP4/MOD5 where a minimum heat transfer coefficient of 5 Btu/hr-ft^2°F was used in lieu of a calculated coefficient in the natural convection region. The increased depressurization rate noted in Figure H-2 is considered to be partly explained by the decreased secondary to primary heat transfer used in the RELAP model.

Fluid density in the topmost control volume (Volume 36) of the lower plenum is noted in Figure H-8 to increase suddenly at 37 sec and reach a plateau at 39 sec which is indicative that refill has been completed. The comparison of refill time with the experimental data is shown in Figure H-9 (hand plotted from digital data), which shows the average density in the three volumes representing the lower plenum and the measured average density in the lower plenum. The experimental data used for this comparison is from a gamma densitometer oriented at an angle of 15.7° with the vertical. The early refill is attributed to the response of the fluid in the pressure suppression system. The pressure suppression vessel was vented by 18 sec, as indicated in Figure H-10, by the pressure turnover. This relief rate is not measured or defined and hence was not modeled. An improved refill time could possibly be obtained by modeling the pressure suppression vessel (Volume 34) as a time-dependent volume with appropriate fluid response parameter inputs.

The discrepancy shown, in Figure H-10, for the calculated and the measured pressurization rates between time zero and the pressure peaks, is attributed to condensation effects in the pressure suppression vessel. That is, the equilibrium assumption on which RELAP4 is based, leads to equilibrium steam condensation in the pressure suppression vessel. The pressure suppression volume in the experiment is not instantaneously equilibriated. Thus, the measured pressure tends to be greater than the calculated pressure. The initial decrease in measured pressure is attributed to condensation effects in the volume above the initially quiescent pool water level. The water surface is broken into droplets upon vent clearing and thrown into the upper volume of the vessel.

Core flow reversal occurred within 0.01 sec. Negative flow was maintained until about 39 sec (Figure H-11) when flow oscillations occurred which were caused by the rapid density changes in the volumes immediately below the simulated core during the refill phase. Refill was indicated as being complete by the positive core flow established after 41 sec as shown in Figure H-11.

Computed cladding temperatures are compared with measured cladding temperatures in Figure H-12. Temperature traces 1, 2, and 3 in Figure H-12 were measured at locations 25, 29, and 29 in., respectively, above the bottom of the core. The RELAP4 temperature trace corresponds to a position approximately 27-1/2 in. above the bottom of the core. In addition, the Semiscale experiment temperatures were measured by a thermocouple in a groove between two clad layers approximately 27 mils beneath the clad surface while the RELAP calculation was modeled at the clad surface. The standard deviation of the RELAP4 results based on the experimental data out to 30 sec is about 150°F. The maximum difference of approximately 330°F was noted at 1.5 sec when pin rewetting was calculated.

The pressurizer pressure shown in Figure H-13 agrees favorably with the experimental data. A resistance of 11,000 $sec^2/in^2\text{-}ft^3$ was calculated from the experimental surge line flow rate prior to the time the pressurizer emptied. This resistance value was used in the RELAP4 calculations. Half of the value was applied to each junction connecting to the surge line.

4. CONCLUSIONS

RELAP4/MOD5 predicts the observed Semiscale Test S-02-9 experimental results reasonably well. Approximately 30 sec into the transient, mass and energy depletion problems were encountered in the RELAP4 control volumes immediately below the simulated core. Mixture level smoothing and decreased time steps were, therefore, required beyond 30 sec. Running time significantly increased beyond that point. The problem ran through refill and into reflood.

Use of the downcomer penetration model based on the Battelle-Columbus Laboratory data (Volume I, Subsection 3.6.4) and use of vertical slip only to calculate ECC Bypass were compared against experimental data for Semiscale Test S-02-9. The downcomer penetration model was found to predict significantly premature liquid penetration of the downcomer--approximately 25 sec into the transient rather than the 50 sec indicated by the experiment. Use of the vertical slip only modeling gave better agreement by predicting downcomer penetration at 41 sec. Based on this comparison with experimental data, use of vertical slip only modeling is recommended until further evaluation of the downcomer penetration model is performed.

5. OUTPUT DATA

The output data traces for the Semiscale Cold Leg Break (Test S-02-9) are included within this section as Figures H-2 through H-13. Experimental data is denoted by a "X" and RELAP data by a "•"

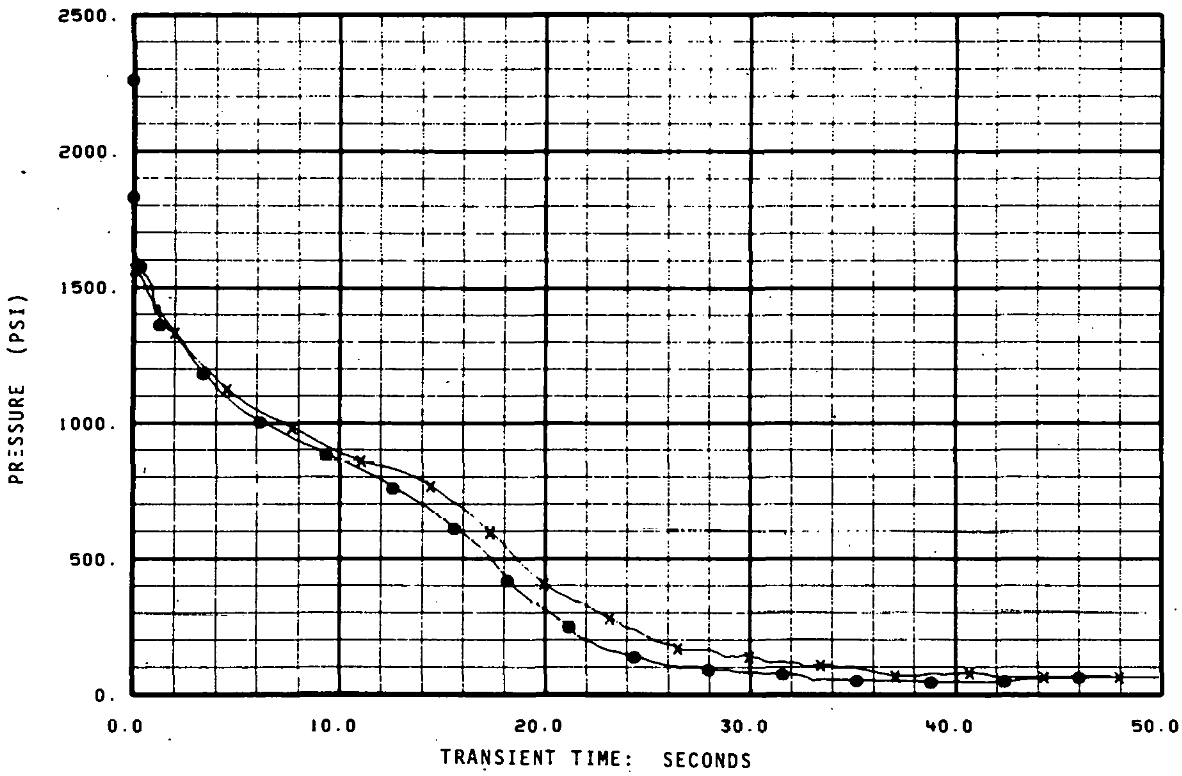

Fig. H-2 Upper plenum pressure history - semiscale (200% break).

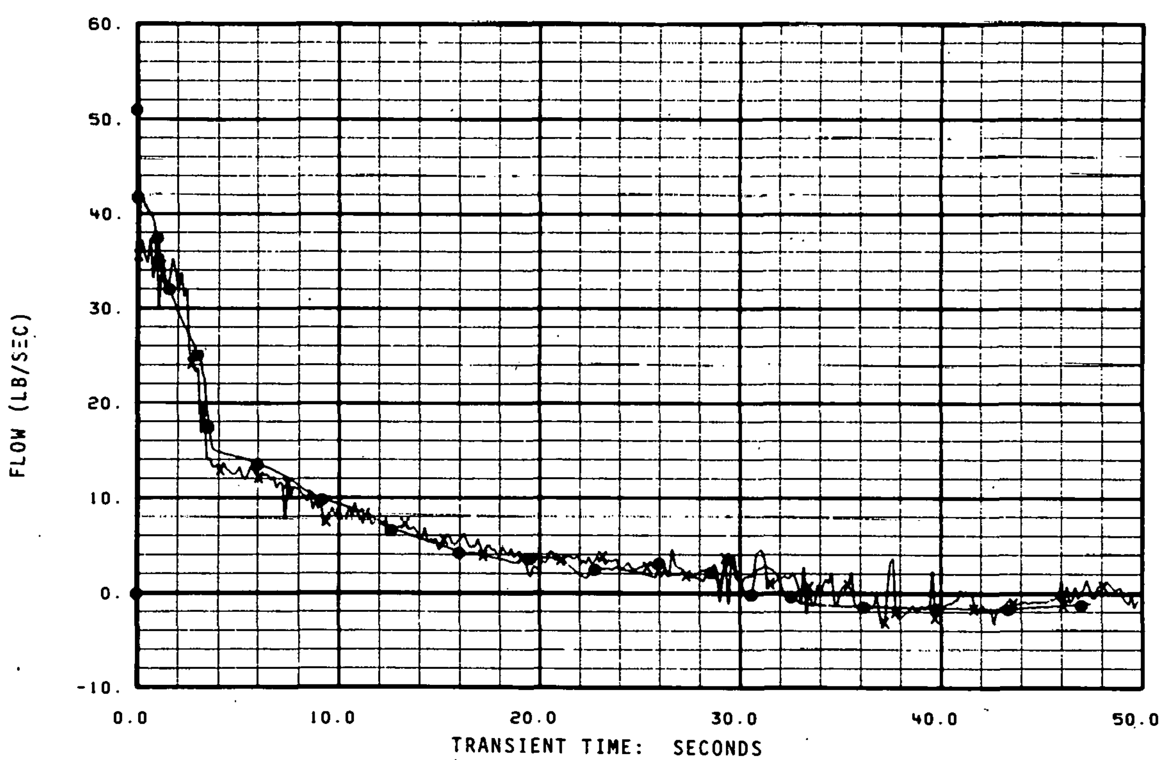

Fig. H-3 Cold leg break flow history - Semiscale (200% break).

