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NSD-NRC-96-4716
DCP/NRC0511
Docket No.: STN-52-003

May 3, 1996

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

ATTENTION: T. R. QUAY

SUBJECT: MATERIAL PRESENTED AT MAY 3, 1996 AP600 THERMAL HYDRAULIC UNCERTAINTY MEETING

Dear Mr. Quay:

The attached material was presented to the NRC technical staff on May 3, 1996 at a meeting to further discuss the thermal hydraulic uncertainty issue. This material supplements the presentation material from our February 29, 1996 meeting and written submittal of April 12, 1996.

Westinghouse expects the NRC to review this material and provide written agreement that the presented approach, if executed properly, will successfully resolve this issue. In addition, comments are expected on the PRA PIRTs and selection of benchmarking cases, along with specific details of any additional information the staff requires to clarify details of how this approach will be implemented.

Please contact me if you have any questions on this material.

John C Butler for
Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

130058

Attachment

cc: W. Huffman, NRC (w/o attachment)
N. Liparulo, Westinghouse (w/o attachment)

2766A

E004.1/1

Westinghouse / NRC Meeting on MAAP4 Benchmarking for AP600 Level 1 PRA

(PIRTs and Case Selection)

May 3, 1996
Rockville, MD

D. K. Ohkawa
L. E. Hochreiter

c:\wp\ap600\050396n.mtg
May 2, 1996

AGENDA

Introduction

- Feedback from NRC
- Benchmarking Process
- Status

Overview of PRA Scenarios

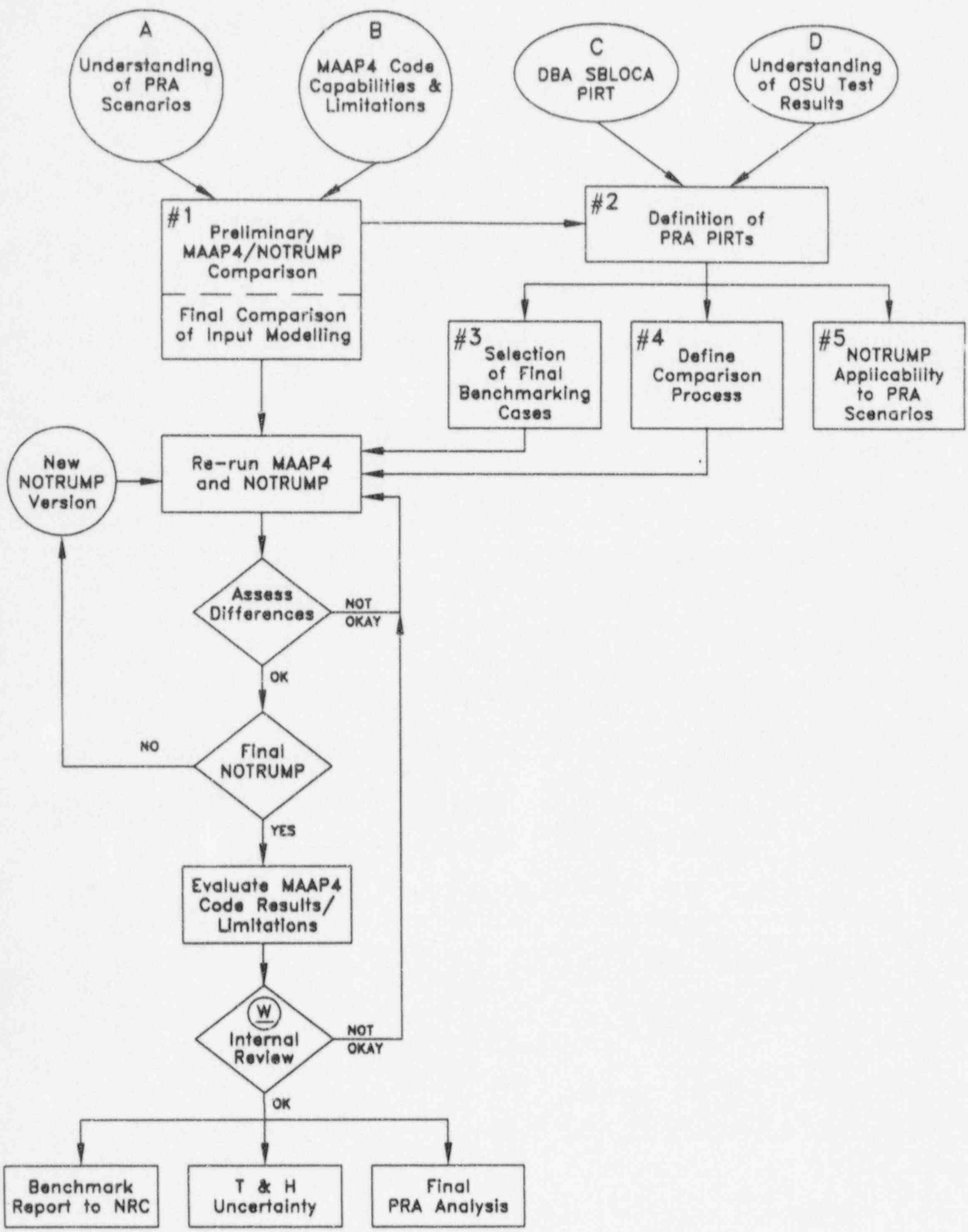
PRA PIRTs

Selection of Benchmarking Cases

Summary / Discussion of Open Items

Benchmarking Process / Status

MAAP4 Benchmarking Process



Overview of PRA Scenarios

Focus of MAAP4 Analyses

- MAAP4 cases have been defined to support the PRA event trees for scenarios that require ADS actuation for successful core cooling

- Event trees are lumped into four groups:

  - Loss of heat sink Transients
  - Small LOCA (SLOCA) up to 2"
  - Intermediate LOCA (NLOCA) up to 6"
  - Medium LOCA (MLOCA) up to 9"

- Initial focus was on a clear correlation between equipment assumed in the event trees and the equipment assumed in the MAAP4 analyses

- The logic on the event trees defines minimum equipment that is needed, such as:

  - At least 1 CMT
  - At least 1 accumulator
  - At least 2 stage 4 ADS
  - At least 1 DVI line for IRWST injection

General Analysis (Scenario) Assumptions

- Minimal heat removal by "normal" methods:
  - No main feedwater, no startup feedwater
  - No PRHR
- Either one CMT or one accumulator
  - Functioning CMT allows automatic ADS actuation
  - No CMT requires manual ADS actuation
- Minimal number of ADS valves
  - Typically 2 out of 4 stage 4 ADS for IRWST gravity injection
  - Typically 1 stage 2, 3 or 4 ADS for RNS pumped injection
- 1 DVI line for injection
- Containment Isolation Failure is assumed
- Nominal conditions

Additional Scope of MAAP4 Analyses

- Break size and location
- Number of tanks (CMTs and accumulators)
- Number of ADS lines
- Operator action times
- Effect of containment isolation

Transients and SLOCAs

- High pressure scenarios that require stage 1, 2, or 3 ADS prior to stage 4 ADS, due to the RCS pressure interlock (~1000 psia) on stage 4 ADS

- Loss of heat sink events, up to 2" break, where

  - SG heat removal plays a role

  - Inventory loss through pressurizer safety valve may occur

  - Duration of event is 2 to 4 hours

- ADS success criterion:

  1 stage 2 or 3 ADS + 2 stage 4 ADS for IRWST gravity injection

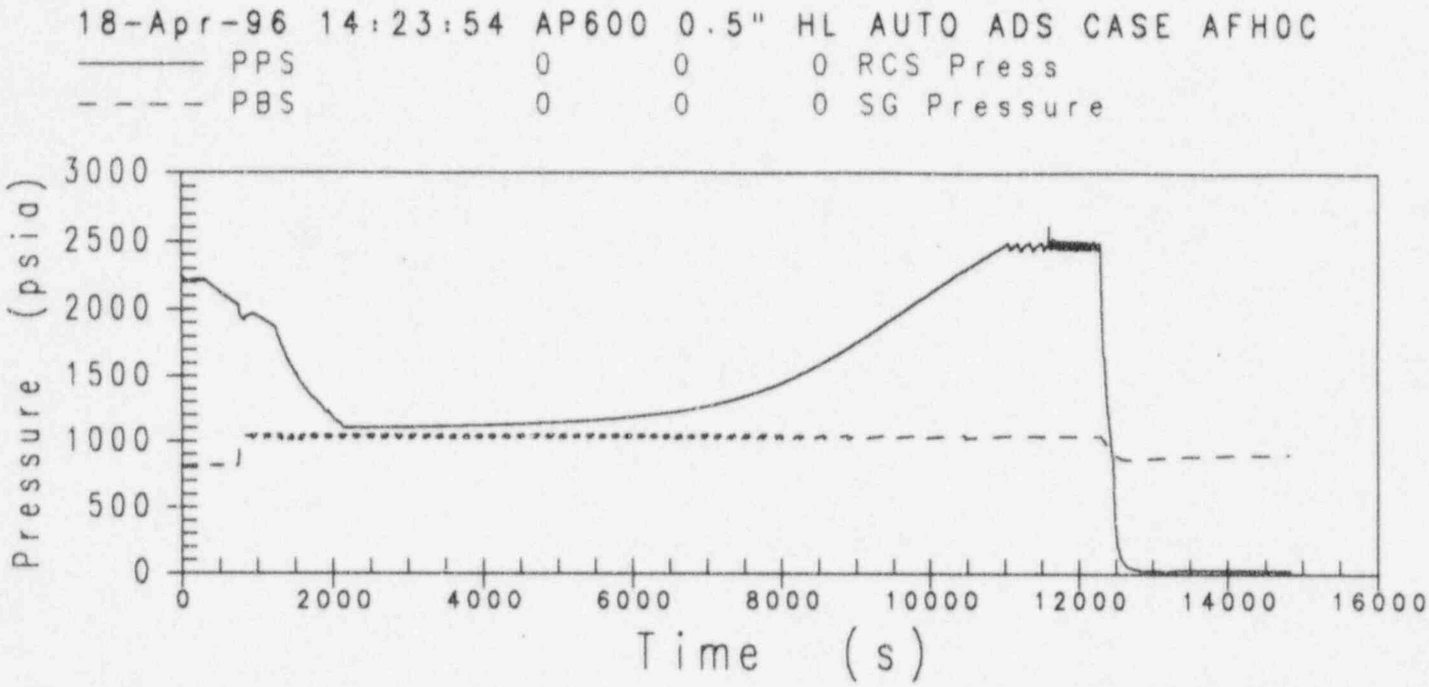
  1 stage 2 or 3 ADS for RNS injection

- Example 0.5" hot leg break to illustrate plant response

Transients and SLOCAs (Cont.)

0.5" Hot Leg Break

Sequence of Events	Time (sec)
Reactor Trip on Low Pressurizer Level (or low pressurizer pressure)	750
CMT Actuation	750
Pressurizer Empties	1200
Pressurizer starts to refill	4000
SG empties	9300
Pressurizer SV Setpoint Reached (greater rate of RCS inventory loss)	10,700
CMT draining begins	11,500
ADS-1 Actuation (Fails - nothing happens)	12,060
ADS-3 Actuation (1 valve opens)	12,300
ADS-4 Actuation (2 valves open)	12,470
Top of core uncovers	12,500
CMT empties	12,750
IRWST begins to inject	12,850
Top of core recovers	13,000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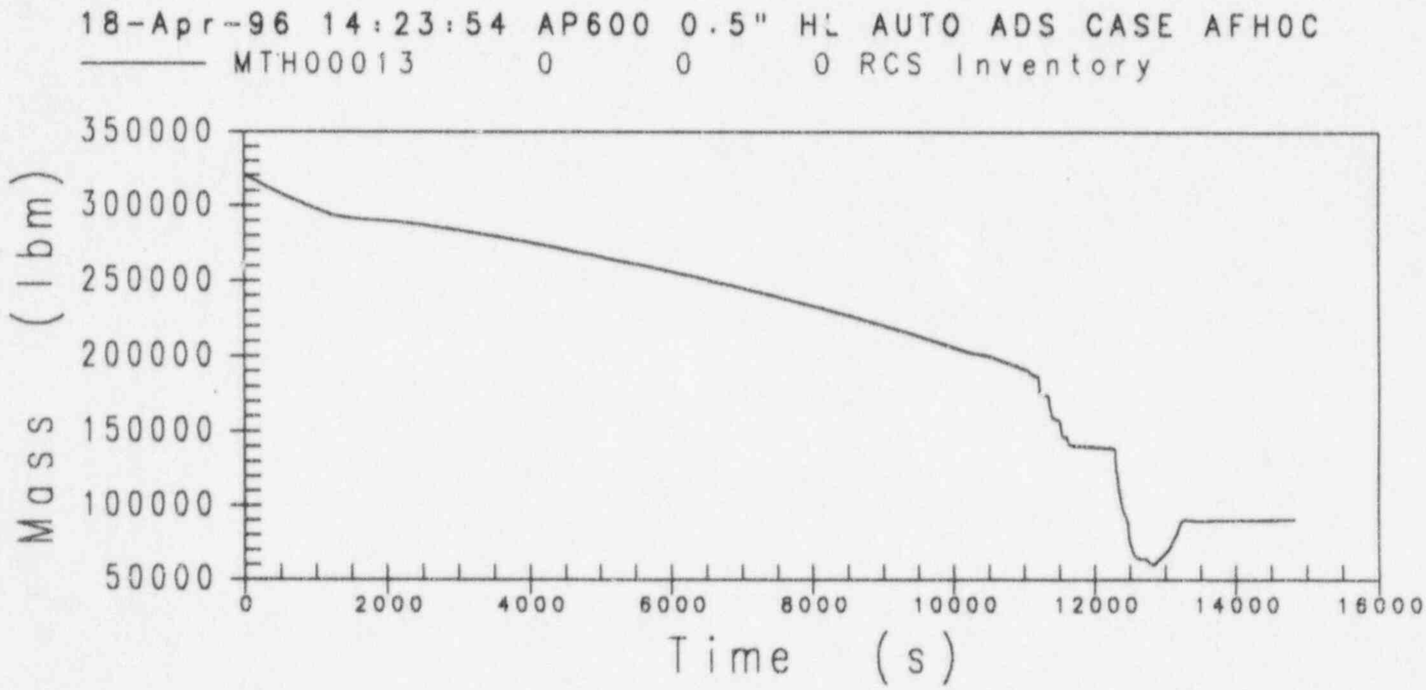
PPS 0 0 0 RCS Press
PBS 0 0 0 SG Pressure
Pressure (psia)
3000
2500
2000
1500
1000
500
0
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (s)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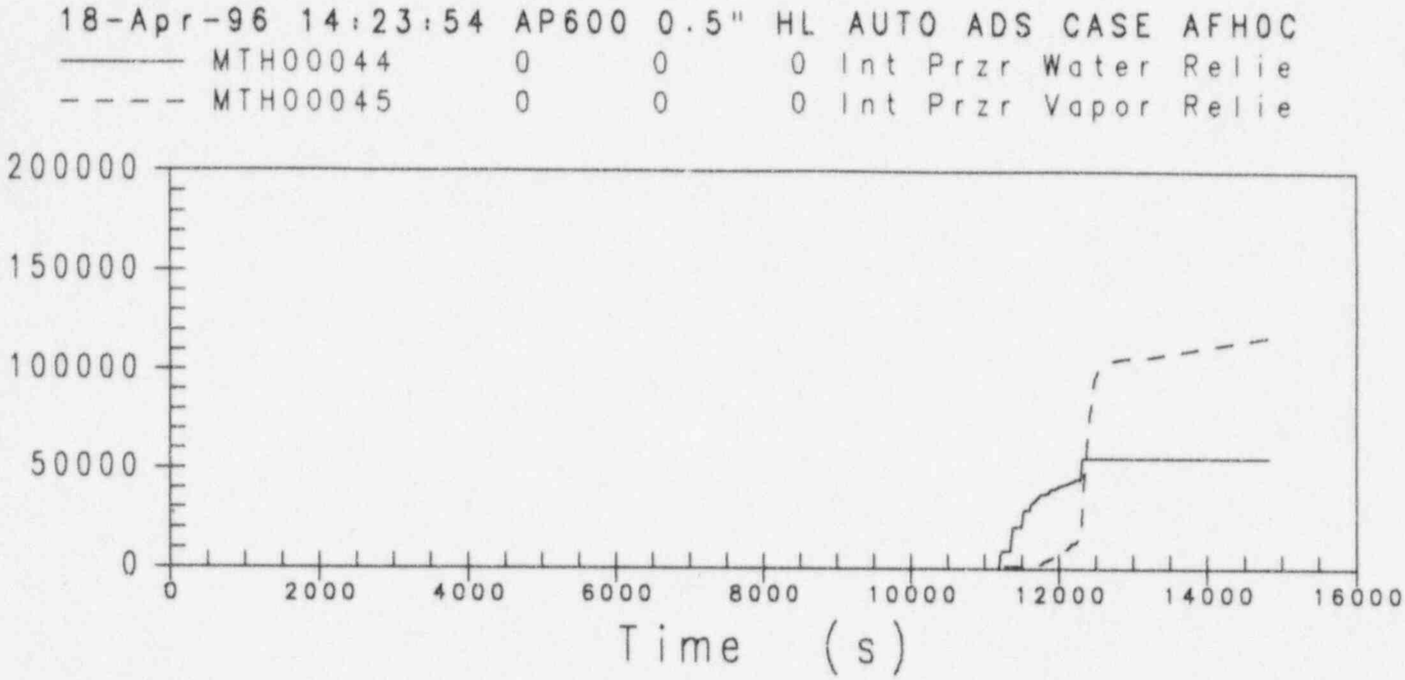
MTH00013 0 0 0 RCS Inventory
Mass (lbm)
350000
300000
250000
200000
150000
100000
50000
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (s)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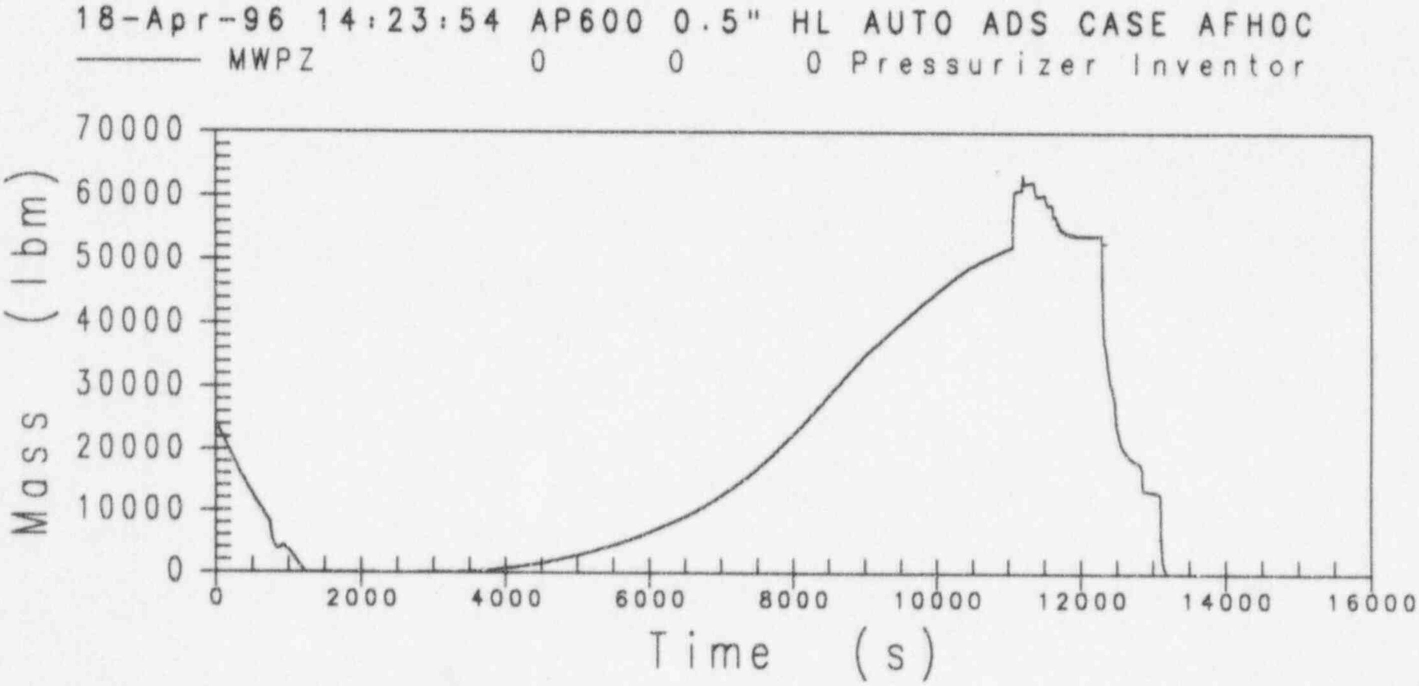
MTH00045 0 0 0 Int Przr Vapor Relie
200000
150000
100000
50000
0
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (s)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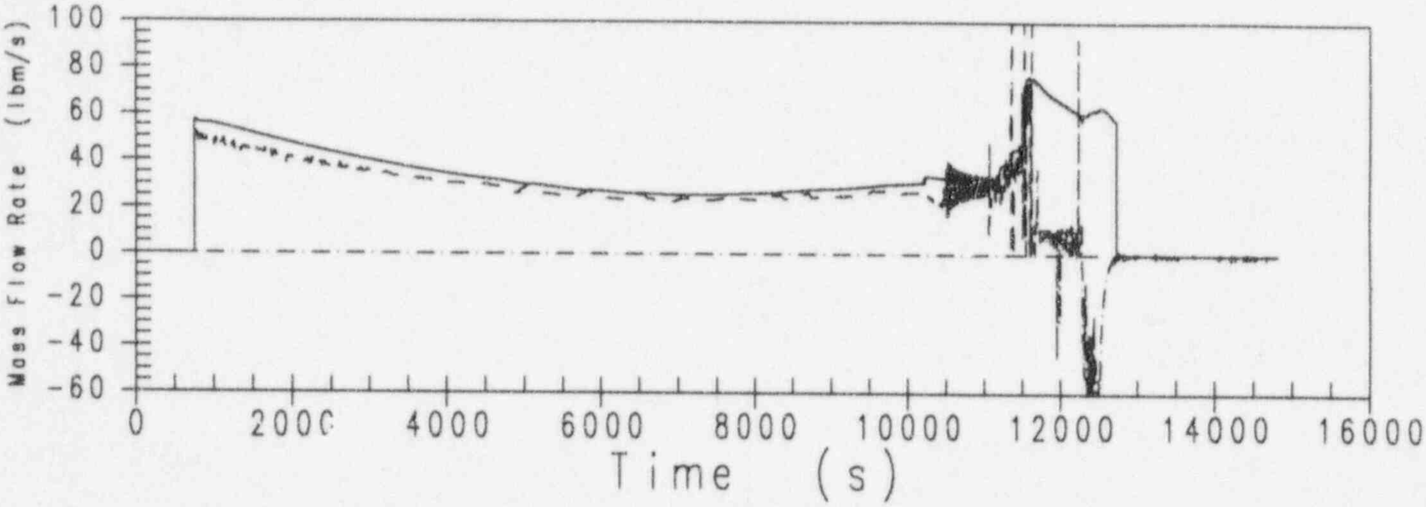
MWPZ 0 0 0 Pressurizer Inventor
Mass (lbm)
70000
60000
50000
40000
30000
20000
10000
0
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (s)