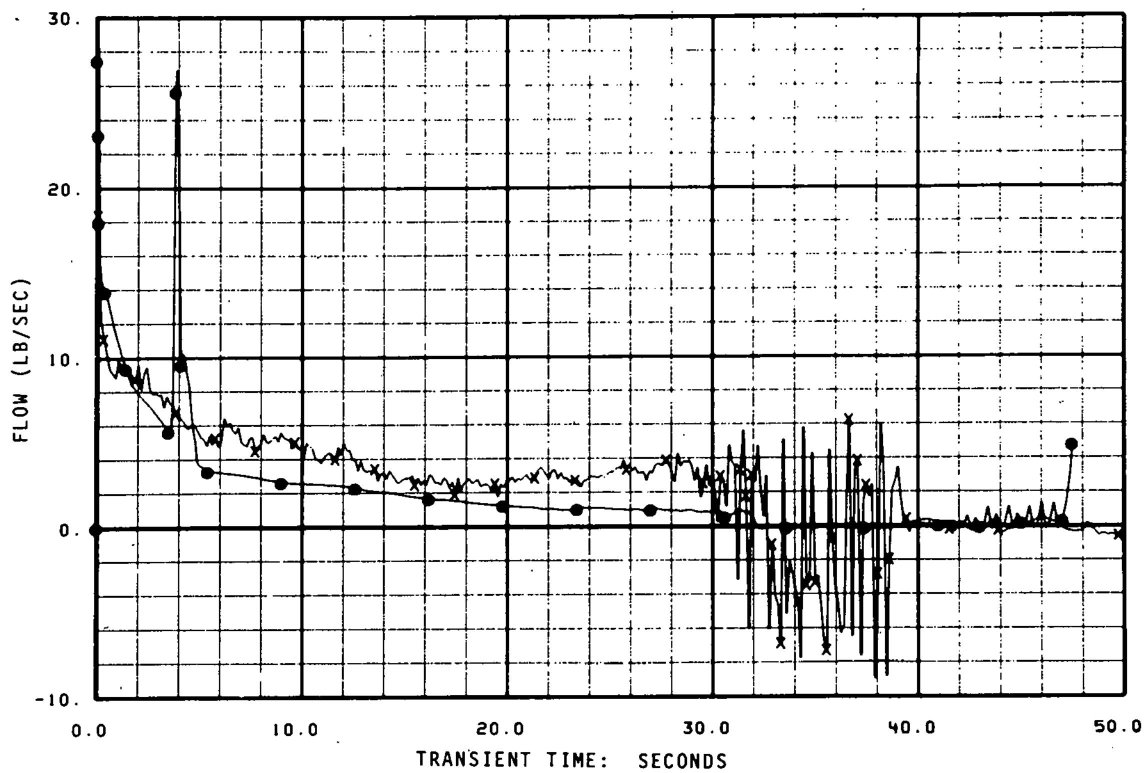

Fig. H-4 Hot leg break flow history - Semiscale (200% break).

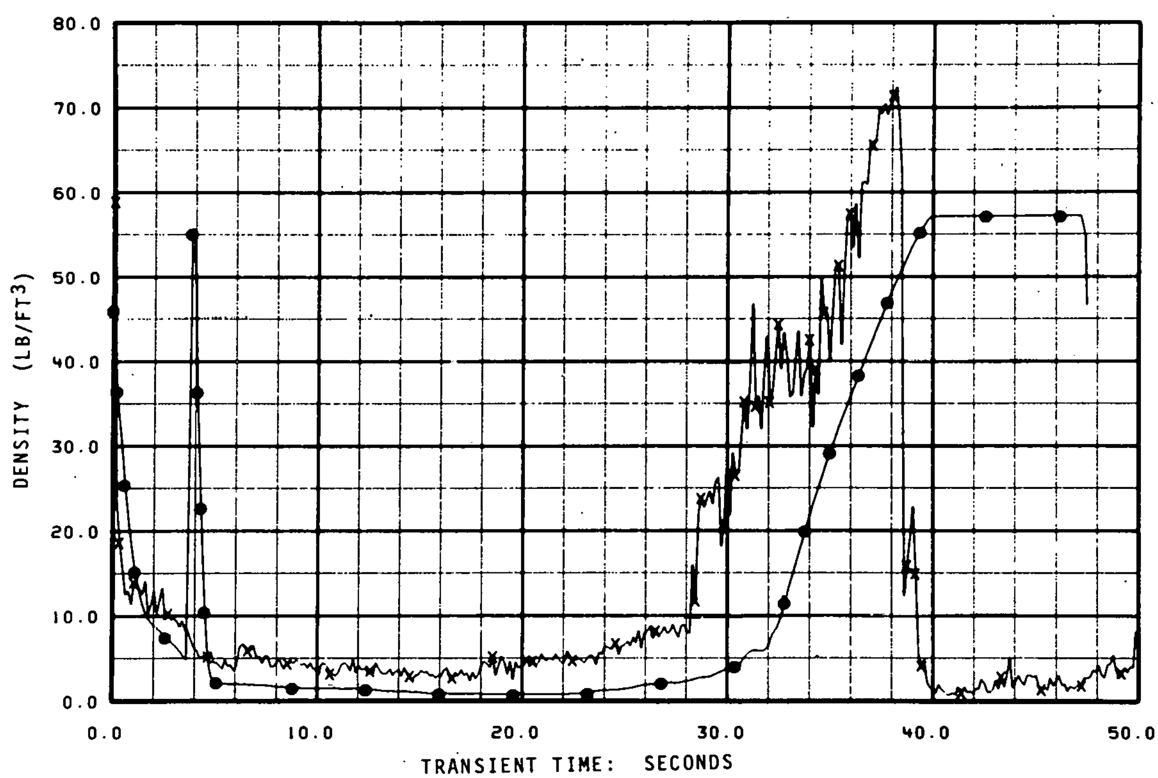

Fig. H-5 Hot leg density history - Semiscale (200% break).

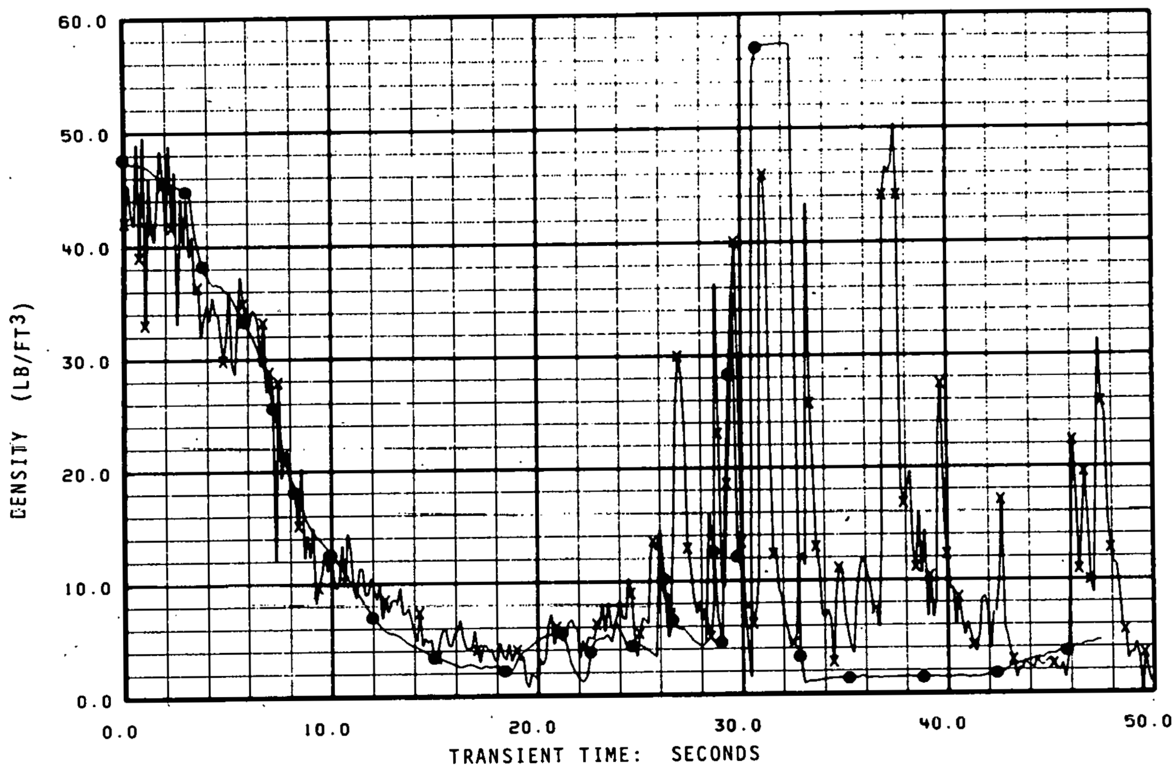

Fig. H-6 Cold leg density history - Semiscale (200% break).

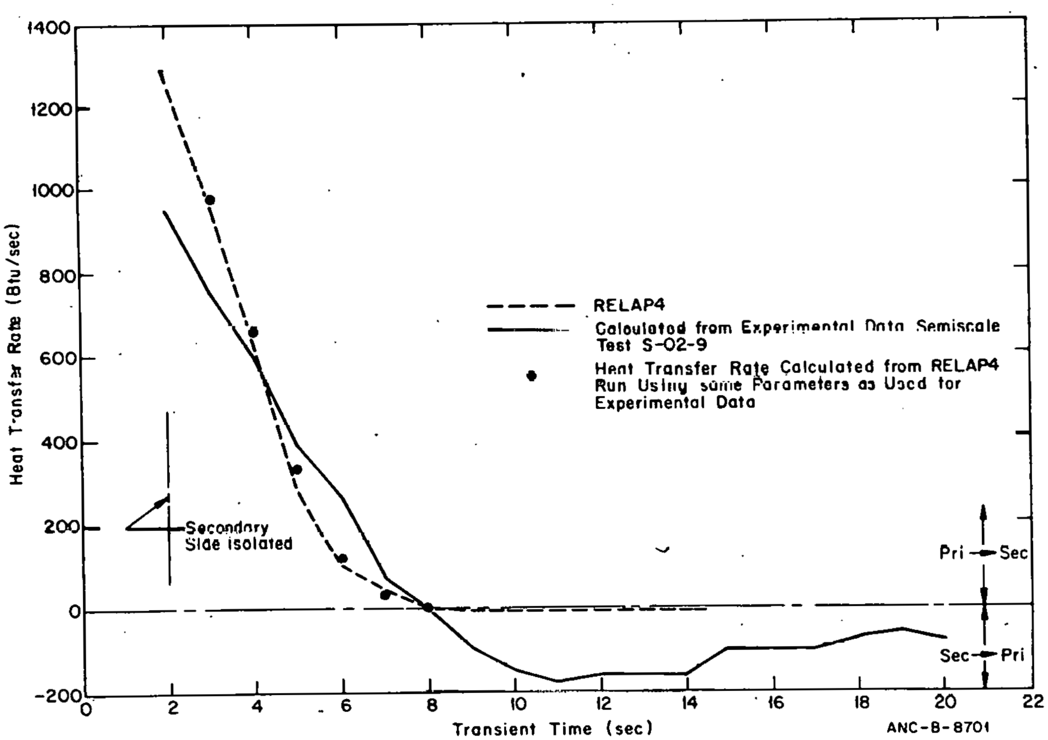

Fig. H-7 Steam generator heat transfer rate history - Semiscale (200% break).

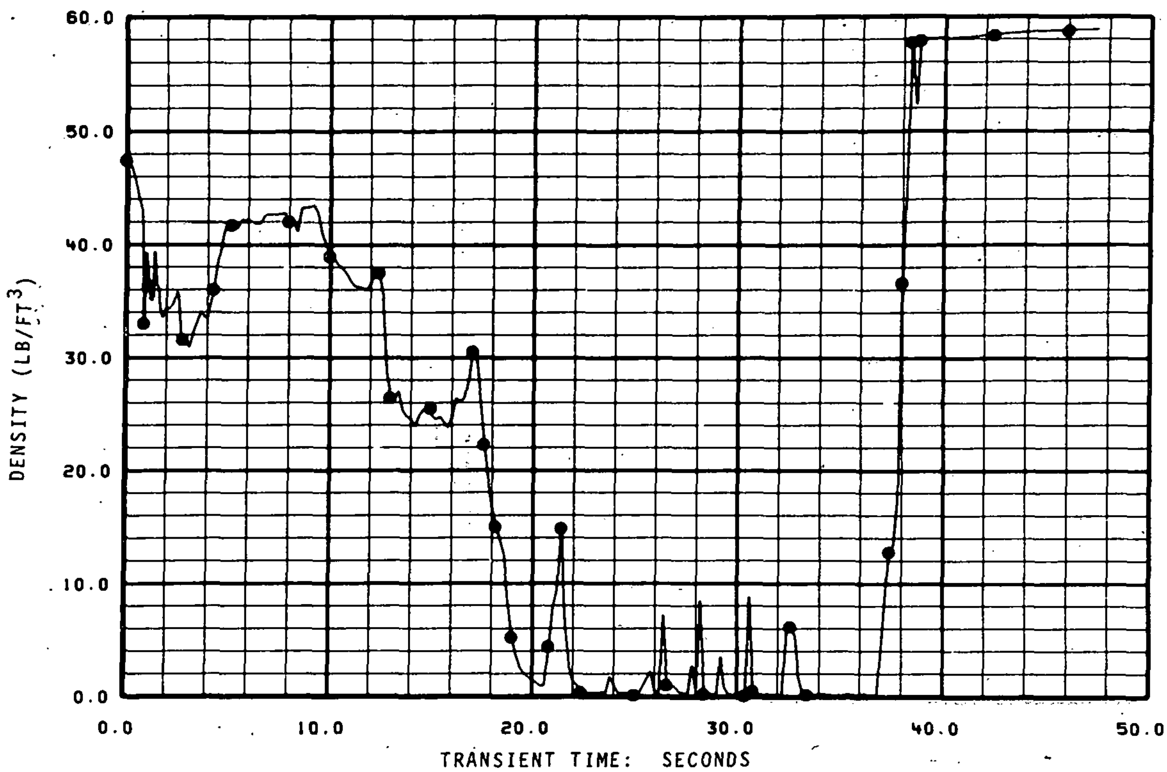

Fig. H-8 Density history, top-most volume in lower plenum - Semiscale (200% break).

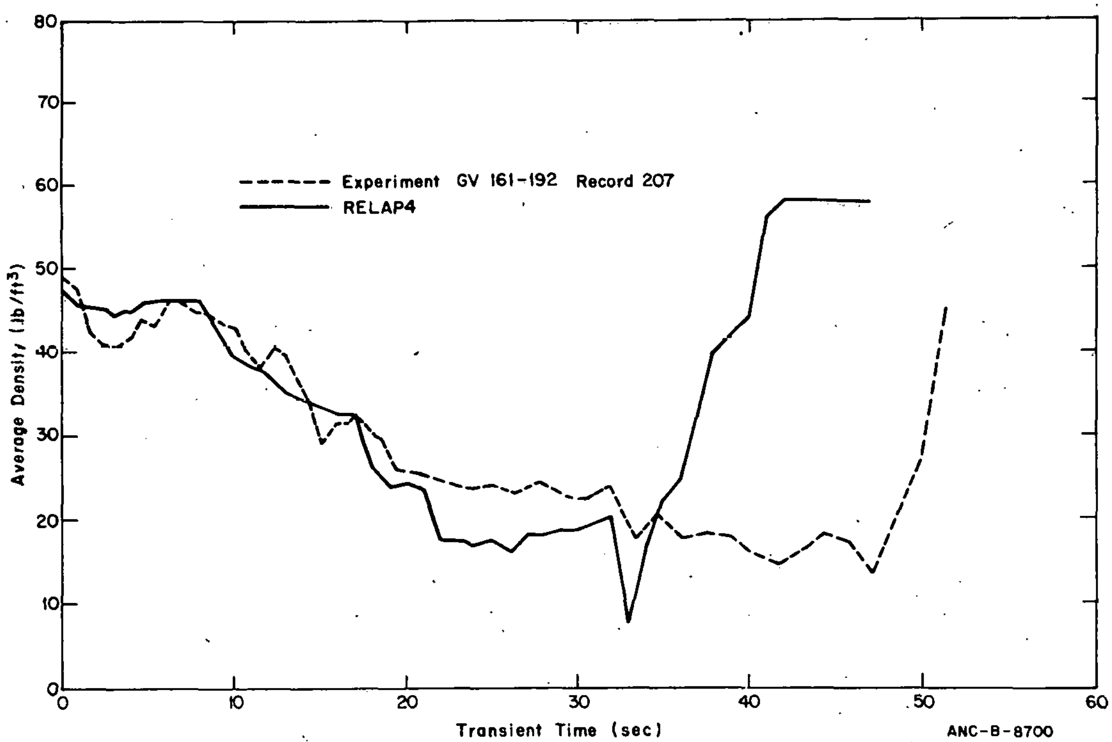

Fig. H-9 Average fluid density in lower plenum - Semiscale (200% break).

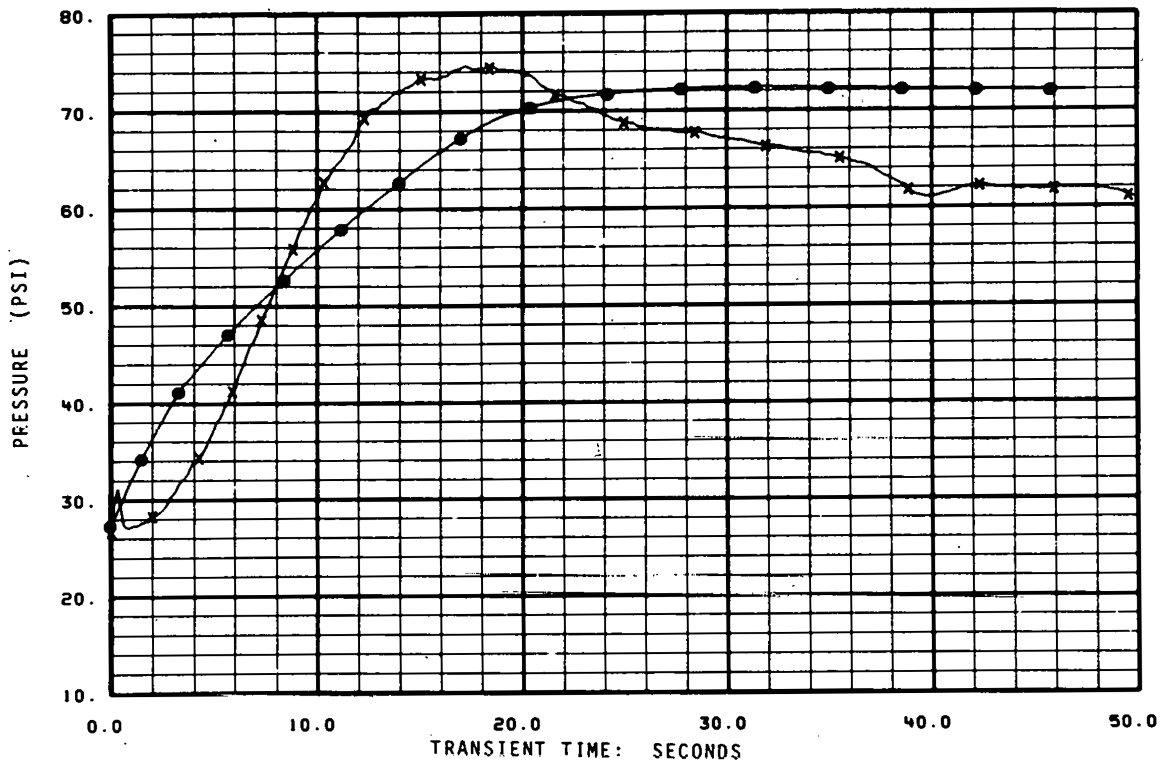

Fig. H-10 Pressure history, suppression vessel - Semiscale (200% break).

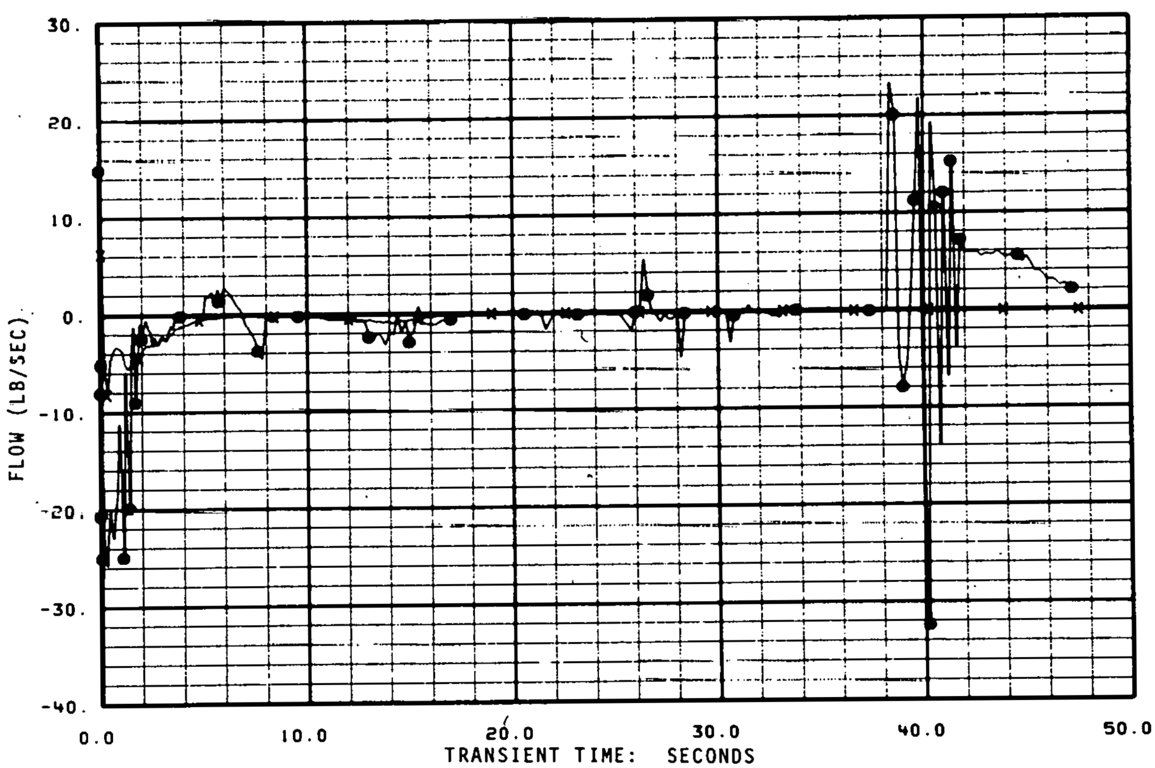

Fig. H-11 Core inlet flow history - Semiscale (200% break).