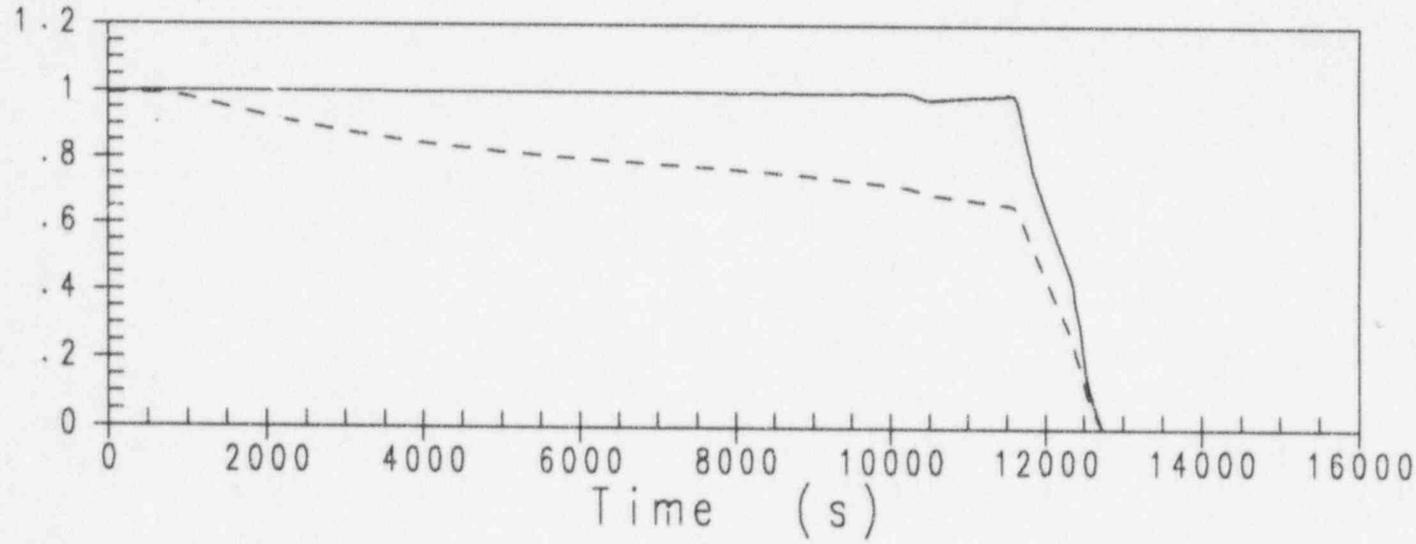
18-Apr-96 14:23:54 AP600 0.5" HL AUTO ADS CASE AFHOC

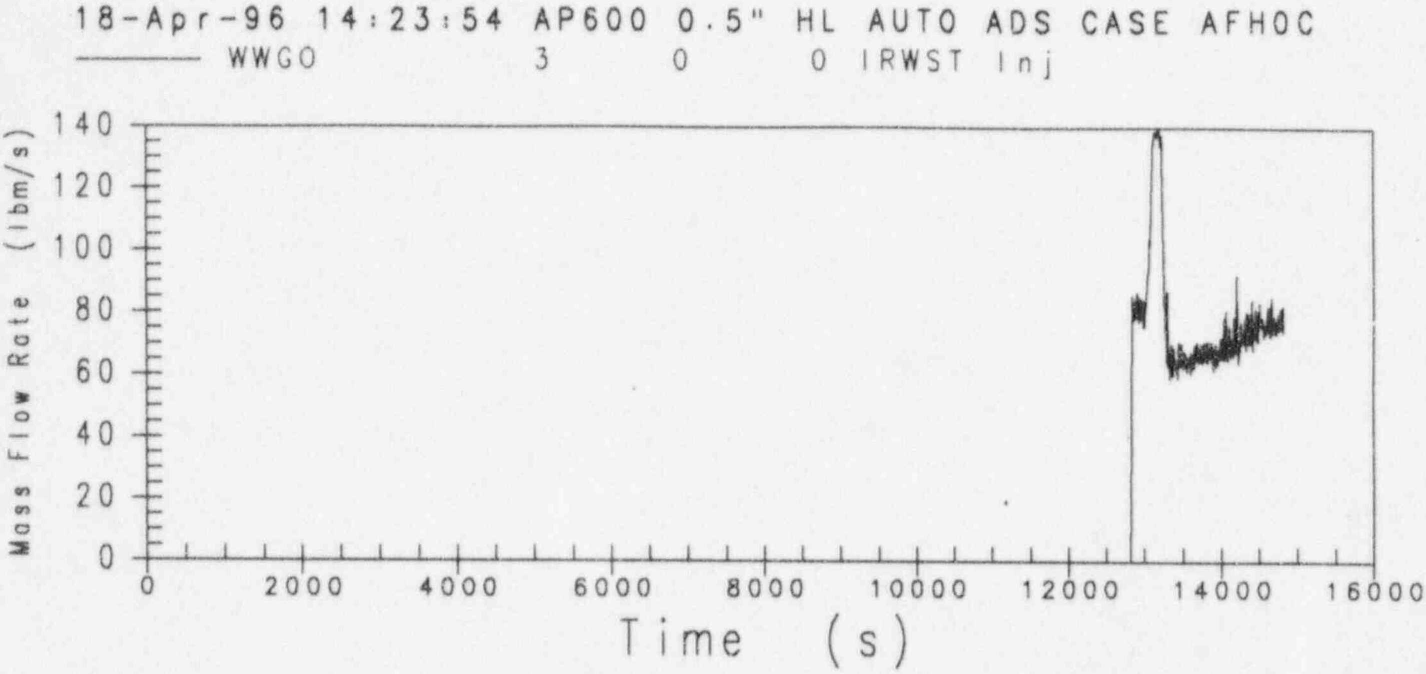
———	WWMT	1	0	0	CMT Inj
– – – –	WWCLMT	1	0	0	CMT Bal Water Inj
— - — -	WGPSMT	1	0	0	CMT Bal Vapor Inj

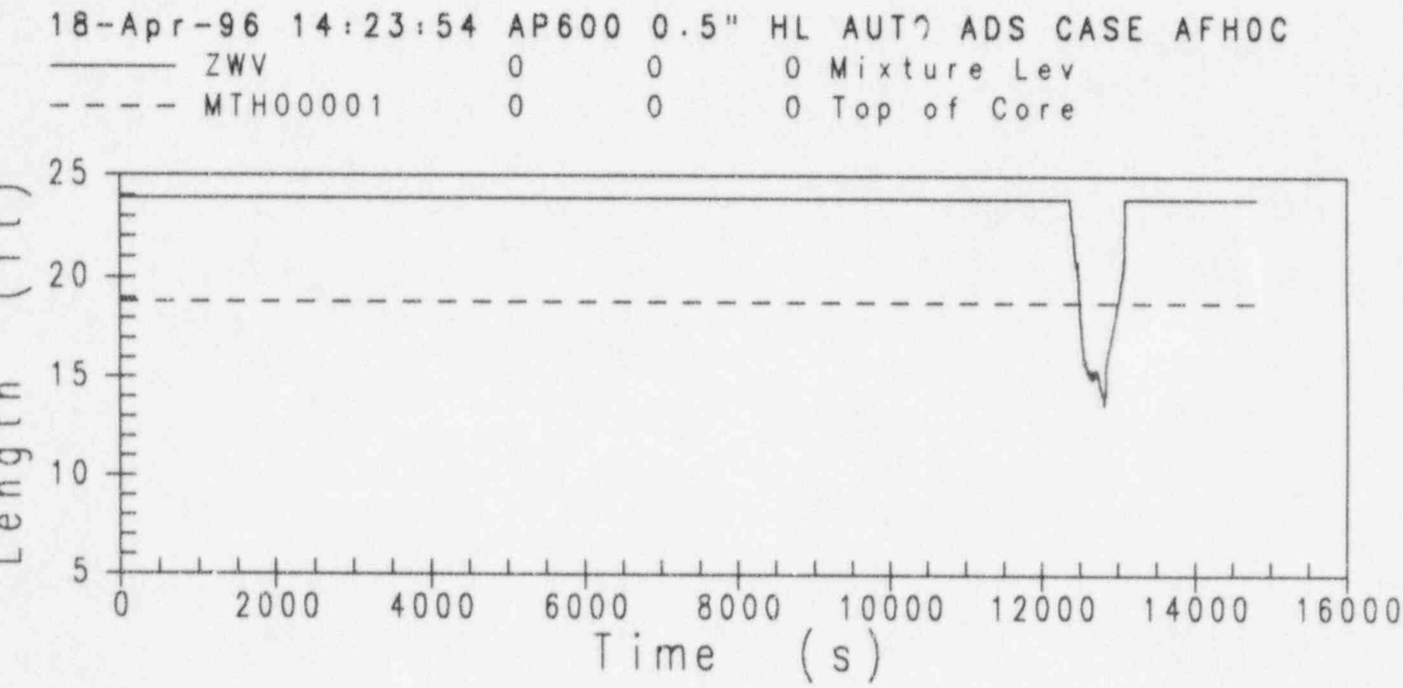


18-Apr-96 14:23:54 AP600 0.5" HL AUTO ADS CASE AFHOC

———	MTH00033	1	0	0	CMT Level (F01)
– – – –	MTH00034	1	0	0	CMT Mass (F01)




18-Apr-96 14:23:54 AP600 0.5" HL AUTO ADS CASE AFHOC
WWGO 3 0 0 IRWST Inj
Mass Flow Rate (lbm/s)
0
20
40
60
80
100
120
140
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (s)


18-Apr-96 14:23:54 AP600 0.5" HL AUTO ADS CASE AFHOC
ZWV 0 0 0 Mixture Lev
MTH00001 0 0 0 Top of Core
Length (ft)
5
10
15
20
25
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (s)

Intermediate LOCAs

- Defined to be large enough that break will reduce pressure below ADS stage 4 RCS pressure interlock (~1000 psia)

- 2" to 6" breaks

  - SG heat removal plays a small role

  - Duration of event is 1 to 2 hours

- ADS success criterion:

  2 stage 4 ADS for IRWST gravity injection

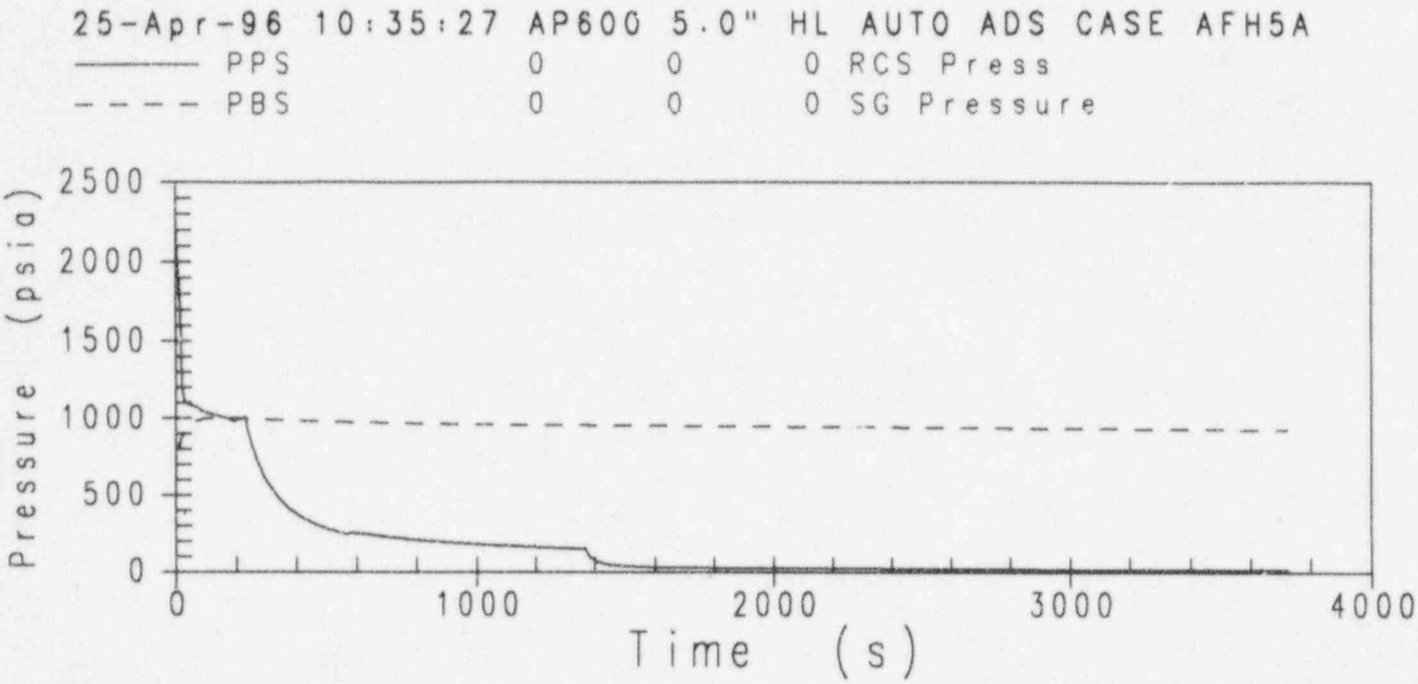
  1 stage 2 or 3 ADS or 1 stage 4 ADS for RNS injection