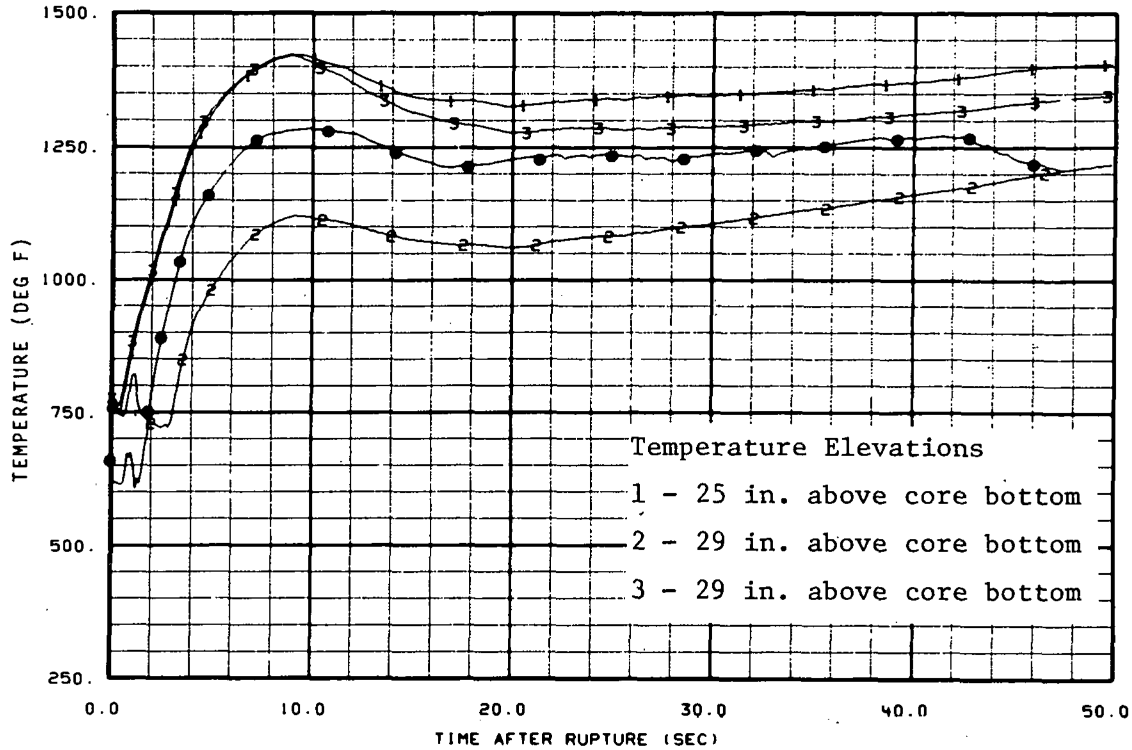

Fig. H-12 Cladding temperature history - Semiscale (200% break).

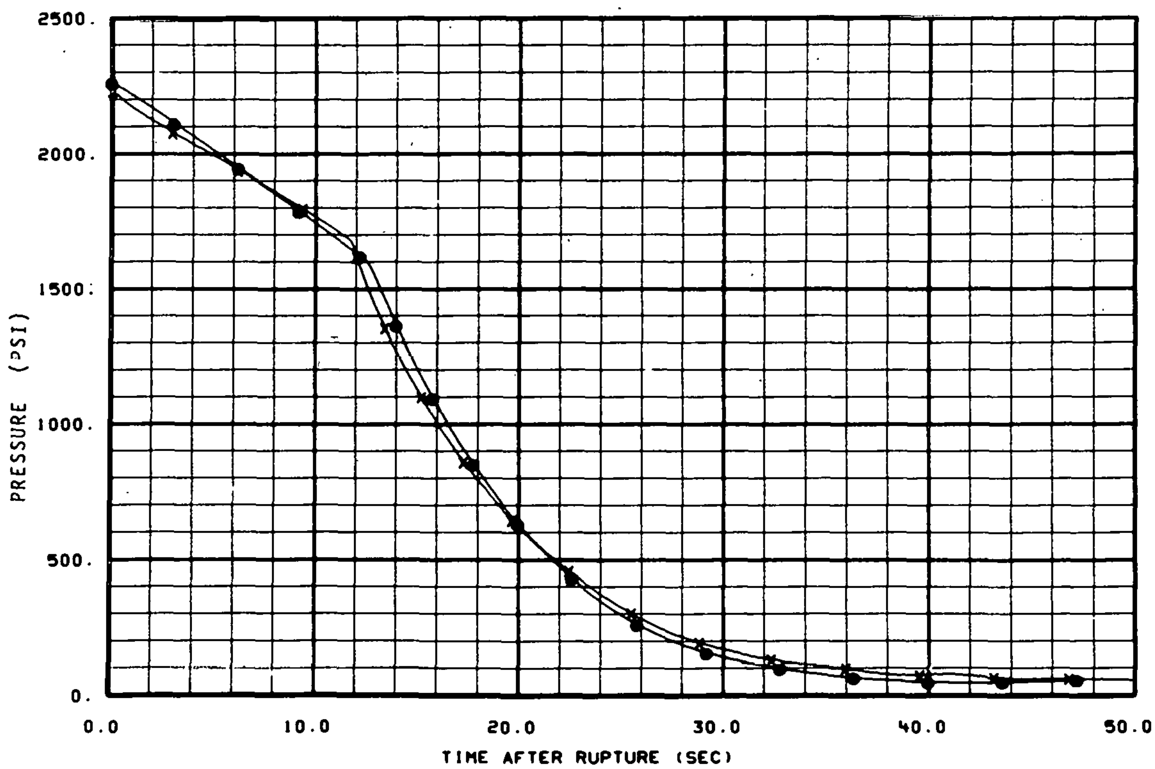

Fig. H-13 Pressurizer pressure history - Semiscale (200% break).

6. SEMISCALE TEST FACILITY

The Semiscale Test Facility is shown in Figure H-14 for the 1-1/2 Loop Mod-1 configuration modeled for this RELAP4/MOD5 problem run. The Semiscale facility is an operating scale model that is used to simulate nuclear reactor plants, generally in Loss of Coolant Accident (LOCA) experiments. The Semiscale installation generates heat in the modeled reactor vessel through the use of electrically heated rods rather than fuel elements. It also accomplishes heat transfer by means of cooling water circulation through the steam generator secondary rather than by vapor generation.

The operating loop (shown with pressurizer, steam generator, and primary coolant pump) is generally modeled to represent the intact loop or loops of a reactor coolant system. The broken loop is modeled with components that hydraulically simulate a steam generator and loop pump. The breaks are simulated by rupture assemblies having controlled characteristic quick opening valves. The blowdown is discharged into a header that conducts the vapor and water mixture to a collection vessel. This vessel has a controllable internal spray for vapor condensation. The combination of the header, vessel, and spray simulates the postulated backpressure of LOCA discharge into the containment of the plant modeled.

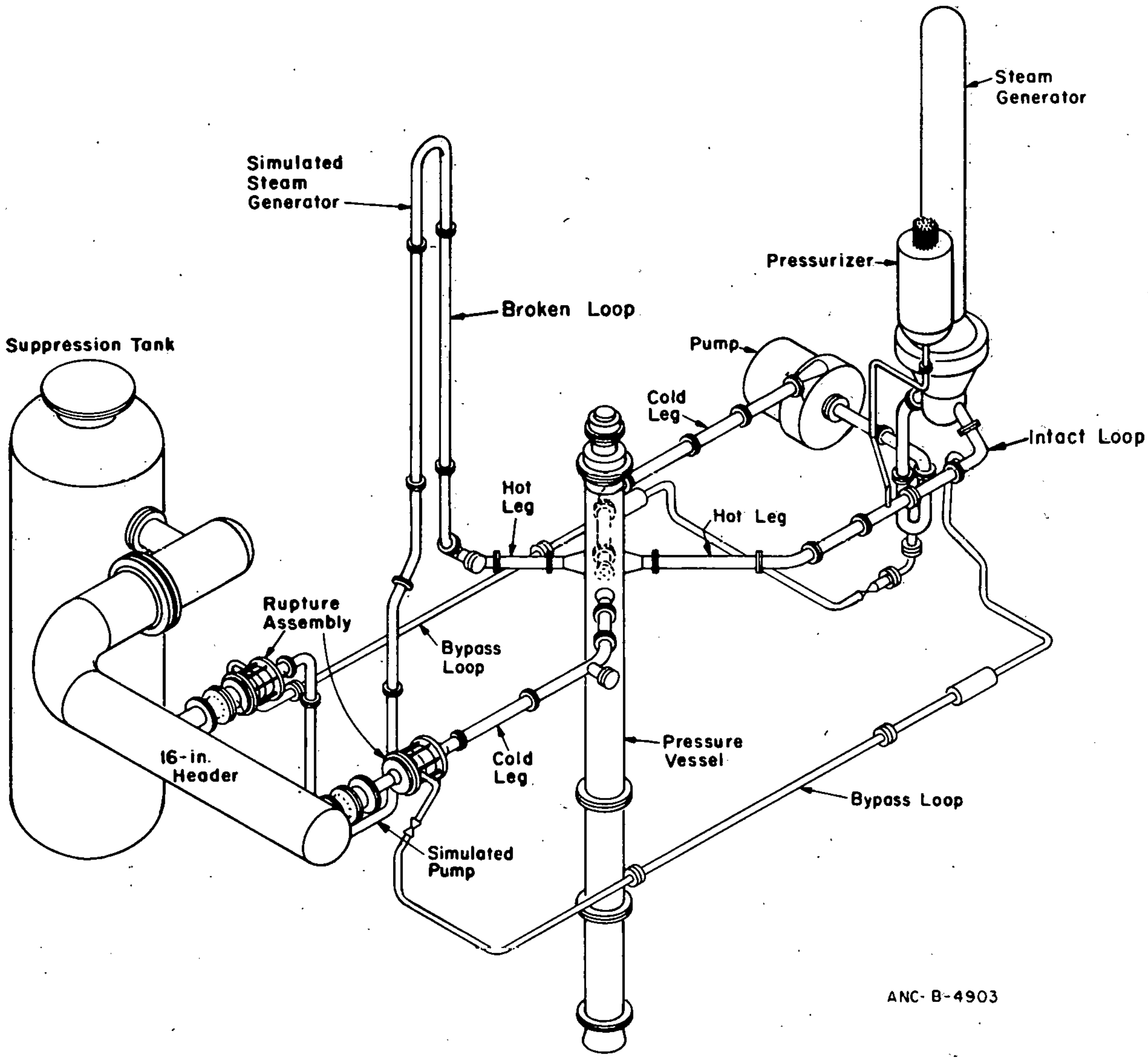

Fig. H-14 1-1/2 loop Mod-1 system - Semiscale Facility.