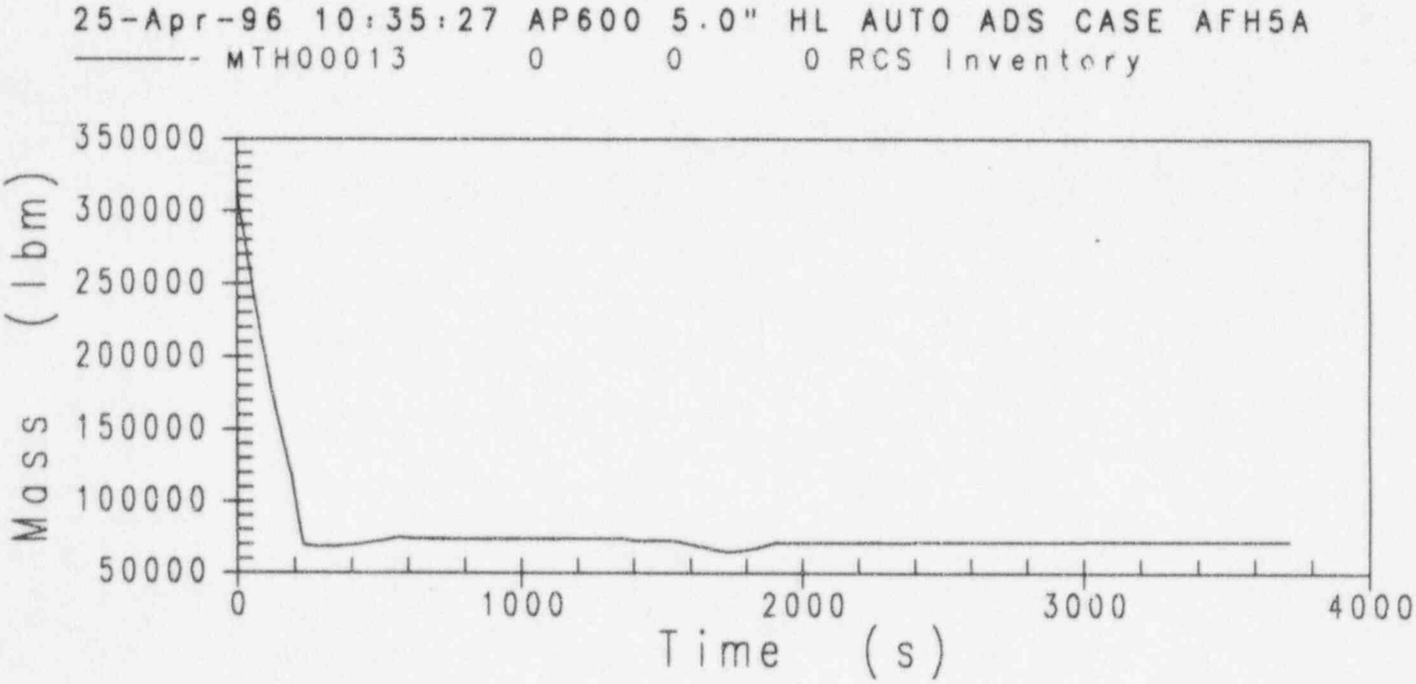
- Example 5.0" hot leg break to illustrate plant response

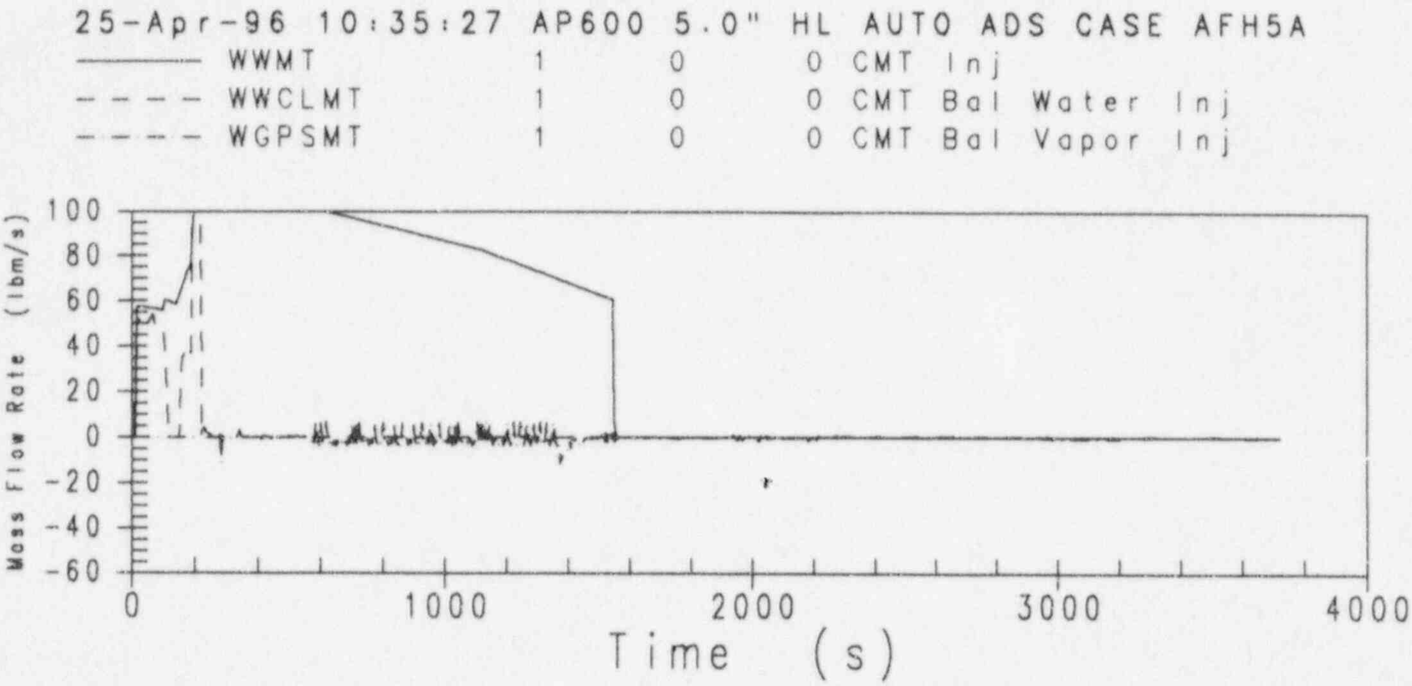
Intermediate LOCA (Cont.)

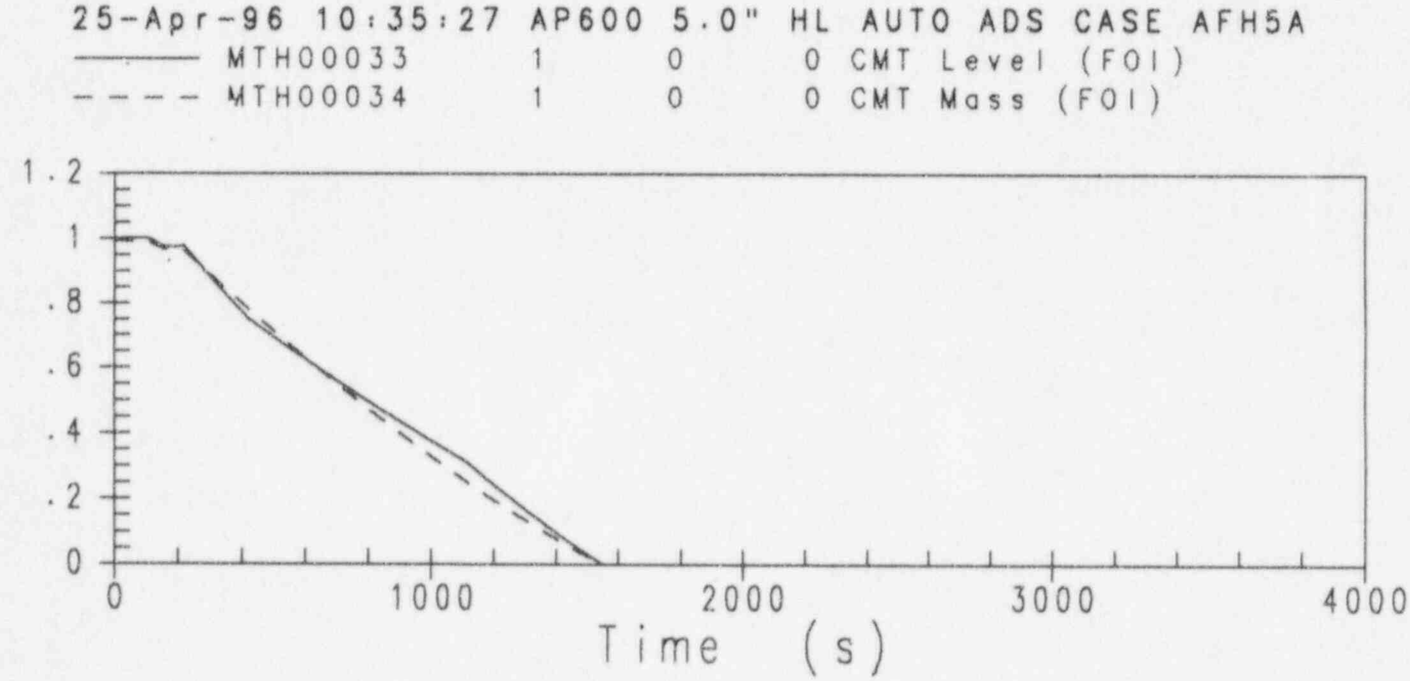
5.0" Hot Leg Break

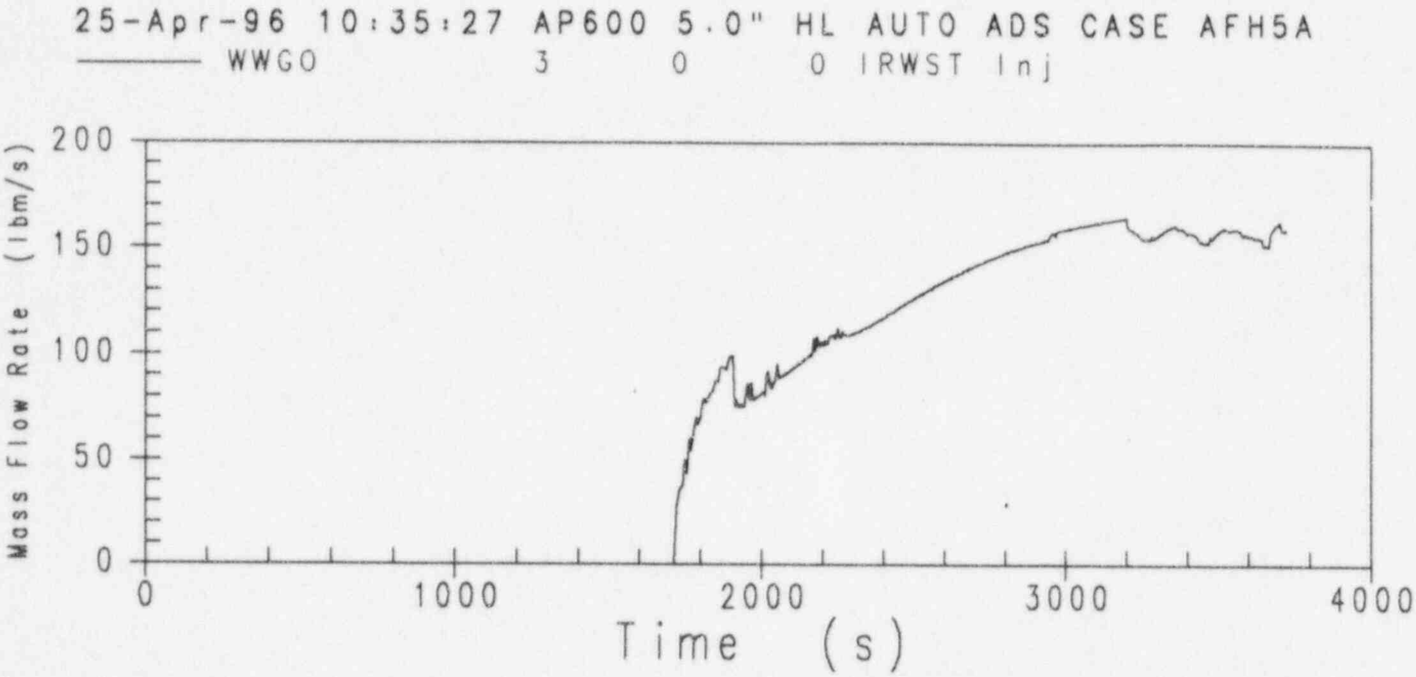
Sequence of Events	Time (sec)
Reactor Trip on Low Pressurizer Level	10
CMT Actuation	10
Pressurizer empties	50
CMT draining begins	200
Vessel mixture level below hot legs	210
ADS-1 Actuation (Fails - nothing happens)	624
ADS-4 Actuation (2 valves open)	1170
CMT empties	1550
Vessel mixture level below hot legs	1700
IRWST begins to inject	1725

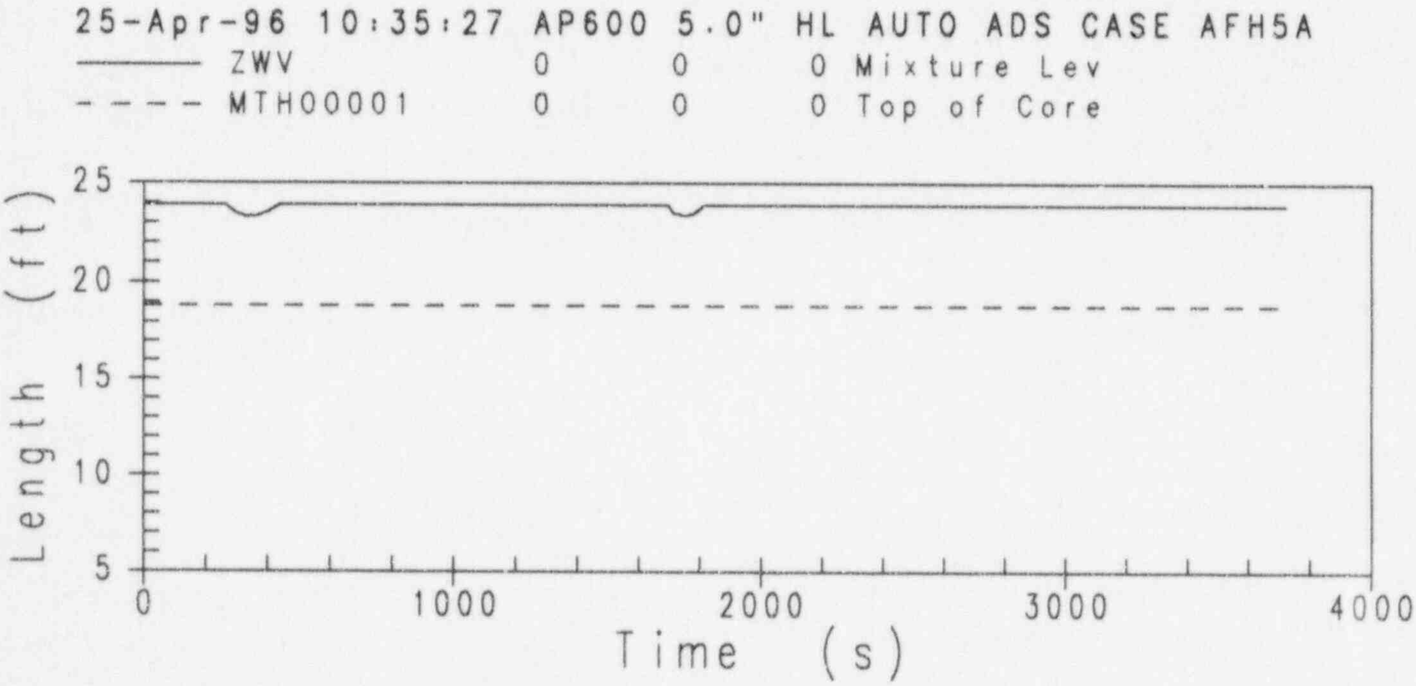

25-Apr-96 10:35:27 AP600 5.0" HL AUTO ADS CASE AFH5A
PPS 0 0 0 RCS Press
PBS 0 0 0 SG Pressure
Pressure (psia)
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
Time (s)


25-Apr-96 10:35:27 AP600 5.0" HL AUTO ADS CASE AFH5A
MTH00013 0 0 0 RCS Inventory
Mass (lbm)
350000
300000
250000
200000
150000
100000
50000
0
1000
2000
3000
4000
Time (s)


25-Apr-96 10:35:27 AP600 5.0" HL AUTO ADS CASE AFH5A
WWMT 1 0 0 CMT Inj
WWCLMT 1 0 0 CMT Bal Water Inj
WGPSMT 1 0 0 CMT Bal Vapor Inj
Mass Flow Rate (lbm/s)
100
80
60
40
20
0
-20
-40
-60
0
1000
2000
3000
4000
Time (s)


25-Apr-96 10:35:27 AP600 5.0" HL AUTO ADS CASE AFH5A
MTH00033 1 0 0 CMT Level (FOI)
MTH00034 1 0 0 CMT Mass (FOI)
1.2
1
.8
.6
.4
.2
0
0
1000
2000
3000
4000
Time (s)


25-Apr-96 10:35:27 AP600 5.0" HL AUTO ADS CASE AFH5A
WWGO 3 0 0 IRWST Inj
Mass Flow Rate (lbm/s)
0
50
100
150
200
Time (s)
0
1000
2000
3000
4000


25-Apr-96 10:35:27 AP600 5.0" HL AUTO ADS CASE AFH5A
ZWV 0 0 0 Mixture Lev
MTH00001 0 0 0 Top of Core
Length (ft)
5
10
15
20
25
Time (s)
0
1000
2000
3000
4000

Medium LOCAs

- Defined to be large enough that break will reduce pressure below RNS shutoff head without any ADS

- 6" to 8.75" breaks

  - SG heat removal plays no role

  - Duration of event is less than an hour

- ADS success criterion:

  2 stage 4 ADS for IRWST gravity injection

  No ADS for RNS injection

- Example 8.75" hot leg break to illustrate plant response

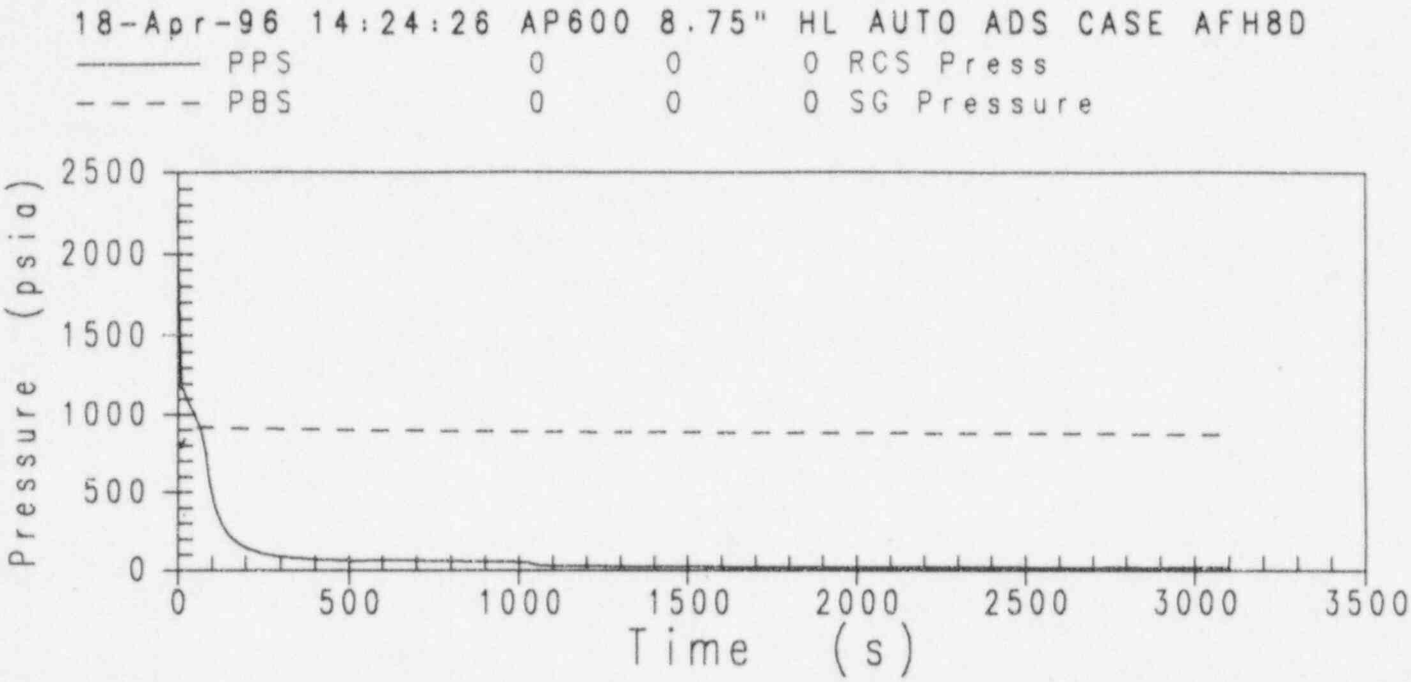
  - The larger breaks do not need much "help" from the ADS to depressurize