7. INPUT LISTING

An input listing for this run is given in Table H-VI which follows.

TABLE H-VI

INPUT LISTING

```
=RUN 014:      SEMISCALE MODEL, 37X43X29 SINGLE D.C. & ANN.
*   HEM DIAL = 1.0,  #21 CV MODEL,
*  U(BUB)=3.0 IN NODES 4&36, BROKEN LEG ECC INTO NODE 15
* K(SURGE LINE)=972. PER S-0-29 TEST DATA
* T(BRKN ECC) SET TO 298.
010001    0  0  6  4  37  2  0  43  1  5  1  3  29  3  4  9  0  0
010001   -2  0  6  4  37  2  0  43  1  5  1  3  29  3  4  9  0  0
010002   1.51685  1.0
030003   50
030004   50  30.0
030010    5  2  0  0       0.005     0.0005          0.01
030020   10 10  0  0       0.0005    .00001          0.100
030030   25  2  0  0       0.002     .00005          0.50
030040   20  5  20 0       0.005     .0001           6.00
030050    40 5   5 0        .005     .00005          20.0
030060   20  5   5  0       .010     .00005          90.0
040010   1  1  0  0 30.00  0.0                       *END TIME
040010   1  1  0  0 50.00  0.0                       *END TIME
040020   2  1  0  0  0.0  0.00010                    *BREAK OPENING
040030   3  -4  28  0  150.0  0.0                    *PUMPED SI START
040040   4  1  0  0  1.0+3  0.0                      *LONG TIME(FOR CLOSED VALVES)
050011   0  0  2267.317  540.     -1.
050021   0  0  2270.62   540.     -0.1
050031   0  0  2268.942  540.     -0.1
050041   1  0  2270.314  540.     -0.1
050051   0  0  2269.525  548.63   -0.1
050061   0  0  2268.716  579.     -0.1
050071   0  0  2267.929  599.68   -0.1
050081   1  0  2265.863  611.994  -0.1
050091   0  0  2262.3    595.     -0.1
050101   0  0  2261.3    591.     -0.1
050111   0  0  2261.3    586.     -0.1
050121   0  0  2263.     581.     -0.1
050131   0  0  2263.6    566.     -0.1
050141   0  0  2263.     566.     -0.1
050151   0  0  2262.4    563.     -0.1
050161   0  0  2266.     536.     -0.1
050171   0  0  2266.     539.     -0.1
050181   0  0  2266.     540.     -0.1
050191   0  0  2261.75   611.994  -0.1
050201   0  0  2259.456  611.994  -0.1
050211   0  0  2255.720  593.     -0.1
050221   0  0  2253.645  569.6    -0.1
050231   0  0  2254.439  544.6    -0.1
050241   0  0  2253.287  540.     -0.1
050251   0  0  2251.711  540.     -0.1
050261   0  0  2261.710  540.     -0.1
050271   0  0  2271.150  540.     -0.1
050281   0  0  2269.010  540.     -0.1
050291   2  0   600.      85.      0.0
050291   2  0   600.     298.      0.0
050301   2  0   600.      85.      0.0
050311   0  0  2262.951  611.     -0.1
050321   2  0  2262.721   -1.      0.0
050331   1  0     0.0    525.      0.0170
050341   0  0    27.4    -1.0      0.0
050351   0  0  2270.29   540.0    -0.1
050361   0  0  2271.044  540.     -0.1
050361   1  0  2270.871  540.     -0.1
050371   0  0    27.4    -1.0      1.0
```

TABLE H-VI (contd.)

050012	0.1720	1.5510	1.5510	0	0.1470	0.2150	-1.04	0		
050022	0.3820	1.2040	1.2040	0	0.2383	0.5508	-1.6008+1	35		
050032	0.7740	1.2570+1	1.2570+1	0	0.0574	0.0780	-1.3610+1	1		
050042	0.1310	1.7770	1.7770	0	0.0687	0.3053	-1.3610+1	0		
050052	0.0945	1.8401	1.8401	0	0.0514	0.0350	-1.1833+1	0		
050062	0.0945	1.8401	1.8401	0	0.0514	0.0350	-9.9929	0		
050072	0.0945	1.8401	1.8401	0	0.0514	0.0350	-8.1528	0		
050082	0.8672	9.6527	9.6527	0	0.0612	0.0489	-6.3136	0		
050092	0.1070	0.7552	0.7552	0	0.0376	0.2188	0.5990	0		
050102	0.3227	8.4408	8.4408	0	0.0397	0.2226	1.3542	0		
050112	0.3262	9.4350	9.4350	0	0.0389	0.2226	0.36	0		
050122	0.0640	3.67	3.67	0	0.0156	0.1407	-3.307	0		
050132	0.0534	0.7545	0.7545	0	0.0294	0.2187	-4.0615	0		
050142	0.0658	4.92	4.92	0	0.0123	0.125	-4.0615	0		
050152	0.0970	0.1616	0.1616	0	0.0205	0.1616	0.6280	0		
050152	0.0970	0.8192	0.8192	0	0.0205	0.1616	-0.0296	0		
050152	0.0970	0.8192	0.8192	0	0.4100	0.1616	-0.0296	0		
050162	0.0440	0.1408	0.1408	0	0.0156	0.1408	-0.1704	0		
050162	0.0440	0.1408	0.1408	0	0.3120	0.1408	-0.1704	0		
050172	0.1000	0.2188	0.2188	0	0.0376	0.2188	-0.2188	0		
050182	0.0670	0.2188	0.2188	0	0.0376	0.2188	-0.2188	0		
050192	0.4130	0.6977	0.6977	0	0.0376	0.2188	0.5990	0		
050202	0.3200	1.1983	1.1983	0	0.2670	0.5038	1.2967	0		
050212	0.2673	5.6162	5.6162	0	0.0476	0.0355	2.4950	0		
050222	0.2673	3.3838	3.3838	0	0.0476	0.0355	8.1112	0		
050232	0.2673	5.6162	5.6162	0	0.0476	0.0355	2.4950	0		
050242	0.3200	1.1983	1.1983	0	0.2670	0.5038	1.2967	0		
050252	0.3900	4.7500	4.7500	0	0.0376	8.2185	-3.4533	0		
050262	0.1600	2.1660	2.1660	0	0.0468	0.1979	-1.8955	0		
050272	0.1661	0.2188	0.2188	0	0.0378	0.2188	0.1094	0		
050282	0.1661	0.2188	0.2188	0	0.0378	0.2188	0.1094	0		
050292	0.9880	2.9650	1.8310	0	1.0	1.0	0.0	0		
050302	2.9680	3.3380	2.1300	0	1.0	1.0	0.0	0		
050312	0.0130	0.6967	0.6967	0	0.0030	0.0618	0.6	0		
050322	0.9650	3.8333	2.12	0	0.2553	0.5701	0.6	0		
050332	7.0	1.5520+1	9.66	0	0.04	0.042	2.4950	00		
050342	8.8400+1	1.1630+1	3.95	0	8.6	2.710	-8.4	0		
050342	8.8400+1	1.1630+1	2.50	0	8.6	2.710	-8.4	0		
050352	0.2540	0.803	0.803	0	0.2383	0.5508	-1.4804+1	36		
050362	0.1270	0.401	0.401	0	0.2383	0.5508	-1.4001+1	4		
050372	2.1760+1	6.3728	6.3728	0	0.3474	0.6651	-5.4	0		
060011	0.0	3.0								
060021	0.0	1.0+6								
080011	3	36	0	0	1.5000+1	4.6840-2	-1.3610+1	0.0	0.0	0.0
080021	4	5	0	0	1.5000+1	5.1400-2	-1.1833+1	0.0	0.0	0.0
080031	5	6	0	0	1.5000+1	5.1400-2	-9.9929	0.0	0.1948	0.1948
080041	6	7	0	0	1.5000+1	5.1400-2	-8.1528	0.0	0.1820	0.1820
080051	7	8	0	0	1.5000+1	5.1400-2	-6.3136	0.0	0.0	0.0
080061	8	19	0	0	1.5000+1	2.0500-2	0.5990	0.0	2.0292	2.17
080071	19	20	0	0	1.5000+1	3.7550-2	1.2967	0.0	5.8488	5.4964
080081	20	21	0	0	1.5000+1	4.7600-2	2.4950	0.0	8.5004	8.8858
080091	21	22	0	0	1.5000+1	0.0476	8.1112	0.0	0.5000	0.5000
080101	22	23	0	0	1.5000+1	0.0476	8.1112	0.0	0.5000	0.5000
080111	23	24	0	0	1.5000+1	0.0476	2.4950	0.0	9.76	9.4546
080121	24	25	0	0	1.5000+1	0.0376	1.2967	0.0	6.0891	6.4406
080131	25	26	-1	0	1.5000+1	0.0376	-1.7863	0.0	5.7411	5.7909
080141	26	27	1	0	1.5000+1	0.0376	0.2188	0.0	5.7913	5.7439
080151	27	28	0	0	1.5000+1	0.0376	0.2188	0.0	5.7055	5.7055
080161	28	1	0	0	1.5000+1	0.0378	0.2188	0.0	6.0022	5.9848
080171	8	9	0	0	0.0	0.0205	0.6771	0.0	0.86	0.86

TABLE H-VI (contd.)