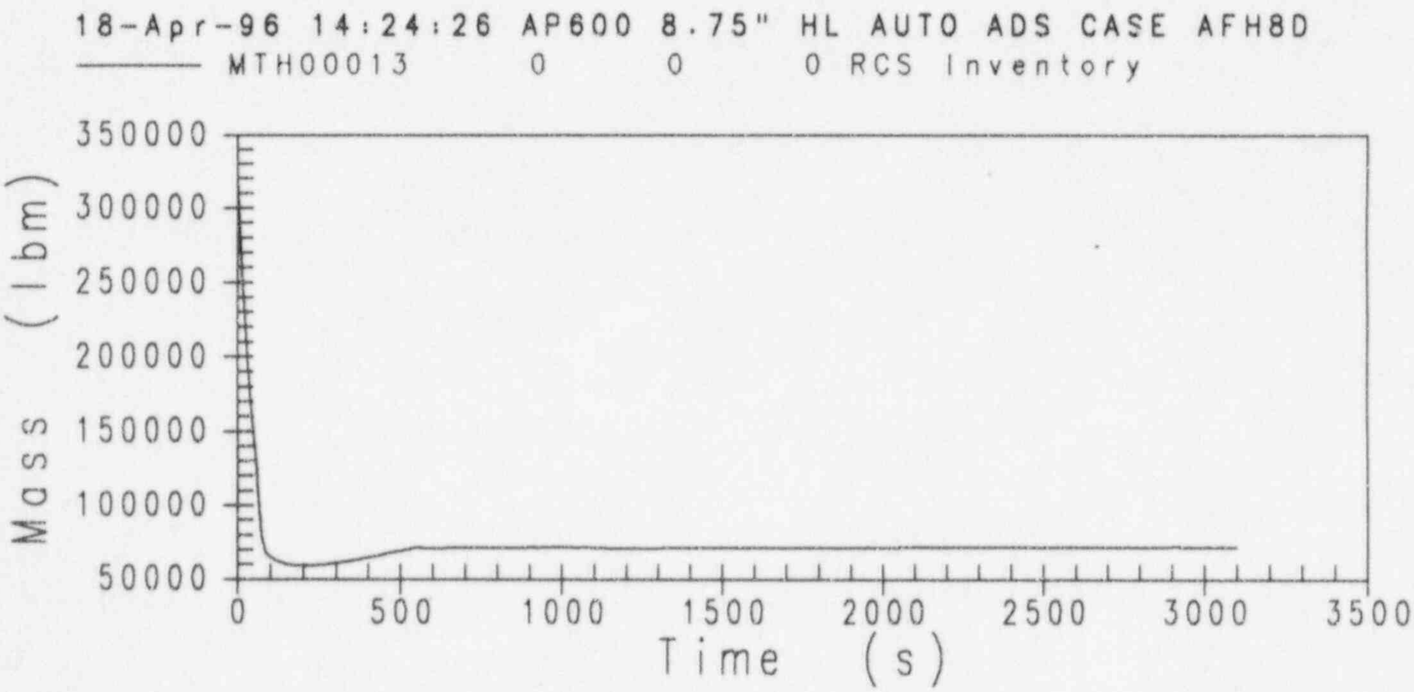
  - Main issue is whether CMT can inject fast enough, in absence of accumulator

Medium LOCA (Cont.)

8.75" Hot Leg Break

Sequence of Events	Time (sec)
Reactor Trip on Low Pressurizer Level	5
CMT Actuation	5
CMT draining begins	<100 *
Vessel mixture level below hot legs	120
ADS-1 Actuation (Fails - nothing happens)	480
ADS-4 Actuation (2 valves open)	1030
IRWST begins to inject	1100
CMT empties	1415
* The time of CMT draining identified above may be sooner than realistic.	


18-Apr-96 14:24:26 AP600 8.75" HL AUTO ADS CASE AFH8D
PPS 0 0 0 RCS Press
PBS 0 0 0 SG Pressure
Pressure (psia)
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
3500
Time (s)


18-Apr-96 14:24:26 AP600 8.75" HL AUTO ADS CASE AFH8D
MTH00013 0 0 0 RCS Inventory
Mass (lbm)
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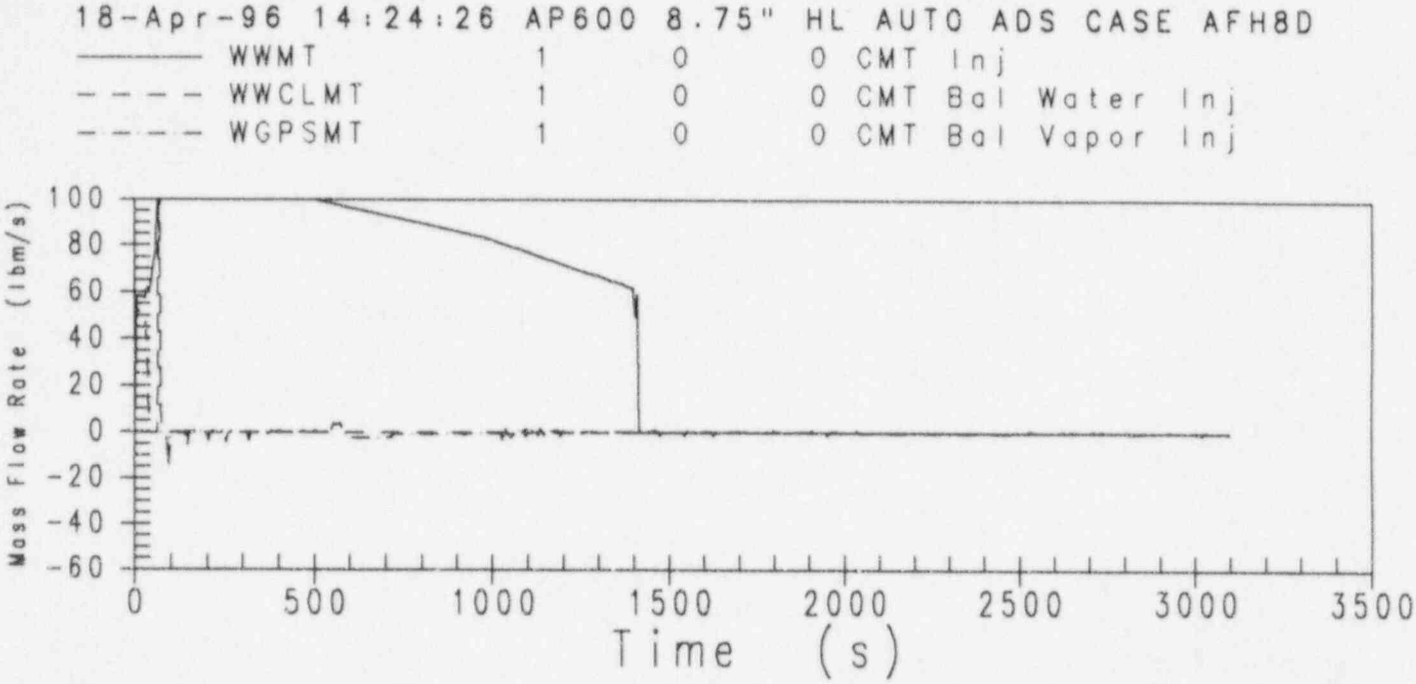
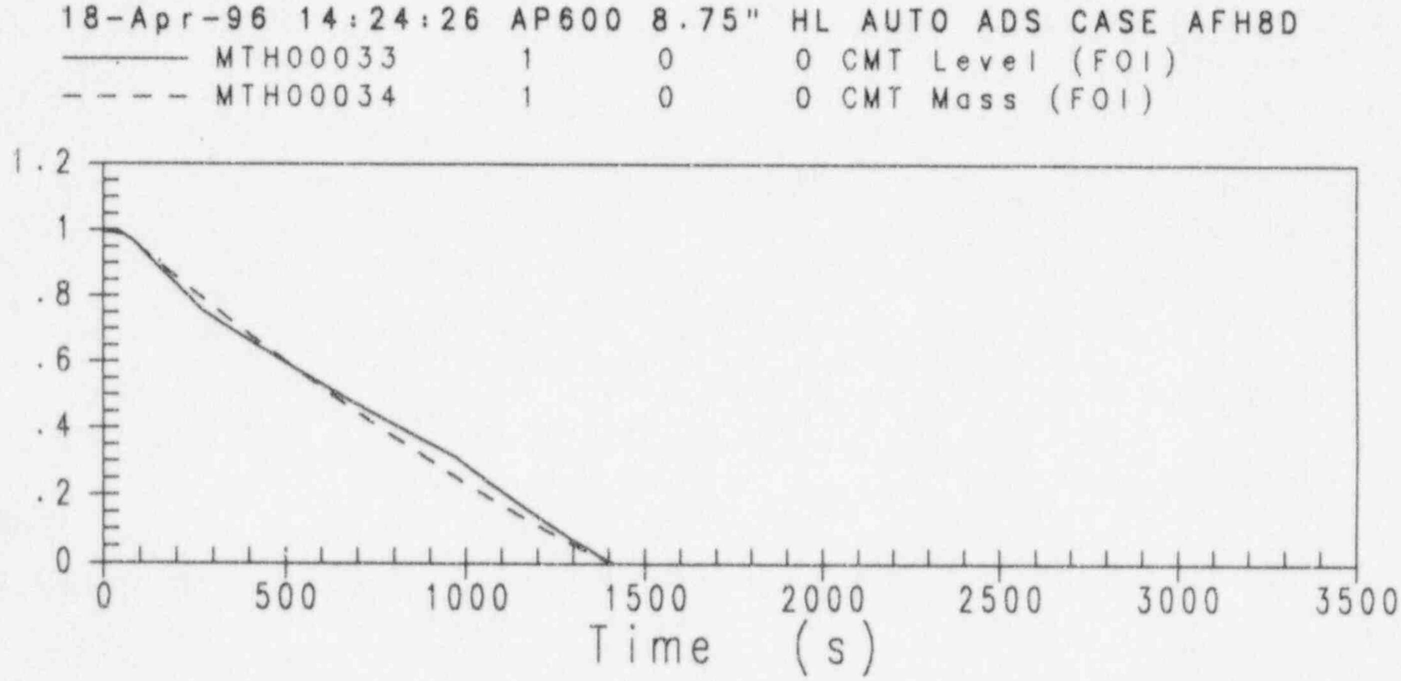
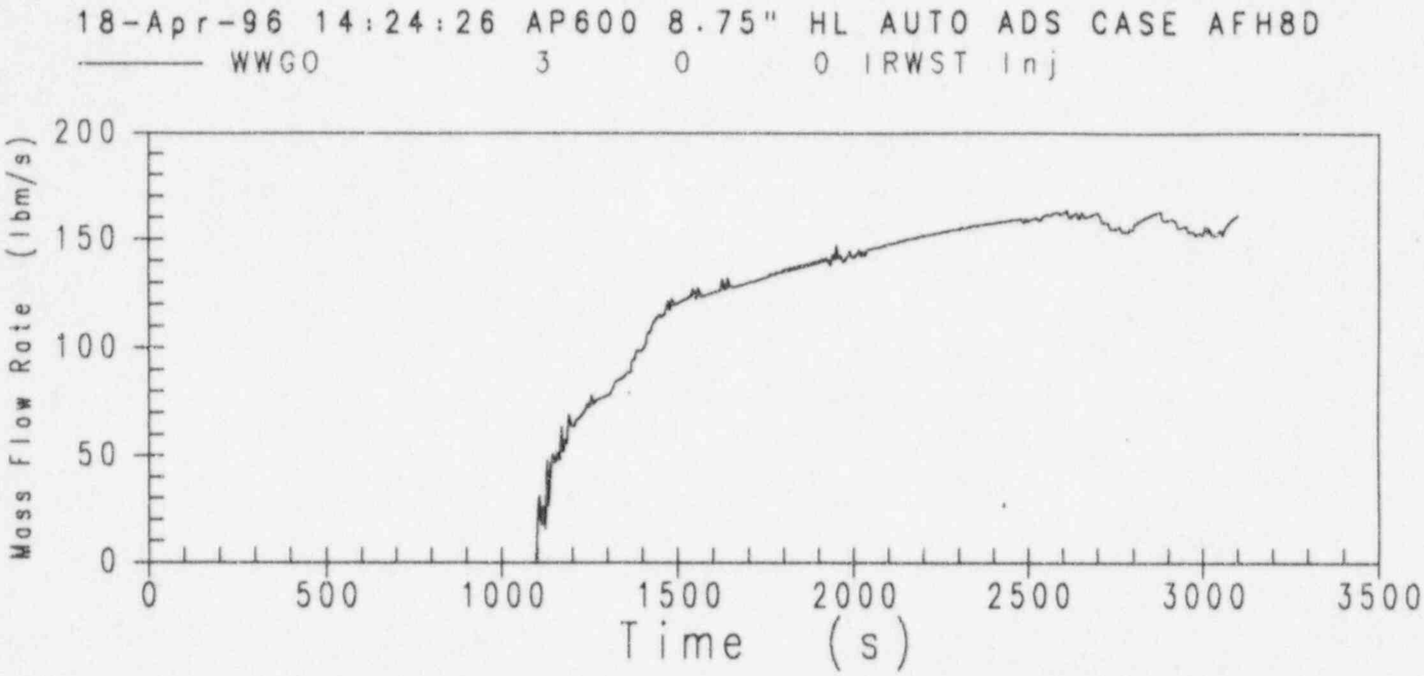
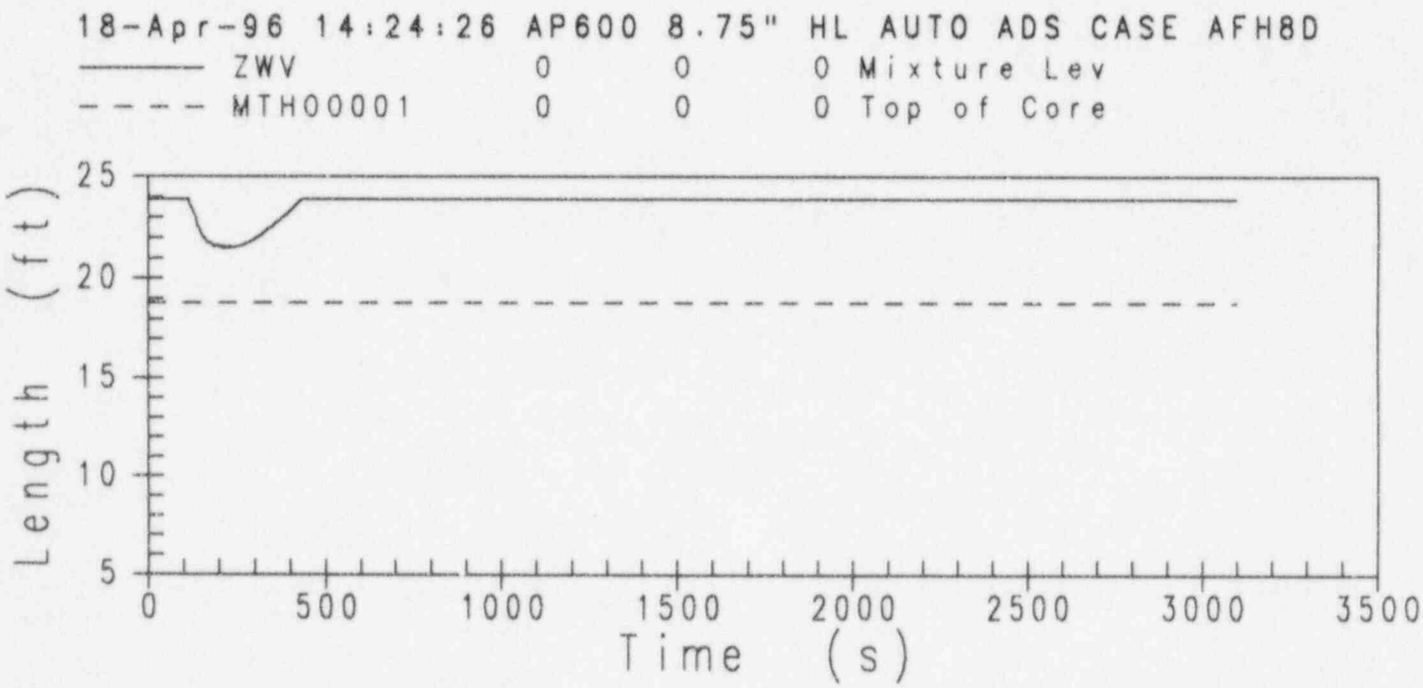
300000
250000
200000
150000
100000
50000
0
500
1000
1500
2000
2500
3000
3500
Time (s)

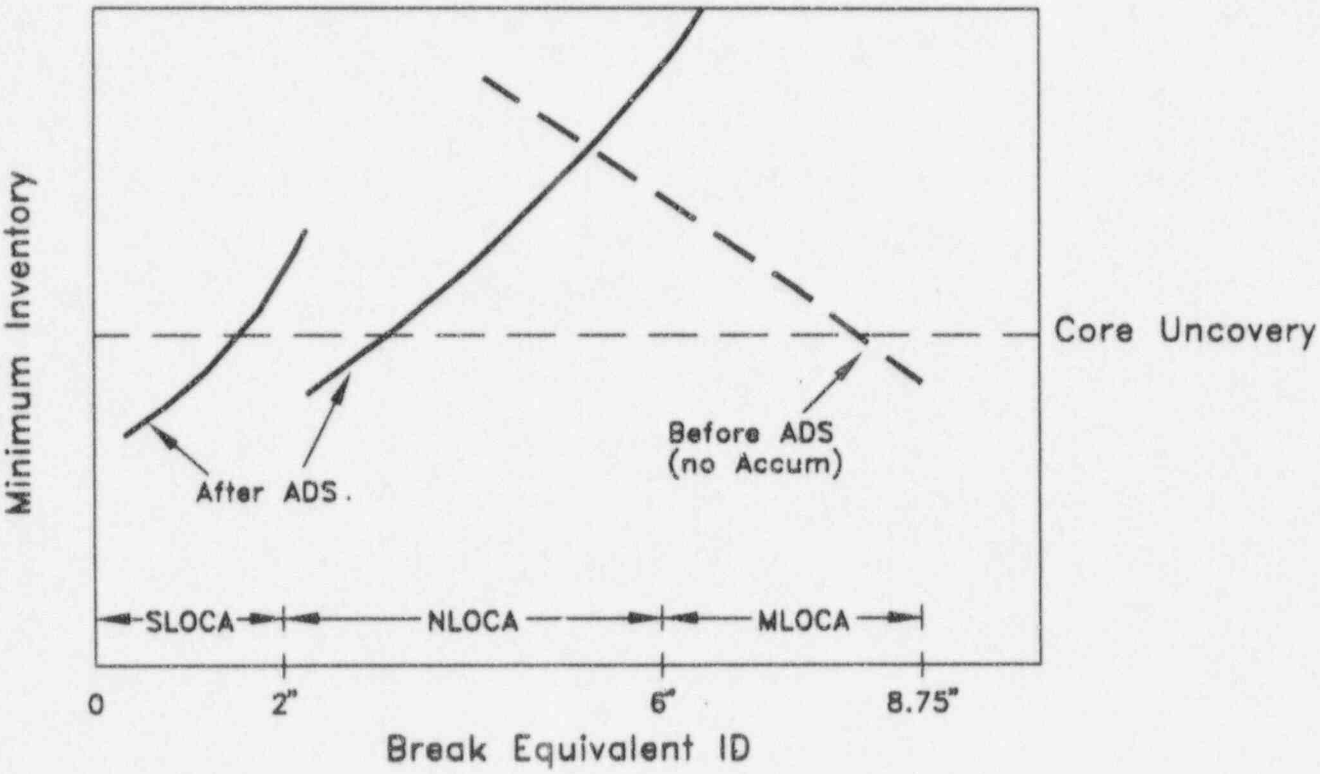

18-Apr-96 14:24:26 AP600 8.75" HL AUTO ADS CASE AFH8D
WWMT 1 0 0 CMT Inj
WWCLMT 1 0 0 CMT Bal Water Inj
WGPSMT 1 0 0 CMT Bal Vapor Inj
Mass Flow Rate (lbm/s)
100
80
60
40
20
0
-20
-40
-60
0
500
1000
1500
2000
2500
3000
3500
Time (s)


18-Apr-96 14:24:26 AP600 8.75" HL AUTO ADS CASE AFH8D
MTH00033 1 0 0 CMT Level (FOI)
MTH00034 1 0 0 CMT Mass (FOI)
1.2
1
.8
.6
.4
.2
0
0
500
1000
1500
2000
2500
3000
3500
Time (s)


18-Apr-96 14:24:26 AP600 8.75" HL AUTO ADS CASE AFH8D
WWGO 3 0 0 IRWST Inj
Mass Flow Rate (lbm/s)
200
150
100
50
0
0 500 1000 1500 2000 2500 3000 3500
Time (s)


18-Apr-96 14:24:26 AP600 8.75" HL AUTO ADS CASE AFH8D
ZWV 0 0 0 Mixture Lev
MTH00001 0 0 0 Top of Core
Length (ft)
25
20
15
10
5
0 500 1000 1500 2000 2500 3000 3500
Time (s)

Inventory Trends for PRA Scenarios With 1 CMT (Automatic ADS)



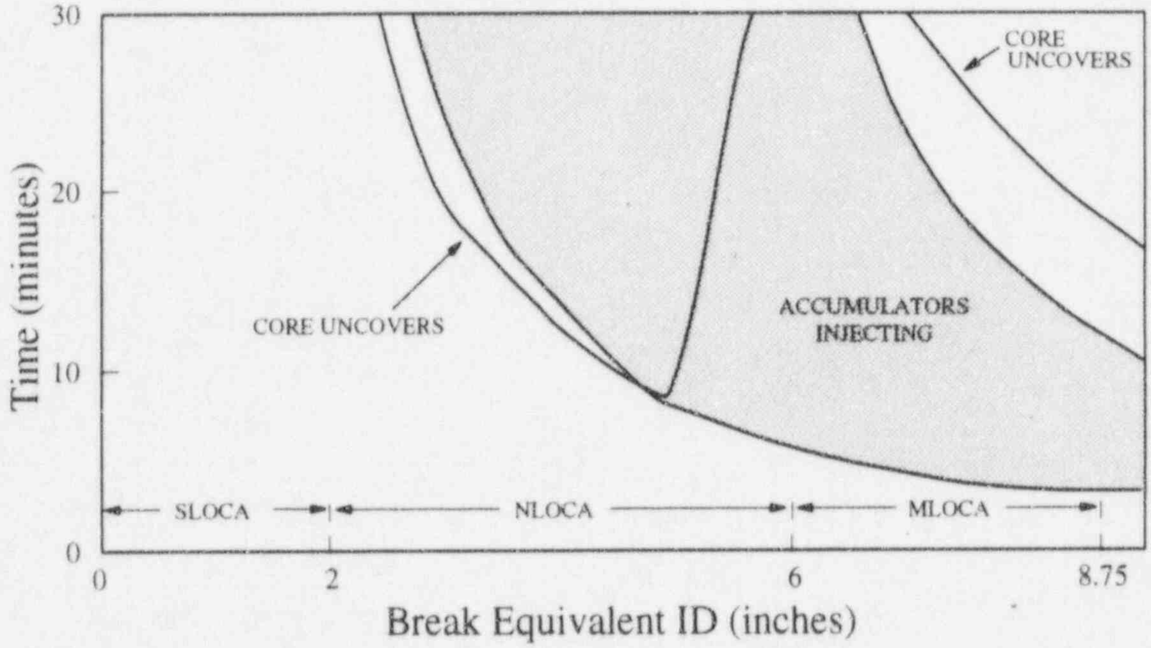
Scenarios Without CMTs

(Manual ADS Cases)

- If both CMTs fail, the operator must manually actuate ADS
- The operator action "clock" is started when the "S" signal fails to actuate CMTs
- SLOCAs are not challenging due to slow inventory loss, allowing ample operator action time (30 minutes is credited)
- Other LOCAs have 20 minute operator action time in PRA

PRA Scenarios Without CMTs

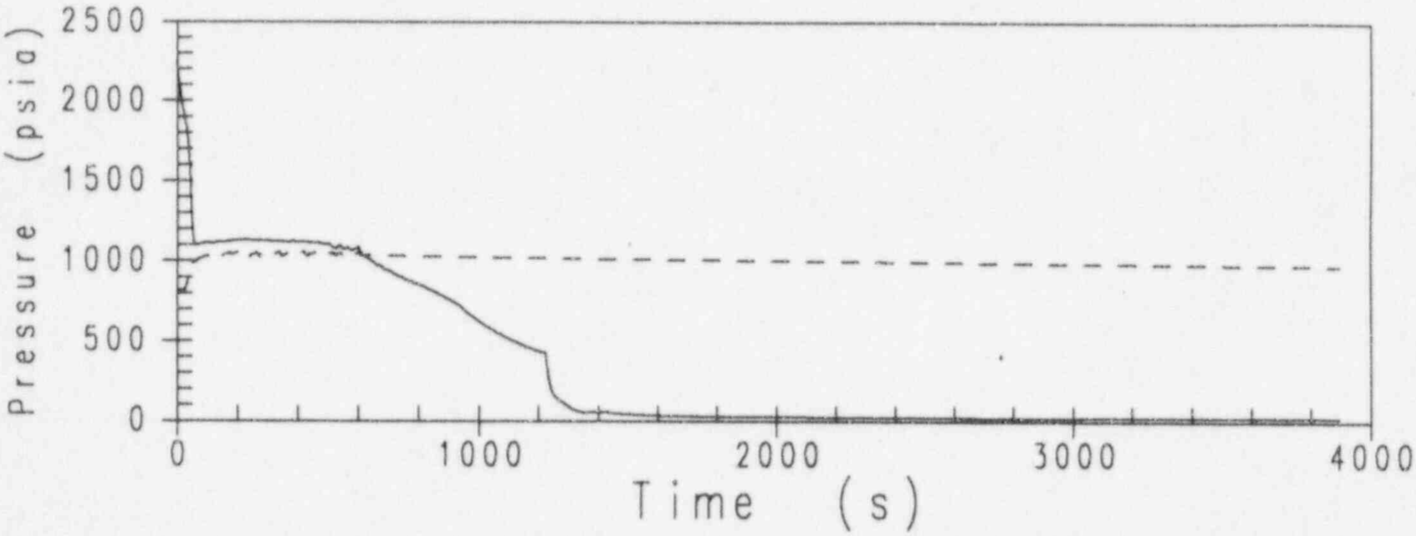
1 Accumulator, No ADS



Manual ADS Cases (Cont)

Sequence of Events	Time (sec)		
	3" HL	6" HL	8.75" HL
Reactor Trip on Low Pressurizer Level	26	7	4
Vessel Mixture Level Below Hot Legs	600	170	--
Accumulator injection starts	--	200	90
Accumulator empties	--	1025	400
Vessel Mixture Level Below Hot Legs	--	1150	500
Top of core uncovers	790	--	730
Accumulator injection starts	940	--	--
Manual ADS-4 Actuation (2 valves open)	1226	1207	1204
Top of core recovers	1300	--	--
Accumulator empties	1425	--	--
Vessel Mixture Level Below Hot Legs	1700	--	--
IRWST begins to inject	1900	1400	1205

18-Apr-96 14:33:51 AP600 3.0" HL MANUAL ADS CASE MFH3A_T20
——— PPS 0 0 0 RCS Press
- - - - PBS 0 0 0 SG Pressure



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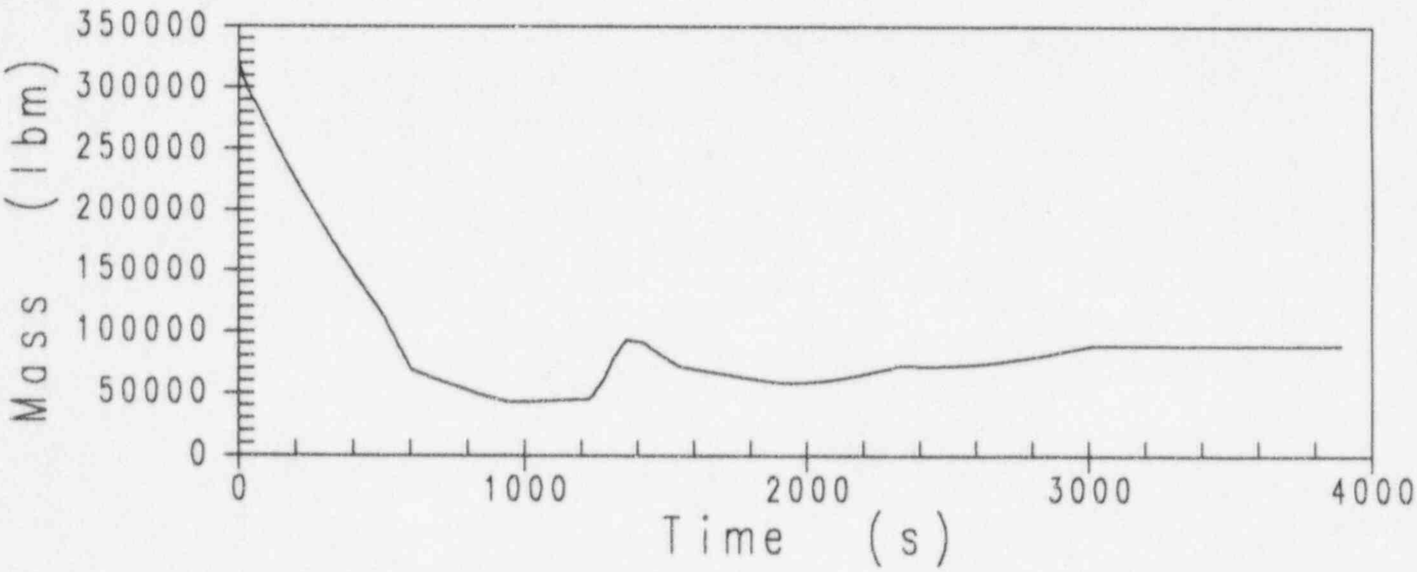
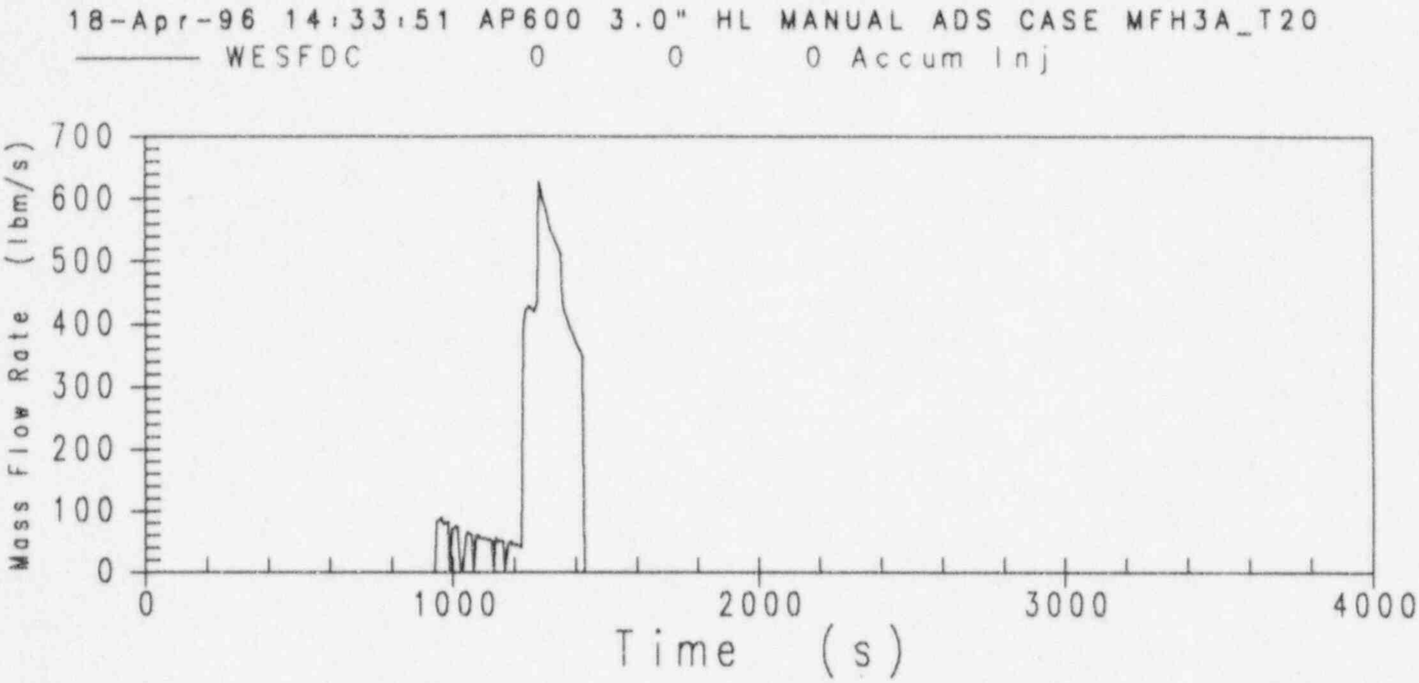
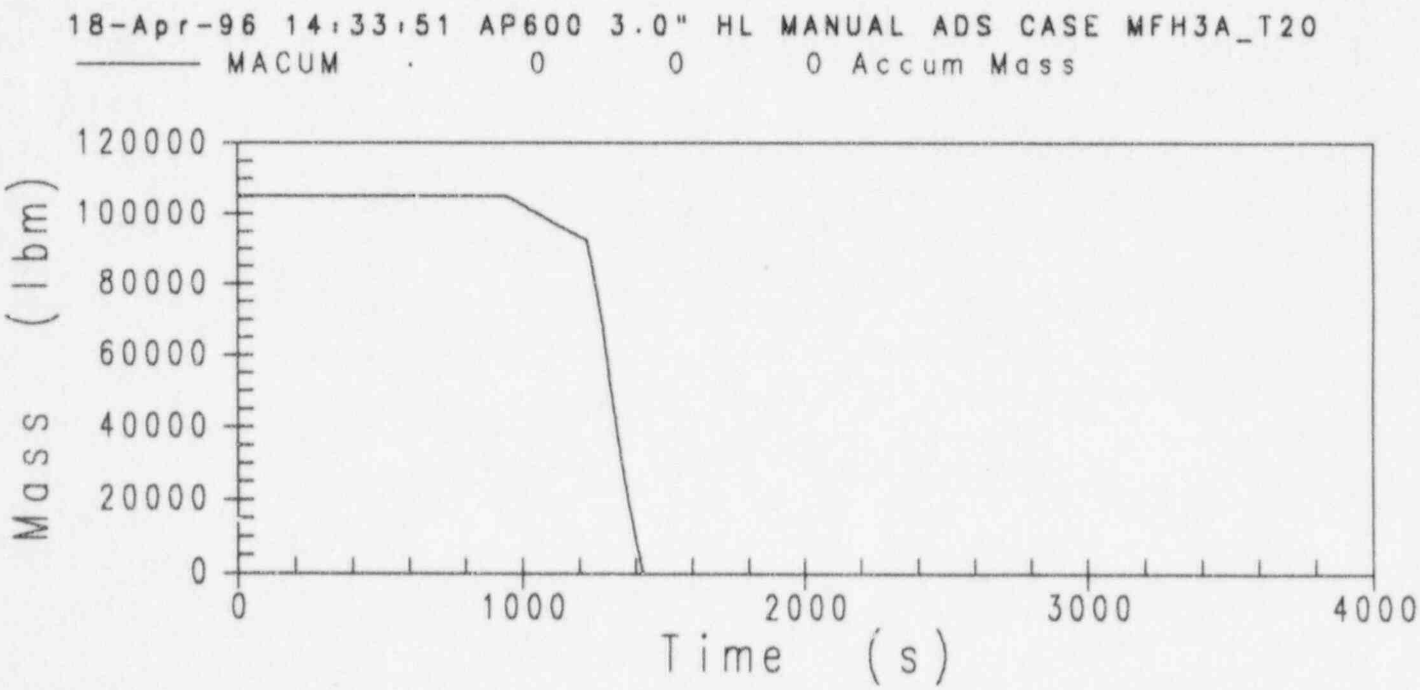
——— MTH00013 0 0 0 RCS Inventory