080181	9	10	0	0	0.0	0.0376	1.3542	0.0	5.9	5.9
080191	10	11	0	0	0.0	0.0376	9.6837	0.0	2.36	2.36
080201	11	12	0	0	0.0	2.6520-3	0.36	0.0	1.6	1.6
080211	12	13	0	0	0.0	2.6340-3	-3.3070	0.0	1.2335+1	1.2335+1
080221	14	15	0	0	0.0	1.2250-2	0.7088	0.0	0.0	0.0
080231	15	16	0	1	0.0	2.6200-3	-0.0296	0.0	4.2	4.2
080241	16	17	0	0	0.0	3.7550-2	-0.1094	0.0	6.39	6.39
080251	17	18	0	0	0.0	3.7550-2	-0.1094	0.0	0.42	0.42
080261	18	1	0	0	0.0	2.0500-2	-0.1094	0.0	0.428	0.428
080271	37	34	0	0	0.0	0.3474	-5.4	0.0	0.921	0.921
080281	13	14	0	0	0.0	.00267	-4.0615	0.0	3.74	3.74
080291	1	3	0	0	1.5000+1	2.8720-2	-1.04	0.0	0.628	0.628
080301	35	36	0	0	0.0	0.2383	-1.4001+1	0.0	0.0	0.0
080311	36	4	0	0	1.5000+1	0.3142-1	-1.3606+1	0.0	0.1897	0.3144
080321	31	19	0	0	0.0	0.0030	0.6	0.0	4.4	4.4
080321	31	19	0	0	0.0	0.0030	0.6	0.0	4.8600+2	4.8600+2
080331	32	31	0	0	0.0	0.003	0.6	0.0	4.4	4.4
080331	32	31	0	0	0.0	0.003	0.6	0.0	4.8600+2	4.8600+2
080341	30	28	0	4	0.0	4.9900-3	0.1094	0.0	2.1100+2	2.1100+2
080351	29	14	0	5	0.0	0.003	0.1094	0.0	2.5000+3	2.5000+3
080351	29	15	0	5	0.0	0.003	0.1094	0.0	2.5000+3	2.5000+3
080361	15	37	0	2	0.0	2.6200-3	0.6580	0.0	2.1	2.1
080371	16	37	0	3	0.0	2.6200-3	-1.0000-1	0.0	2.1	2.1
080381	2	35	0	0	0.0	0.2383	-1.4804+1	0.0	0.0	0.0
080391	0	19	0	0	0.0	4.9900-3	0.8178	0.0	0.752	0.39
C80401	0	28	1	0	0.0	4.9900-3	0.1094	0.0	0.752	0.390
080411	0	14	2	0	0.0	5.0000-3	0.10	0.0	0.752	0.390
080411	0	15	2	0	0.0	5.0000-3	0.10	0.0	0.752	0.390
080421	0	33	3	0	1.4660	1.2000-2	2.50	0.0	0.752	0.39
080431	33	0	1	0	1.466	0.0210	1.5400+1	0.0	3.3500+3	3.3500+3
080012	0	5	3	0	0.5508	0.0	0	0	1.0	0
080022	0	5	3	0	0.0350	0.0	0	0	0.0	0
080032	0	5	2	0	0.0350	0.0	0	0	0.0	0
080042	0	5	2	0	0.0350	0.0	0	0	0.0	0
080052	C	5	3	0	0.0489	0.0	0	0	0.0	0
080062	1	5	2	0	0.2188	0.0	0	0	0.0	0
080072	1	5	2	0	0.2188	0.0	0	0	0.0	0
080082	0	5	2	0	0.0355	0.0	0	0	0.0	0
080092	0	5	2	3	0.0355	0.0	0	0	0.0	0
C80102	0	5	2	3	0.0355	0.0	0	0	0.0	0
080112	0	5	2	0	0.0355	0.0	0	0	0.0	0
080122	0	5	2	0	0.2185	0.0	0	0	0.0	0
080132	1	5	2	3	0.2185	0.0	0	0	0.0	0
080142	1	5	2	3	0.2188	0.0	0	0	0.0	0
080152	1	5	2	3	0.2188	0.0	0	0	0.0	0
080162	1	5	2	0	0.2188	0.0	0	0	0.0	0
080172	0	5	2	0	0.2188	0.0	0	0	0.0	0
080182	0	5	2	0	0.0376	0.0	0	0	0.0	0
080192	1	5	2	3	0.0376	0.0	0	0	0.0	0
080202	1	5	2	0	0.1407	0.0	0	0	0.0	0
080212	0	5	2	3	0.0579	0.0	0	0	0.0	0
080222	0	5	2	3	0.1616	0.0	0	0	0.0	0
080232	1	5	2	0	0.0578	0.0	0	0	0.0	0
080242	1	5	2	3	2.1883-1	0.0	0	0	0.0	0
080252	1	5	2	3	2.1883-1	0.0	0	0	0.0	0
080262	1	5	2	0	1.6156-1	0.0	0	0	0.0	0
080272	0	5	2	3	0.6651	0.0	0	0	0.0	
080282	0	0	2	0	0.05792	0.0	0	0	0.0	
080292	0	5	2	0	0.0	0.0	0	0	1.0	0
080302	0	5	2	3	0.0	0.0	0	0	1.0	0

TABLE H-VI (contd.)

```
080312  0  5  2  3  0.24       0.0    0  0  1.0  0
080322  0  5  2  0  0.0        0.0    0  0  0.0  0
080332  0  5  2  0  0.0        0.0    0  0  0.0  0
080342  1  5  2  0  0.0797     0.0    0  0  0.0  0
080352  0  5  2  0  0.0797     0.0    0  0  0.0  0
080362  1  5  2  0  5.7750-2   0.0    0  0  0.0  0
080372  1  5  2  0  0.0583     0.0    0  0  0.0  0
080382  0  5  3  3  0.0        0.0    0  0  1.0  00
080392  0  5  2  3  0.0797     0.0    0  0  0.0
C80402  0  5  2  3  0.0797     0.0    0  0  0.0
080412  0  5  2  3  0.0800     0.0    0  0  0.0
080422  0  5  2  3  0.1250     0.0    0  0  0.0
080432  0  5  2  0  6.1804-2   0.0    0  0  0.0
082000  0
C82003  1.0  0.9  0.9  0.01
C82004  0.6
090011   1  2  1  1  0   3560.   .6537 180. 192. 34.8  38.3   62.3  0. 0. 6.7
091001 -11 0. 0. .1 0. .15 .05 .24 .8 .3 .96 .4 .98 .6 .97 .8 .9 .9 .8 .96 .5
091002 1. 0.
092001 -9 0. -.17 .0001 -.17 .006 0. .1 0. .15 .05 .24 .56 .8 .56 .96 .45 1. 0.
100000  16  0  0  16
*               PUMP HEAD AND TORQUE MULTIPLIER CURVES
101011 1 1 -2 0. 1.2 1. 1.
101021 1 2 -5 0. -0.35 0.3 -0.2 0.5 0.0 0.8 0.545 1.0 1.0
101031 1 3 -5 -1. 1.5 -.8 1.275 -.6 1.375 -.4 1.375 0. 1.2
101041 1 4 -6 -1. 1.5 -.8 1.15 -0.6 0.95 -0.4 0.83 -0.2 0.775 0.0 0.725
101051 1 5 -3  0. .975  0.5 1.35 1. 1.95
101061 1 6 -5  0. .725  0.2 .725  .4  .8  .6 1.025 1. 1.95
101071 1 7 -3 -1.0 0.175 -0.50 0.65 0.0 .975
101081 1 8 -5 -1.0 0.175  -0.75 -.15 -.55 -0.3 -.275 -.4 0. -0.35
101090   2 1 -8       0. 0.54  0.2 0.59  0.4 0.65  0.6 0.77  0.8 0.95
101091                0.9 0.98  0.95 0.96  1.0 0.87
101100   2 2 -8       0. -0.15  0.2 0.02  0.4 0.22  0.6 0.46  0.8 0.71
101101                0.9 0.81  0.95 0.85  1.0 0.87
101110   2 3 -6       -1.0 0.62  -0.8 0.68  -0.6 0.53  -0.4 0.46
101111                -0.2 0.49  0. 0.54
101120   2 4 -6       -1.0 0.62  -0.8 0.53  -0.6 0.46  -0.4 0.42
101121                -0.2 0.39  0. 0.36
101130   2 5 -7       0. -0.63  0.2 -0.51  0.4 -0.39  0.6 -0.29
101131                0.8 -0.20  0.9 -0.16  1.0 -0.13
101140   2 6 -6       0. 0.36  0.2 0.32  0.4 0.27  0.6 0.18
101141                0.8 0.05  1.0 -0.13
101150   2 7 -6       -1.0 -1.44  -0.8 -1.25  -0.6 -1.08
101151                -0.4 -0.92  -0.2 -0.77  0. -0.63
101160   2 8 -6       -1.0 -1.44  -0.8 -1.12  -0.6 -0.79
101161                -0.4 -0.52  -0.2 -0.31  0. -0.15
104011 1 1 7 0. 0. .1 .83 .2 1.09 .5 1.02 .7 1.01 .9 .94 1. 1.
104021 1 2 8 0. 0. .1 -.04 .2 0. .3 .1 .4 .21 .8 .67 .9 .8 1. 1.
104031 1 3 10 -1. -1.16 -.9 -1.24 -.8 -1.77 -.7 -2.36 -.6 -2.79 -.5 -2.91
104032  -.4 -2.67 -.25 -1.69 -.1 -.5 0. 0.
104041 1 4 10 -1. -1.16 -.9 -.78 -.8 -.5 -.7 -.31 -.6 -.17 -.5 -.08 -.35 0.
104042      -.2 .05 -.1 .08 0. .11
104051 1 5 6 0. 0. .2 -.34 .4 -.65 .6 -.93 .8 -1.19 1. -1.47
104061 1 6 10 0. .11 .1 .13 .25 .15 .4 .13 .5 .07 .6 -.04 .7 -.23 .8 -.51
104062   .9 -.91 1. -1.47
104071 1 7 2 -1. 0. 0. 0.
104081 1 8 2 -1. 0. 0. 0.
104090   2 1 -8       0. 0.54  0.2 0.59  0.4 0.65  0.6 0.77  0.8 0.95
104091                0.9 0.98  0.95 0.96  1.0 0.87
104100   2 2 -8       0. -0.15  0.2 0.02  0.4 0.22  0.6 0.46  0.8 0.71
104101                0.9 0.81  0.95 0.85  1.0 0.87
104110   2 3 -6       -1.0 0.62  -0.8 0.68  -0.6 0.53  -0.4 0.46
104111                -0.2 0.49  0. 0.54
104120   2 4 -6       -1.0 0.62  -0.8 0.53  -0.6 0.46  -0.4 0.42
104121                -0.2 0.39  0. 0.36
104130   2 5 -7       0. -0.63  0.2 -0.51  0.4 -0.39  0.6 -0.29
104131                0.8 -0.20  0.9 -0.16  1.0 -0.13
104140   2 6 -6       0. 0.36  0.2 0.32  0.4 0.27  0.6 0.18
104141                0.8 0.05  1.0 -0.13
104150   2 7 -6       -1.0 -1.44  -0.8 -1.25  -0.6 -1.08
104151                -0.4 -0.92  -0.2 -0.77  0. -0.63
104160   2 8 -6       -1.0 -1.44  -0.8 -1.12  -0.6 -0.79
104161                -0.4 -0.52  -0.2 -0.31  0. -0.15
```