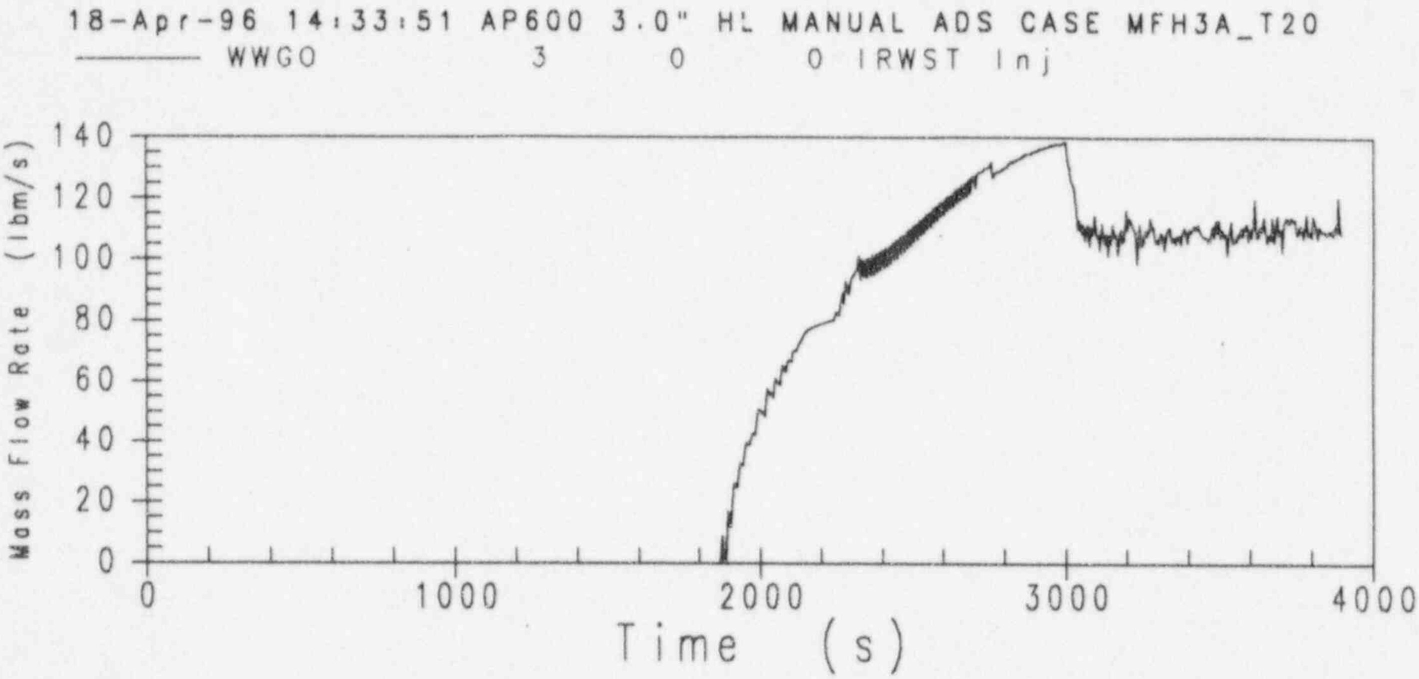


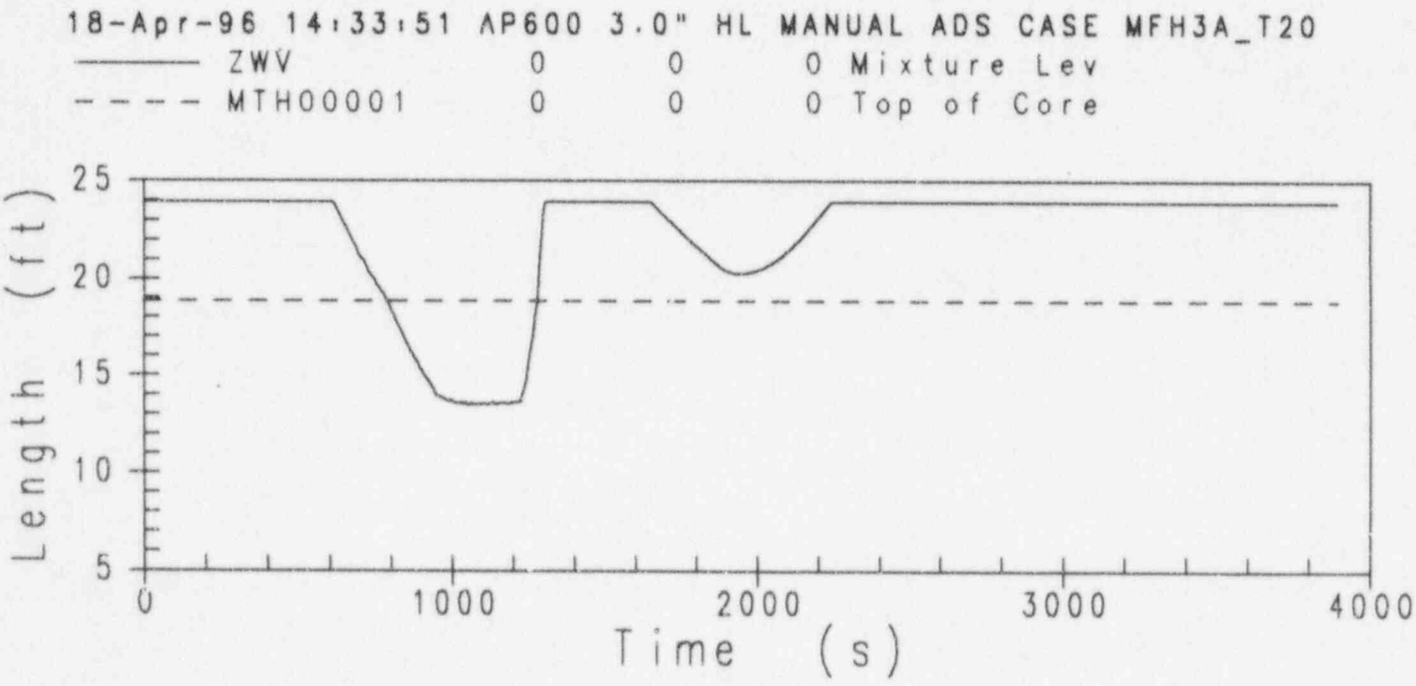


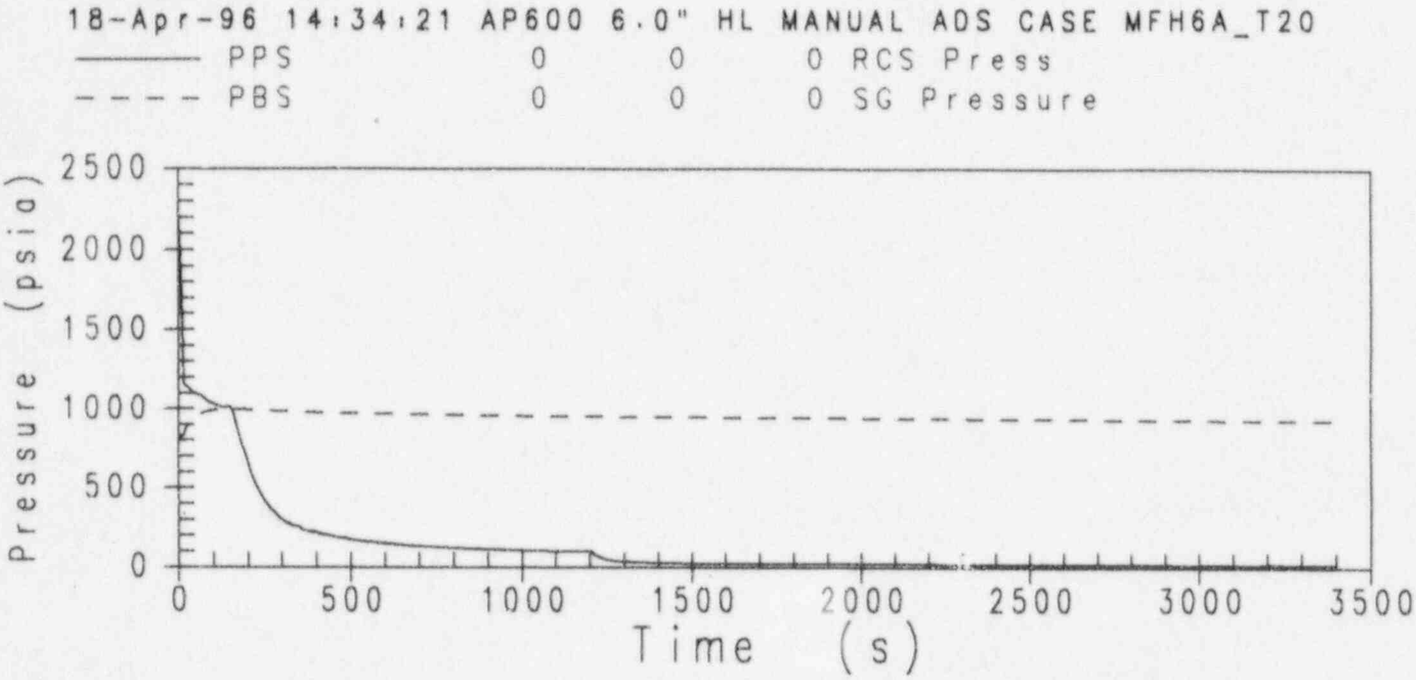
18-Apr-96 14:33:51 AP600 3.0" HL MANUAL ADS CASE MFH3A_T20
WESFDC 0 0 0 Accum Inj
Mass Flow Rate (lbm/s)
700
600
500
400
300
200
100
0
1000
2000
3000
4000
Time (s)



18-Apr-96 14:33:51 AP600 3.0" HL MANUAL ADS CASE MFH3A_T20
MACUM 0 0 0 Accum Mass
Mass (lbm)
120000
100000
80000
60000
40000
20000
0
1000
2000
3000
4000
Time (s)


18-Apr-96 14:33:51 AP600 3.0" HL MANUAL ADS CASE MFH3A_T20
WWGO 3 0 0 IRWST Inj
Mass Flow Rate (lbm/s)
140
120
100
80
60
40
20
0
0
1000
2000
3000
4000
Time (s)


18-Apr-96 14:33:51 AP600 3.0" HL MANUAL ADS CASE MFH3A_T20
ZWV 0 0 0 Mixture Lev
MTH00001 0 0 0 Top of Core
Length (ft)
25
20
15
10
5
0
1000
2000
3000
4000
Time (s)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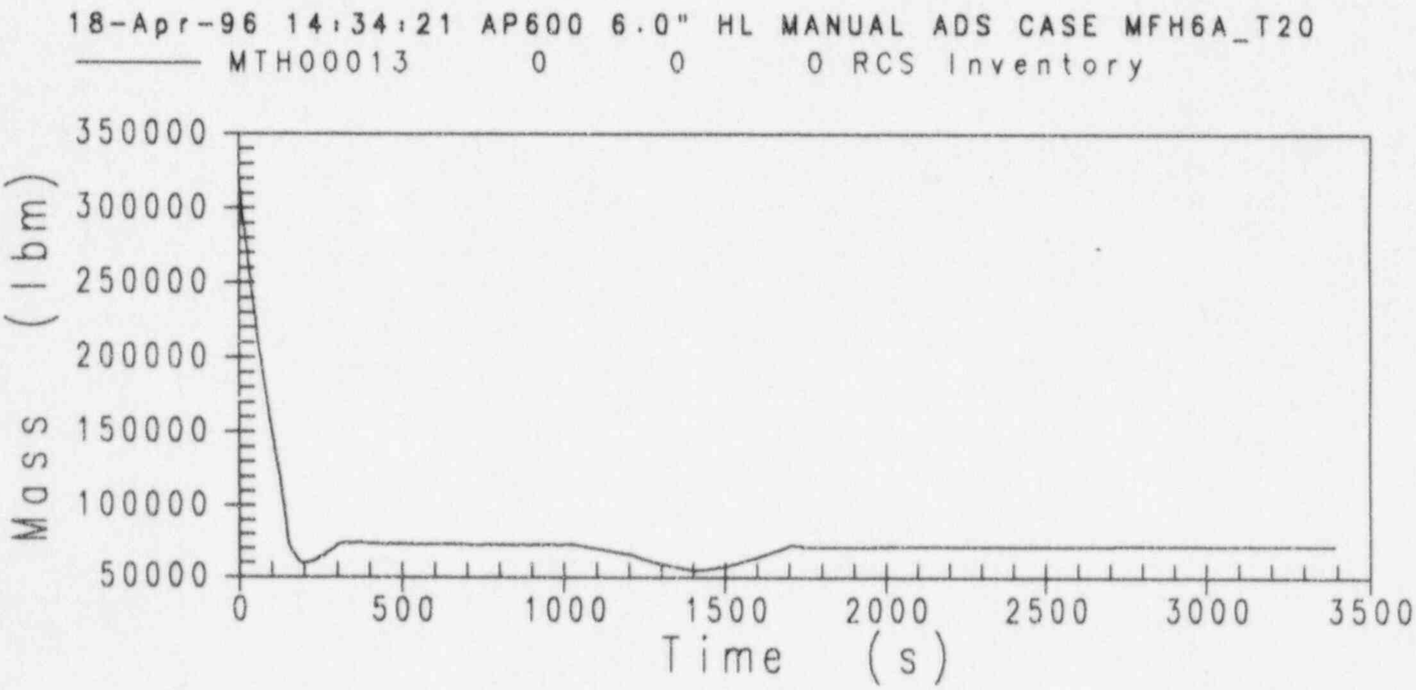
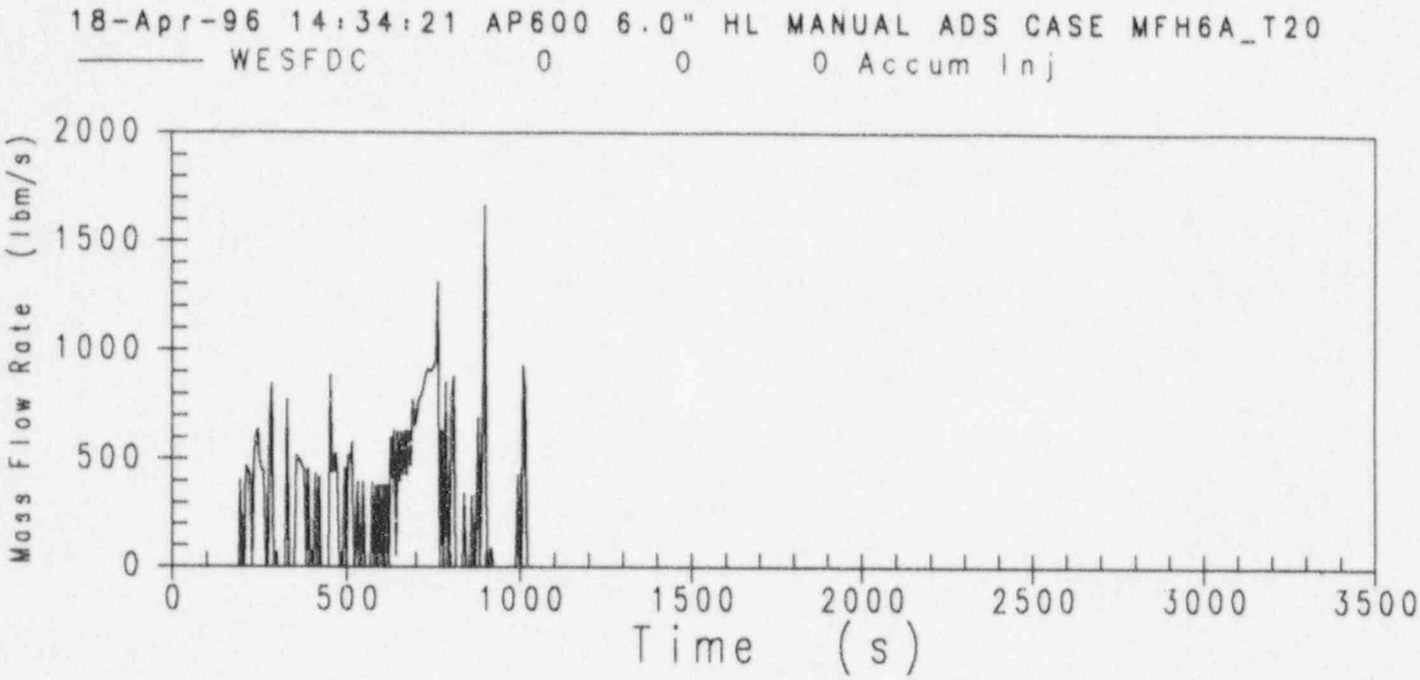
PPS 0 0 0 RCS Press
PBS 0 0 0 SG Pressure
Pressure (psia)
2500
2000
1500
1000
500
0
0 500 1000 1500 2000 2500 3000 3500
Time (s)


18-Apr-96 14:34:21 AP600 6.0" HL MANUAL ADS CASE MFH6A_T20
MTH00013 0 0 0 RCS Inventory
Mass (lbm)
350000
300000
250000
200000
150000
100000
50000
0 500 1000 1500 2000 2500 3000 3500
Time (s)


18-Apr-96 14:34:21 AP600 6.0" HL MANUAL ADS CASE MFH6A_T20
WESFDC 0 0 0 Accum Inj
Mass Flow Rate (lbm/s)
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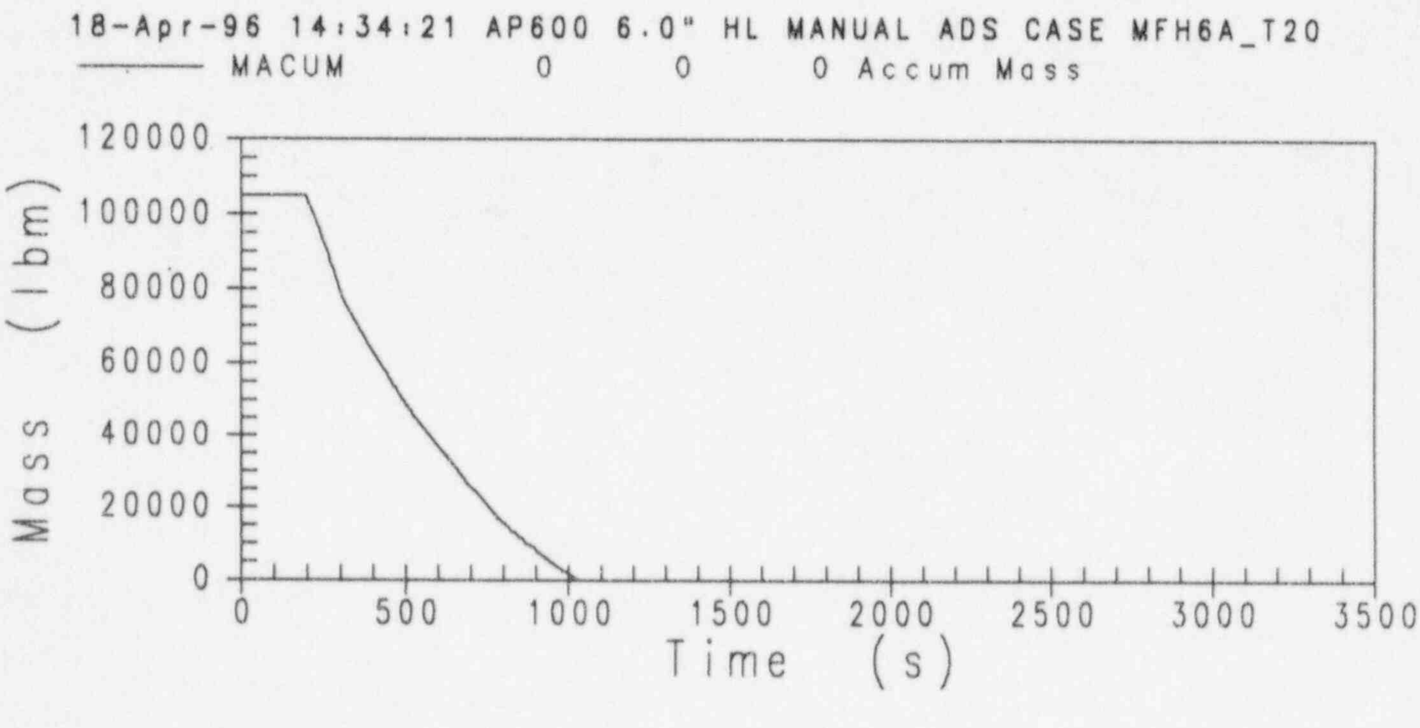
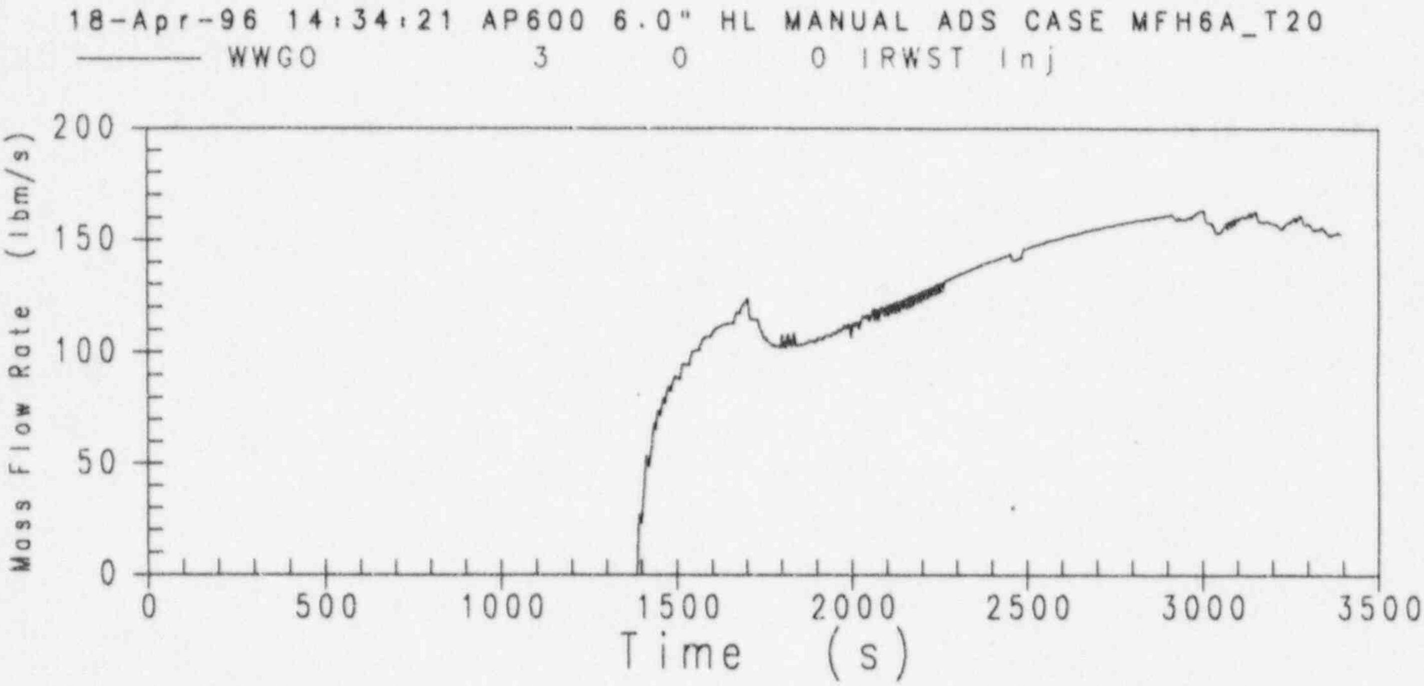
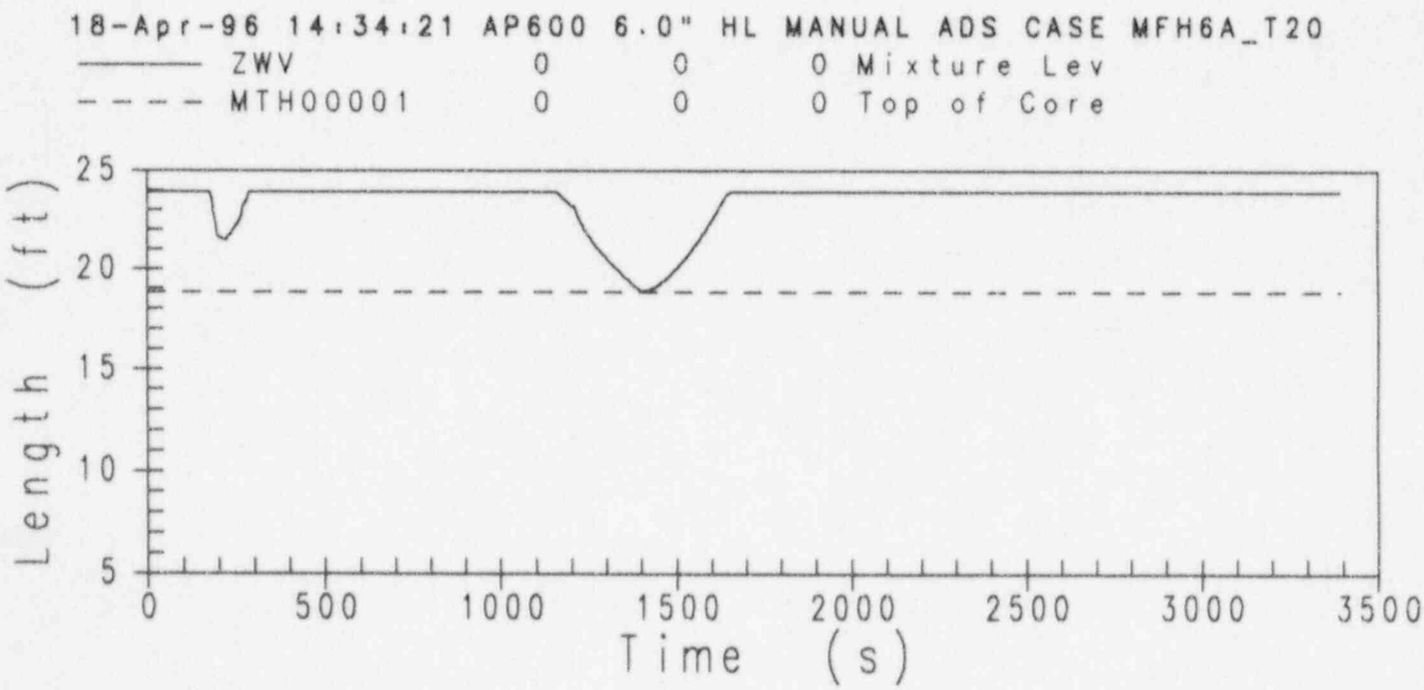
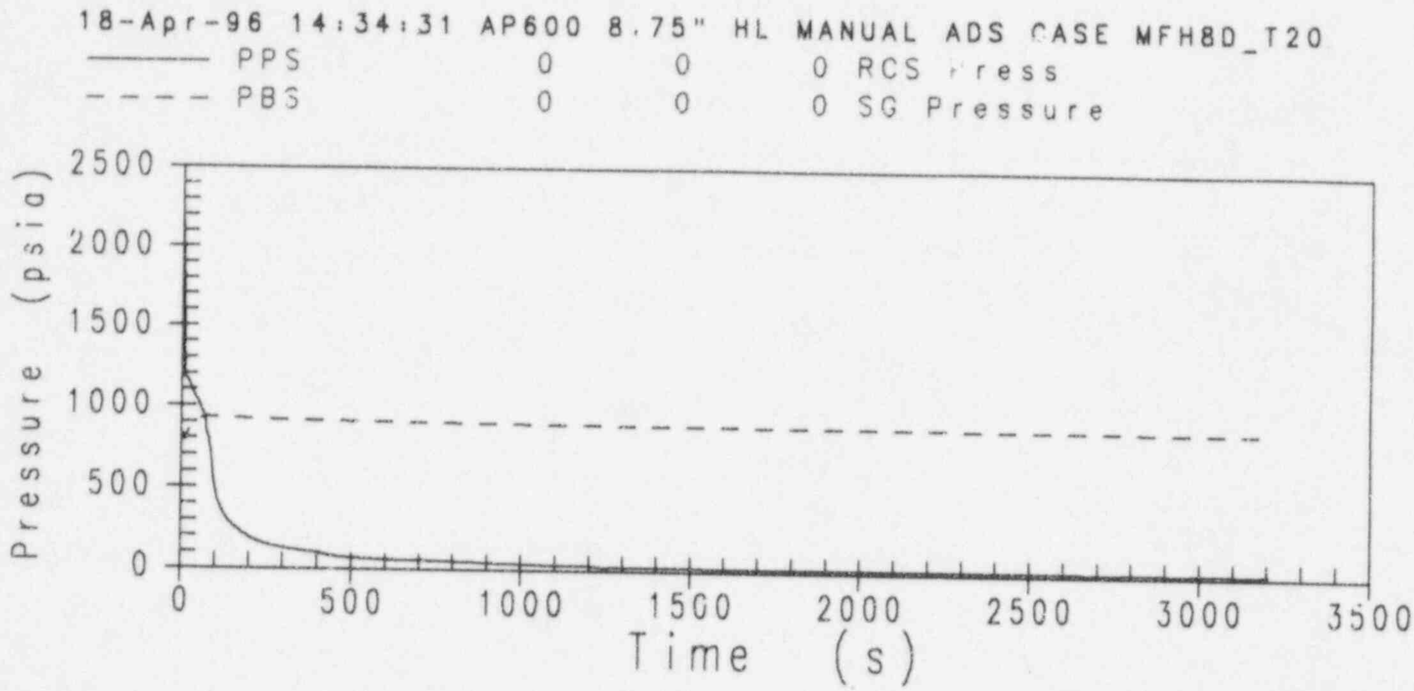
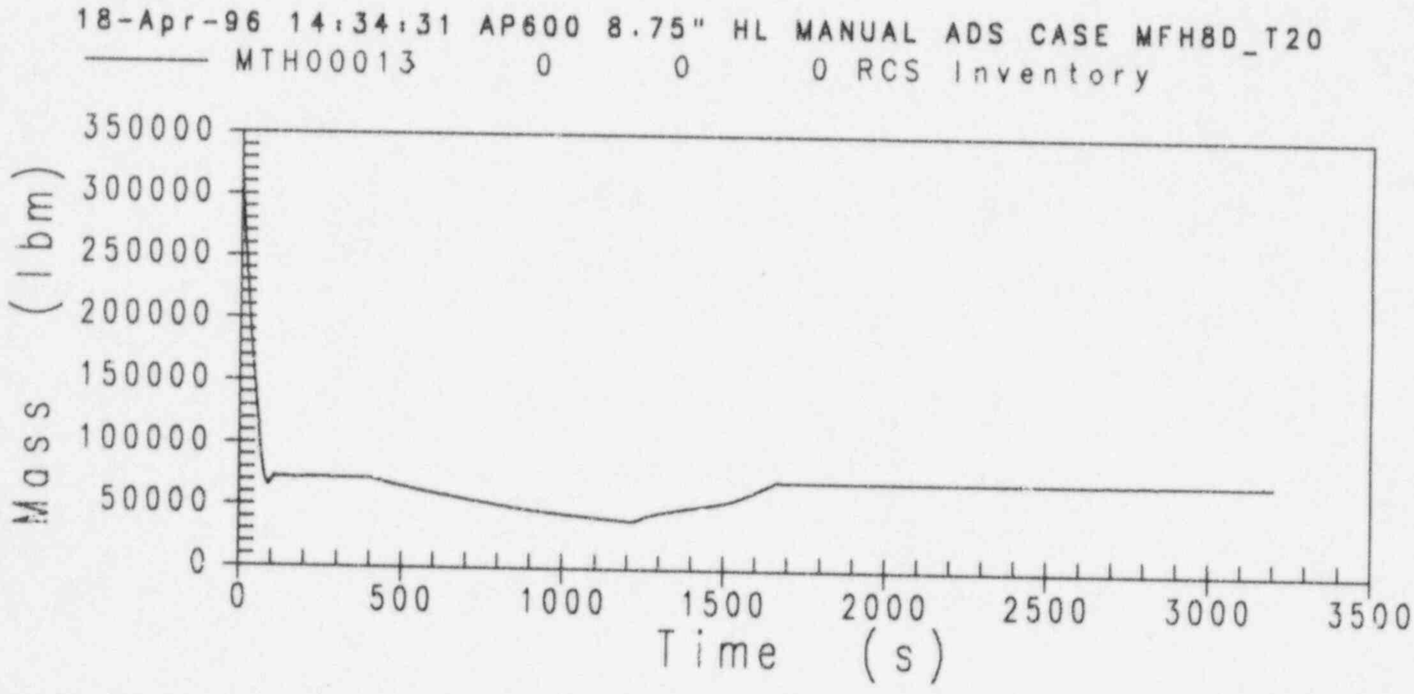
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
3500
Time (s)

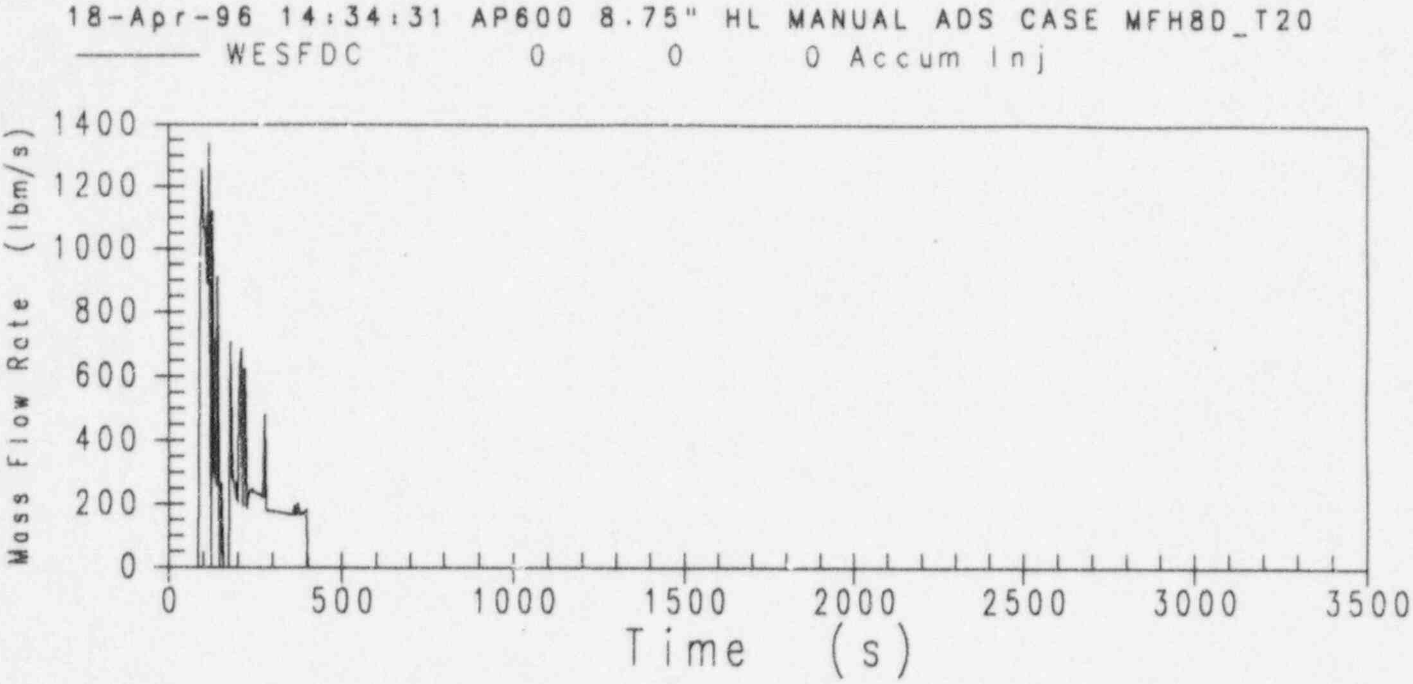

18-Apr-96 14:34:21 AP600 6.0" HL MANUAL ADS CASE MFH6A_T20
MACUM 0 0 0 Accum Mass
Mass (lbm)
120000
100000
80000
60000
40000
20000
0
0
500
1000
1500
2000
2500
3000
3500
Time (s)

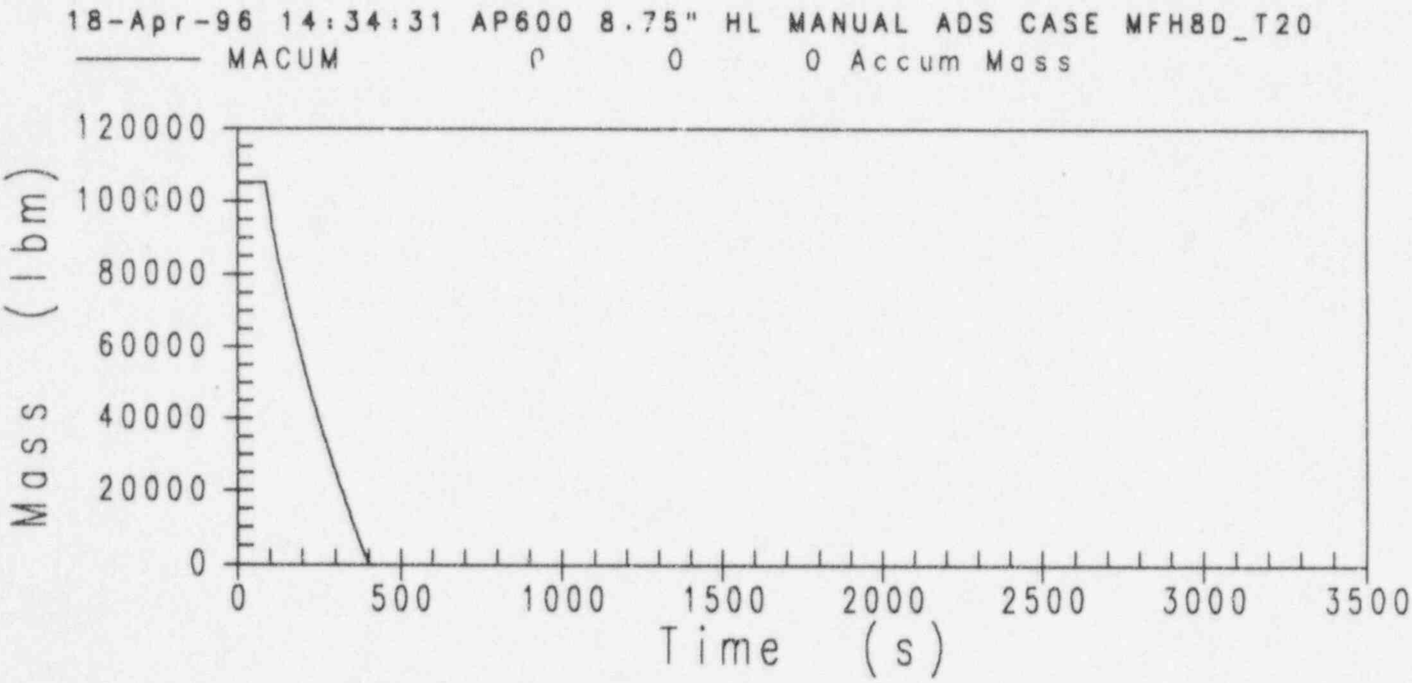

18-Apr-96 14:34:21 AP600 6.0" HL MANUAL ADS CASE MFH6A_T20
WWGO 3 0 0 IRWST Inj
Mass Flow Rate (lbm/s)
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
Time (s)