TABLE H-VI (contd.)

```
110010  2  0  1  0.0  0.0  0.0  0.0
110020  -2  0  1  0.0  0.0  0.0  0.0
110030  -2  0  1  0.0  0.0  0.0  0.0
110040  21 0  0  0.0  0.0  1.0+20  1.0+20
110050  21 0  0  0.0  0.0  1.0+20  1.0+20
120101  4  2  12.1  0.  1.0  1.0  1.0  2.0  0.0  600.0  0.0
130100  3  1  2  4  LBS/SEC  100.0  85.0  0.0
130101  0.0  118.0  1.0+4  118.0
130200  4  1  2  4  LBS/SEC  100.0  85.0  0.0
130200  3  1  2  4  LBS/SEC  100.0  298.0  0.0
130201  0.0  39.2  1.0+4  39.2
130300  2  1  4  4  LBS/SEC  900.0  440.0  0.0
130301  0.0  122.17  1.0  122.17  2.0  0.0  1.0+3  0.0
140000  0  0.0  0.0  0.0  0.0
141001 -14  2  0.0  1.0  2.6  1.0  3.2  0.68  4.0  0.34  5.0  0.34  6.4  0.22
141002  7.4  0.084  8.4  0.068  9.0  0.041  10.0  0.035  12.6  0.032
141003  16.9  0.034  17.4  0.039  36.0  0.038
150011  0  5  1  0  2  0  0  0.0  7.3185  0.0643  0.0  0.03610  0.0  0.0465
150012  0.  5.5202  0.0  0.0
150021  0  6  1  1  2  0  0  0.0  7.3185  0.0643  0.0  0.03610  0.0  0.0465
150022  0.0  5.5202  0.0  0.0
150031  0  7  1  1  2  0  0  0.0  7.3185  0.0643  0.0  0.03610  0.0  0.0465
150032  0.0  5.5202  0.0  0.0
150041  0  8  1  1  2  0  0  0.0  38.3920  0.3375  0.0  0.0361  0.0  0.0
150042  0.0  0.0  0.0  0.0
150051  0  5  1  0  2  0  0  0.0  0.4066  3.5740-3  0.0  0.03610  0.0  0.0465
150052  0.0  0.9200  0.0  0.9200
150052  0.0  5.5202  0.0  0.9200
150061  0  5  1  1  2  0  0  0.0  0.4066  3.5740-3  0.0  0.03610  0.0  0.0465
150062  0.0  0.9200  0.9200  1.8400
150062  0.0  5.5202  0.9200  1.8400
150071  0  6  1  1  2  0  0  0.0  0.4066  3.5740-3  0.0  0.03610  0.0  0.0465
150072  0.0  0.9200  0.0  0.9200
150072  0.0  5.5202  0.0  0.9200
150081  0  6  1  1  2  0  0  0.0  0.4066  3.5740-3  0.0  0.03610  0.0  0.0465
150082  0.0  0.9200  0.9200  1.8400
150082  0.0  5.5202  0.9200  1.8400
150091  0  7  1  1  2  0  0  0.0  0.4066  3.5740-3  0.0  0.03610  0.0  0.0465
150092  0.0  0.9200  0.0  0.9200
150092  0.0  5.5202  0.0  0.9200
150101  0  7  1  1  2  0  0  0.0  0.4066  3.5740-3  0.0  0.03610  0.0  0.0465
150102  0.0  0.9200  0.9200  1.8400
150102  0.0  5.5202  0.9200  1.8400
150111  0  8  1  1  2  0  0  0.0  4.2656  3.7502-2  0.0  0.0465  0.0  0.0
150112  0.0  0.0  0.0  0.0
* SG SLAB AREAS INCREASED BY 1.26567
150121  21  33  2  0  3  0  0  40.4003  50.0532  0.1813  0.0  0.0  0.0  0.0
150122  5.6162  5.6162  0.0  5.6162
150131  22  33  2  1  3  0  0  20.2001  25.0265  0.0905  0.0  0.0  0.0  0.0
150132  3.3838  3.3838  5.6162  9.0000
150141  23  33  2  0  3  0  0  40.4003  50.0532  0.1813  0.0  0.0  0.0  0.0
150142  5.6162  5.6162  0.0  5.6162
150151  22  33  2  1  3  0  0  20.2001  25.0265  0.0905  0.0  0.0  0.0  0.0
150152  3.3838  3.3838  5.6162  9.0000
150161  19  0  2  0  1  0  0  7.57  0.0  0.6436  0.0  0.0  0.0  0.0
150162  8.0  0.0  0.0  0.0
150171  25  0  2  0  1  0  0  6.59  0.0  0.556  0.0  0.0  0.0  0.0
150172  0.0  0.0  0.0  0.0
150181  28  0  2  0  1  0  0  5.44  0.0  0.463  0.0  0.0  0.0  0.0
150182  7.0  0.0  0.0  0.0
150191  9  0  2  0  0  0  0  1.7  0.0  0.144  0.0  0.0  0.0  0.0
150192  3.0  0.0  0.0  0.0
150201  10  0  2  0  0  0  0  5.895  0.0  0.5015  0.0  0.0  0.0  0.0
150202  7.0  0.0  0.0  0.0
150211  11  0  2  0  0  0  0  6.625  0.0  0.5625  0.0  0.0  0.0  0.0
150212  0.0  0.0  0.0  0.0
150221  12  0  2  0  1  0  0  1.17  0.0  0.1  0.0  0.0  0.0  0.0
150222  0.0  0.0  0.0  0.0
150231  14  0  2  0  1  0  0  1.2  0.0  0.1  0.0  0.0  0.0  0.0
150232  0.0  0.0  0.0  0.0
150241  15  0  2  0  1  0  0  1.42  0.0  0.12  0.0  0.0  0.0  0.0
150242  0.0  0.0  0.0  0.0
150251  16  0  2  0  1  0  0  1.250  0.0  0.0776  0.0  0.0  0.0  0.0
```

TABLE H-VI (contd.)

```
150252  0.0  0.0  0.0  0.0
150261  17  0  2  0  1  0  0  1.821  0.0  0.0776  0.0  0.0  0.0  0.0
150262  0.0  0.0  0.0  0.0
150271  18  0  2  0  1  0  0  1.220  0.0  0.0520  0.0  0.0  0.0  0.0
150272  0.0  0.0  0.0  0.0
150281  3  0  3  0  1  0  0  10.8750  0.0  1.4640  0.0  0.0  0.0  0.0  0.0
150282  0.0  0.0  0.0  0.0
150291  3  0  3  0  1  0  0  10.8750  0.0  1.4640  0.0  0.0  0.0  0.0
150292  0.0  0.0  0.0  0.0
* CORE POWER: 37 ACTIVE RODS (40.99585 KW/ROD), 4 OF WHICH MODEL HOT CHANNEL
* HOT CHANNEL SLABS(5 THRU 10) HAVE AVG CHANNEL POWER
160010  1  2  6  10  0.0  0.32676  0.0  0.0
160020  2  2  6  10  0.0  0.42145  0.0  0.0
160030  3  2  6  10  0.0  0.14368  0.0  0.0
160040  5  2  6  10  0.0  0.01413  0.0  0.0
160050  6  2  6  10  0.0  0.02548  0.0  0.0
160060  7  2  6  10  0.0  0.02828  0.0  0.0
160070  8  2  6  10  0.0  0.02280  0.0  0.0
160080  9  2  6  10  0.0  0.01330  0.0  0.0
160090  10  2  6  10  0.0  0.00412  0.0  0.0
* CORE SLABS: GEOM=1, MTRL=1,2,3
170101 2 4 1 1 0. .002917 0.
170102 0 3 4 .007167 1.
170103 0 1 4 .00425 0.
170104 0 2 8 .00325 0.
* SG SLABS: GEOM=2, MTRL=2
170201 2 1 2 5 .01675 .C04 0.
170301  2  3  2  3  0.2750  0.0104  0.0
170302  0  4  2  0.004  0.0
170303  0  2  3  0.094  0.0
180101    -7        500. 16.6  1000. 15.9  1500. 15.3  2000. 14.7
180102              2500. 14.1  3000. 13.5  3500. 12.8      *BORON NITRATE
180201    -3        100. 7.75  800. 11.0  1600. 14.3        *316L STAINLESS
180301    -2        0. 14.0  3000. 14.0                     *CONSTANTAN
180401  -2  0.0  0.013  2000.0  0.05
190101    -7        400. 37.5  800. 48.3  1200. 54.6  1600. 58.3
190102              2000. 60.5  2400. 61.4  3400. 62.5    * BORON NITRATE
190201    -4        400. 61.3  600. 64.6  800. 67.1  2200.  82.9  * 316L SS
190301    -7        212. 56.  572. 61.  932. 67.  1472. 73.
190302              2192. 78.  2552. 84.  3000. 90.        *CONSTANTAN
190401  -2  0.0  0.2  2000.0  0.2
```

APPENDIX I

RELAP 4/MOD5, UPDATE 2

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APPENDIX I

RELAP 4/MOD5, UPDATE 2

1. INTRODUCTION

RELAP4/MOD5, Update 1 was released to the Nuclear Regulatory Commission in January 1976. Six months of extensive use of Update 1 has led to the identification and correction of a number of errors in the code; as well as some logic changes, additional Evaluation Model (EM) checks, and one model revision. These changes have culminated in the release of an improved code identified as RELAP4/MOD5, Update 2. The following two sections of Appendix I discuss the major differences between Updates 1 and 2 and the checkout of Update 2. The User's Manual is written in accordance with Update 2.

2. DIFFERENCES BETWEEN UPDATE 1 AND UPDATE 2

The differences between Updates 1 and 2 of MOD5 are made up of error corrections, logic changes, additional EM (Evaluation Model) checks, additional options, and one model revision (modified momentum choking model). The error corrections have been made over the course of six months of extensive use of MOD5, Update 1. The major differences between Updates 1 and 2 are itemized below. Minor error corrections not involving problem input or modeling consideration are neither listed nor discussed.

2.1 Heat Transfer

The heat transfer correlations discussed in Volume I, Subsection 3.4.6 were modified as follows:

(1) In heat transfer mode 4, if the calculated heat flux exceeds the critical heat flux (CHF), the wall temperature is recalculated as that temperature at which the conduction equation equals CHF before the flux is set equal to CHF. This is restricted to right slab surfaces. This was an internal change in the code and required no change in problem input data.

(2) Changes were made to the heat slab left heat transfer surface calculation during the transient. On the left side of the slab, subroutine HRTC is used only to get a heat transfer coefficient, and the temperature is not calculated in subroutine QDOT (both subroutines are described in Volume II, Subsection 5.1.2). When the fluid is subcooled, the last time step temperature TOLD is greater than TSAT, and the last time step heat transfer mode is 1 or 2. The test to choose between the new heat transfer modes 1 and 2 is invalid.

This is because the two temperatures both equal TOLD, and the current logic will always select mode 1. The correction causes the choice between modes 1 and 2 in this situation to be based on fluxes, rather than temperatures. These were internal changes and required no change in problem input data.

2.2 Water Packing

The water packing option discussed in Volume I, Subsection 3.6.7 was modified as follows:

(1) The water packing fix was originally coded to never allow its application through a pump volume. This was changed in Update 2 to allow water packing through the pump volume whenever it is the only available compressible volume. This is an internal modification of the code and required no change in problem input data.

2.3 Critical Flow

The critical flow models discussed in Volume I, Subsection 3.6.8 were modified extensively. Some of the modifications affected data shown on Tables V and XI. The modifications to the Critical Flow Models were as follows:

(1) In case the estimated junction flow is opposite in sign to the old flow, the volume enthalpy from the estimated flow direction is now used as input to the critical flow tables. Also, the saturated liquid enthalpy from the estimated flow direction is now used to check the phase for the choice of critical flow tables. This was an internal modification of the code and required no change in problem input data.

(2) In the modified momentum homogenous equilibrium choking model, a check against the inertial flow was added for subcooled conditions. The inertial flow value is used if it is less than the modified momentum value. This was an internal modification and required no change in problem input data.

(3) Changes were made to the modified momentum critical flow model, as follows:

(a) The Bernoulli form of the momentum equation is now used to calculate mass flow.

(b) The stipulation that the calculated back pressure must not be allowed to increase was removed.

(c) The calculated "back pressure" in the modified momentum model is now applied to the volume upstream, rather than downstream, of the flow junction under consideration.

2.4 Jet Pump Model

The jet pump model discussed in Volume I, Subsection 3.6.11 was modified as follows:

(1) Changes were made to the BWR jet pump model (momentum mixing model) coding to correct errors existent in Update 1. The errors in Update 1 were due to the use of partial junction properties (density, enthalpy, velocity, and mass flow of the liquid and gas) rather than homogenous junction properties. These modifications were internal and required no change in problem input data.

2.5 Enthalpy Transport

The functioning of the enthalpy transport model discussed in Volume I, Subsection 3.6.14 was modified as follows:

(1) An option was added to allow turning off the enthalpy transport calculation at any transient time. This option is accessed by entering the starting time for XOPTON(4) at W4-R on the Water Packing, Choking Smoothing, and Enthalpy Transport Card outlined in Volume II, Subsection 4.2.2 (8). Default was programmed to equal 1E6. This option is intended to be used for restarting jobs which have encountered enthalpy transport problems late in the transient.

2.6 Time Step Control

The time step control discussed in Volume I, Subsection 3.8.2 was modified as follows:

(1) The saturation line crossing time step control is now turned off for time-dependent volumes entered on the Time Dependent Volume Data Cards described in Volume II, Subsection 4.2.2 (19). This was an internal modification of the code and required no change in problem input data.

2.7 Dials

The critical flow dial use outlined in Volume I, Section 3.9 has been extended as follows:

(1) Dials were added to the critical flow derivative calculation for use in the leak junction calculation. The use of these dials was an internal modification and required no change in input data other than entering specific values for the required dials if default values are not desired.

2.8 Evaluation Model

The changes to the Evaluation Model described in Volume I, Section 3.10 provided for the following additional requirements and/or eliminations.

(1) Downcomer and lower plenum entrainment models are not allowed.

(2) Dials are not allowed.

(3) Subcooled voiding credit is not allowed in the reactor kinetics calculation.

(4) The pump option for the single-phase minus two-phase difference curves is required.

(5) The stagnation pressure option is required.

(6) The two-phase friction multiplier is required.

These were internal modifications and required no change in program input data.

2.9 Subroutines FLOSRH and PREW

A number of modifications and corrections were made to the ICHOKE-JCHOKE logic in subroutines FLOSRH and PREW described in Volume II, Subsection 5.1.2 to improve calculational accuracy. These affect the program handling of ICHOKE-JCHOKE values entered as provided in the revisions described in Paragraph 2.2 preceeding. The modifications were internal, however, and required no changes in input data other than those previously accounted for.

3. CHECKOUT OF RELAP4/MOD5, UPDATE 2

A large number of short checkout runs were made on the IBM 360 and the CDC-7600 computers during the evaluation of Update 2. These were made to verify the functioning of changes being made to RELAP4/MOD5 for Update 2. Two short checkout problems were added to the 28 reported in Volume III, Section 7.1 in order to further verify that coding changes to one part of the program were not adversely affecting other parts and that a reasonable comparison of results between the IBM and the CDC versions of the code could still be obtained.

Three complete plant models were selected from the eight reported in Volume III and rerun using Update 2. These were:

(1) Trojan (Westinghouse) 6% Cold Leg Break - Appendix B

(2) Calvert Cliffs (Combustion Engineering) 1-ft^2 Cold Leg Break (Evaluation Model Option) - Appendix C

(3) Hope Creek (General Electric) 200% Recirculation Line Break - Appendix D.

As in the case of Update 1, checkout was limited to the blowdown and refill phases of the transient.

All of the foregoing checkout problems and runs were successfully completed. Some differences were noted between runs made on Updates 1 and 2. These differences are considered to be explained in terms of the differences between the two code Updates.

3.1 Trojan 6% Cold Leg Break

This run was modified for Update 2 to remove some conflicting options used in the Update 1 analysis. In particular, simultaneous use of the bubble rise model in a volume and vertical slip in an adjacent junction as was done in the Update 1 modeling is a conflict in that each model calculates its own slip velocity. The revised modeling used in Update 2 consisted of removing the bubble rise model from the reactor vessel and the intact and broken loops of the original Update 1 model. Bubble rise was used in the accumulators, pressurizer, and steam generator secondaries in both Updates 1 and 2.

The results of the Update 2 analysis differed from those obtained using Update 1. The results of analyses using Updates 1 and 2 with no bubble rise in the loops or reactor vessel were nearly identical, however. Also, no difficulty was encountered in making the runs without enthalpy transport and without bubble rise in the loops. Removal of the bubble rise model from volumes connected by vertical slip junctions decreased the running time by a factor of approximately three for these runs.

Although no obvious errors in Update 2 were uncovered by this analysis, certain conclusions were drawn regarding the use of some of the models. These conclusions, are presented in Section 3.4 of this appendix.

3.2 Calvert Cliffs 1 ft^2 Cold Leg Break

The Model features of the RELAP4/MOD5, Update 2 run duplicate those of the corresponding run performed during the checkout of Update 1. The only change for this run was the inclusion of the stagnation properties subroutine for the choked flow calculations, which has become an Evaluation Model requirement since the checkout of Update 1. The general trends of the transients calculated with Updates 1 and 2 compare closely. Small differences are apparent in the timing of some features:

(1) End-of-bypass and lower plenum refill are retarded 1 sec.

(2) Upper plenum dumping into the core began 2 sec earlier in the Update 2 calculations.

Use of the stagnation pressure option did not significantly affect the calculated break flow because of the relatively small break size. Update 2 displayed considerable sensitivity to use of the enthalpy transport option. This sensitivity was most apparent during the period from 40 to 55 sec, which was the time of the first core flow reversal. Since other studies have also demonstrated the sensitivity of enthalpy transport during flow reversals, the Calvert Cliffs calculation was continued after 38 sec without use of the enthalpy transport option.

The run was completed (lower plenum refilled) at 102 sec after rupture. Update 2 required the same total CPU time (48 min) as did Update 1. It was discovered, however, that RELAP4 was selecting the Compressible Single Stream Flow with Momentum Flux Equation as would be normal for entry of MVMIX=0 on the Junction Data Card (080021). This was inconsistent with the Evaluation Model Criteria which requires the use of the Incompressible Mechanical Energy Balance Equation along with the Henry-Fauske (subcooled)/Moody (saturated) discharge model. Proper operation of the code would provide this latter form of the momentum equation when MVMIX=0, ICHOKE=11, and JCHOKE=0. Two source cards within Subroutine PREW were corrected prior to the release of Update 2 in order to provide the proper function selection for the Evaluation Model.

3.3 Hope Creek 200% Recirculation Line Break

The results predicted by Updates 1 and 2 matched fairly closely in general for this study. The most significant difference in calculated results between Updates 1 and 2 was in prediction of core centerline temperature. The reason for the temperature difference can be traced to correction of an error in the Update 1 flow mixing model which is used in the jet pump flow calculations. The jet pump flow difference leads to break flow, pressure, and core flow differences, which ultimately result in a difference in core temperature. Because of correction of the flow mixing model, Update 2 is a definite improvement over Update 1 for analyzing postulated BWR accidents.

No difficulty was encountered in running the BWR 200% recirculation line break problem to completion. It was run to 170 sec transient time in 33.1 min of CPU time on the CDC-7600. The problem ran approximately 3 min (10%) faster on Update 2 than on Update 1.

3.4 Conclusions and Recommendations

Running of the three checkout problems on Update 2, as well as other runs made since Update 1 was released, has resulted in the following conclusions and recommendations:

(1) Use of the bubble rise model in volumes adjacent to vertical slip junctions can lead to operational problems with the code. If these two models are used together, particularly close attention must be paid to fluid behavior in those volumes. A mixture level crossing a vertical slip junction from below can still be a problem in Update 2, particularly during slow transients. If problems are encountered, it is recommended that the bubble rise model be replaced with the homogeneous option. Use of the homogeneous option normally results in a substantial time saving, thereby allowing the use of more control volumes, if required.

(2) The enthalpy transport option should not be used during periods of flow reversal occuring at low flows. If problems are indicated under conditions wherein enthalpy transport is being used and flow reversals at low flows 5 to 10% of initial flow are encountered, it is recommended that the enthalpy transport option be turned off and the problem restarted. Update 2 will automatically turn off enthalpy transport once a quality value exceeding zero is observed at a vertical slip junction.

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