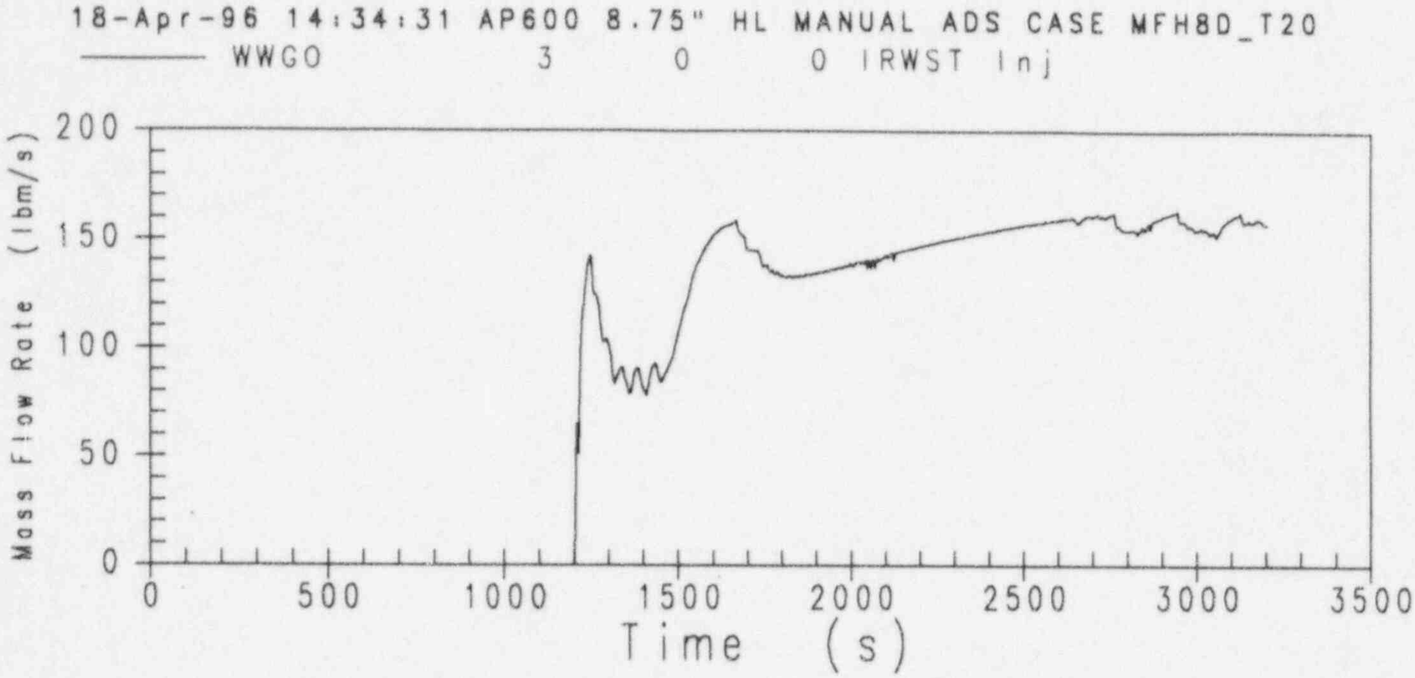

18-Apr-96 14:34:21 AP600 6.0" HL MANUAL ADS CASE MFH6A_T20
ZWV 0 0 0 Mixture Lev
MTH00001 0 0 0 Top of Core
Length (ft)
25
20
15
10
5
0
500
1000
1500
2000
2500
3000
3500
Time (s)

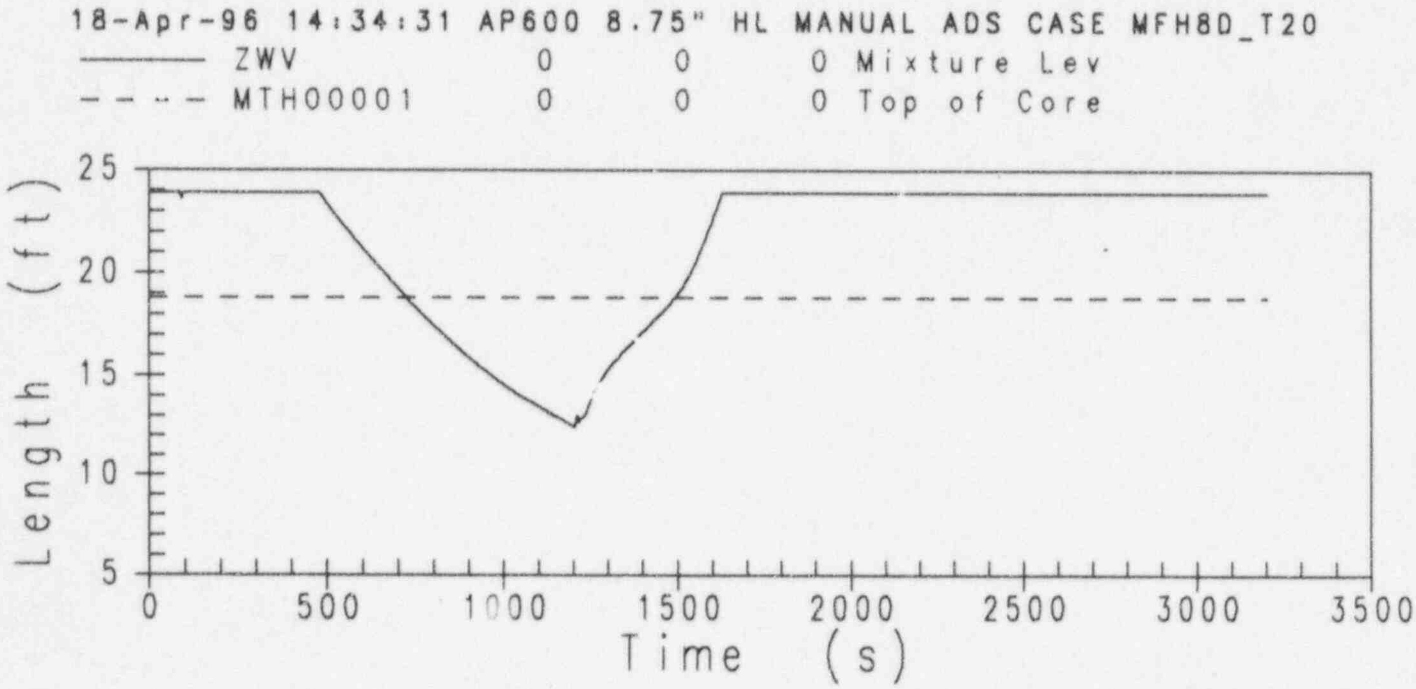

18-Apr-96 14:34:31 AP600 8.75" HL MANUAL ADS CASE MFH8D_T20
PPS 0 0 0 RCS Press
PBS 0 0 0 SG Pressure
Pressure (psia)
Time (s)


18-Apr-96 14:34:31 AP600 8.75" HL MANUAL ADS CASE MFH8D_T20
MTH00013 0 0 0 RCS Inventory
Mass (lbm)
Time (s)

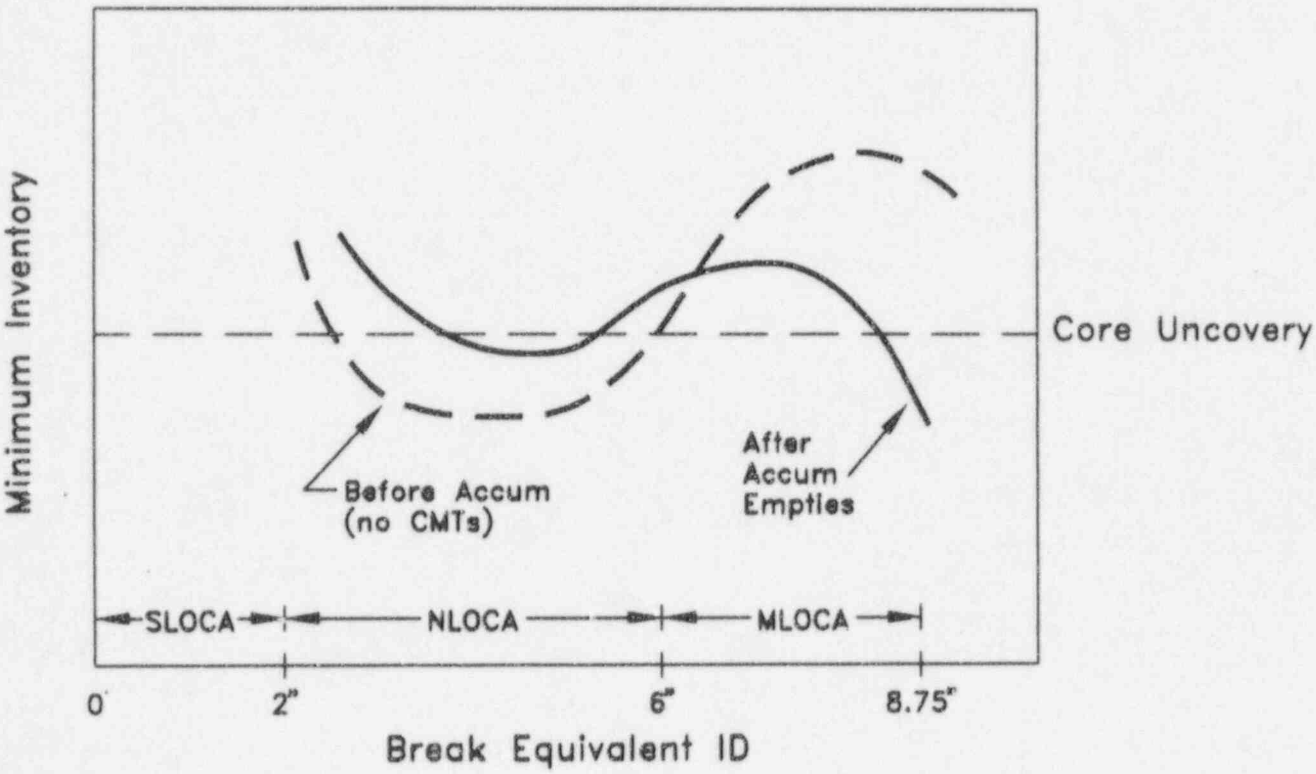

18-Apr-96 14:34:31 AP600 8.75" HL MANUAL ADS CASE MFH8D_T20
WESFDC 0 0 0 Accum Inj
Mass Flow Rate (lbm/s)
1400
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
2500
3000
3500
Time (s)


18-Apr-96 14:34:31 AP600 8.75" HL MANUAL ADS CASE MFH8D_T20
MACUM 0 0 0 Accum Mass
Mass (lbm)
120000
100000
80000
60000
40000
20000
0
0
500
1000
1500
2000
2500
3000
3500
Time (s)


18-Apr-96 14:34:31 AP600 8.75" HL MANUAL ADS CASE MFH8D_T20
WWGO 3 0 0 IRWST Inj
Mass Flow Rate (lbm/s)
200
150
100
50
0
0
500
1000
1500
2000
2500
3000
3500
Time (s)


18-Apr-96 14:34:31 AP600 8.75" HL MANUAL ADS CASE MFH8D_T20
ZWV 0 0 0 Mixture Lev
MTH00001 0 0 0 Top of Core
Length (ft)
25
20
15
10
5
0
500
1000
1500
2000
2500
3000
3500
Time (s)

Inventory Trends for PRA Scenarios Without CMTs (Manual ADS)



PRA PIRTs

PRA PIRT Process

- A group of experts were assembled who have experience in AP600 systems design, small-break LOCA, PRA, and PIRTs

- The different transients which are used to describe the plant performance for beyond design basis accidents were reviewed and contrasted to the AP600 small-break LOCA

  - Focus was the role of different equipment for preventing and mitigating core uncovery

  - Discussion also focused on how MAAP4 does the calculations relative to NOTRUMP

- The small-break LOCA PIRT was the starting point to identify the high ranked phenomena for the PRA scenarios

- The PRA scenarios were categorized to develop two PIRTs:

  - Scenarios with CMTs

  - Scenarios without CMTs

PRA PIRT Process (Cont.)

- The "high" ranked phenomena were also ranked in a relative fashion
  - The differentiation between the "really" high ranked phenomena and the other highly ranked phenomena was the expected tolerance of the calculation to increased uncertainty in the lower ranked phenomena
  - The lower ranked phenomena (which are still important) are indicated as an "I"
- The small-break LOCA PIRT was then evaluated in this fashion to create the PRA PIRT
- The highly ranked phenomena were grouped, where logical, and the parameters which should be compared when benchmarking MAAP4 to NOTRUMP were identified
- The important PIRT items were cross-checked against the proposed benchmarking cases to address the highly ranked phenomena

Nomenclature for PRA PIRTs

H	High Importance:	Has controlling influence on minimum vessel inventory; high accuracy needed on prediction
I	High Interest:	Phenomenon that is unique to AP600 and/or PRA scenarios that should be examined, but moderate differences in the predictions are not expected to have controlling influence on the minimum vessel inventory. These phenomena were identified as high importance on the Chapter 15 SBLOCA PIRT.
-	(Dash):	Neither a high importance nor a high interest item for benchmarking.
O	Omitted:	Same as Dash, but it was a high importance item on the Chapter 15 SBLOCA PIRT.

Bold **H** or **I** indicates that item was not identified as high importance on the Chapter 15 SBLOCA PIRT.

TABLE 1A
PIRT for PRA Scenarios with CMTs

Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
Break Critical Flow (in complex geometries)	H	H	H	-	Break Critical break flow occurs when the break is the main vent path from the reactor system. The break flow rate determines the rate of inventory loss, the system depressurization, and the timing of the accident progression. For larger breaks, the prediction of break flow and depressurization is most important during the blowdown phase because it can impact coolant inventory in the core region. For smaller breaks, inaccuracies in break flow predictions may have a cumulative effect, impacting the timing of the accident progression.	Integrated break water Integrated break vapor RCS pressure
Subsonic Flow	-	-	-	-	--	--
Line Resistance	-	-	-	-	--	--
Discharge Coefficient	-	-	-	-	--	--
CMT Recirculation Natural circulation of CMT and CL balance leg	I	I	-	-	CMT Recirculation CMT recirculation consists of cold water being injected to the downcomer through the DVI line, and hot water returning to the CMT via the cold leg and balance line. This results in a small net injection to the RCS. CMT recirculation occurs for a long period of time in smaller breaks, controlling the timing of the accident progression.	CMT water injection flow rate Balance line water flow rate CMT water mass inventory
Liquid mixing of CL balance leg, condensate, and CMT liquid	I	I	-	-	Thermal mixing and stratification was observed in experiments, but code numerical diffusion is not expected to have a significant impact on the overall recirculating and draining behavior.	CMT temperature
Flashing effects of hot CMT liquid layer	-	-	-	-	--	--
CMT wall heat transfer	-	-	-	-	--	--

TABLE 1A
PIRT for PRA Scenarios with CMTs

Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
CMT Balance Lines Pressure Drop	-	I	I	-	<u>CMT Transition to Draining</u> The phenomena in the balance lines and cold legs determine when vapor will enter the balance line, ending the recirculation period of the CMT. Phas separation indicates when the CMT starts to drain. Draining of the CMT initiates ADS. These phenomena are unique to the AP600 plant, and have been the focus of testing and analyses. However, differences in the prediction of the transition from recirculation to draining do not have a controlling influence on core cooling.	Balance line water flow rate Balance line vapor flow rate CMT level Time recirculation ends
Flow Composition	-	I	I	-		
Cold Legs PBL-to-Cold Leg Tee	-	I	I	-		
Phase Separation	-	I	I	-		
Flashing	-	-	-	-	--	--
Stored Energy Release	-	-	-	-	--	--
CMT Draining Effects Thermal stratification and mixing of warmer condensate with colder CMT water	-	I	I	-	<u>CMT Draining</u> These phenomena are related to the determination of the pressure at the top of the CMT, which controls the draining rate of the CMT. The impact of the interfacial condensation is to reduce the pressure at the top of the CMT such that the CMT drain flow is reduced; this is more important for larger breaks. The overall draining rate of the CMT is important since it determines the time of ADS actuation.	CMT water injection flow rate CMT mass inventory CMT level CMT temperature Time draining starts
Interfacial condensation on CMT water surface	-	-	H	-		
Condensation on cold thick steel surfaces	-	-	-	-	--	--
Transient conduction in CMT walls	-	-	-	-	--	--
Dynamic effects of steam injection and mixing with CMT liquid and condensate	-	-	O	-	This is only a possible effect for the larger breaks; the CMT diffusor helps to mitigate this effect.	--

TABLE 1A
PIRT for PRA Scenarios with CMTs

Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
Upper Head Draining Effects	-	-	-	-	--	--
Upper Head (Cont) Flashing	-	-	-	-	--	--
Mixture Level	O	O	O	O	Mixture level in the upper plenum is considered below; mixture level in the upper head is not a concern.	--
Entrainment / De-entrainment	-	-	-	-	--	--
Upper Plenum Draining Effects	-	-	-	-	--	--
Flashing	-	-	-	-	--	--
Entrainment / De-entrainment	-	-	-	-	--	--
Mixture Level	H	H	H	H	Core Cooling These phenomena are ranked high since the two-phase drift flux and mixture level models determine the distribution of a two-phase mixture, which determines if the core would become uncovered and experience a clad temperature heat up. These are the key phenomena for PRA success criteria.	RCS mass inventory Vessel mass inventory Core mixture level Core collapsed level
Vessel/Core Mixture Level / Mass Inventory	H	H	H	H		
Decay Heat	H	H	H	H	The decay heat to be removed is a sensitive boundary condition.	
Forced Convection	-	-	-	-	--	--
Flashing	-	-	-	-	--	--
Natural Circulation Flow and Heat Transfer	-	-	-	-	--	--
Mass Flow	-	-	-	-	--	--
Flow Resistance	-	-	-	-	--	--

TABLE 1A
PIRT for PRA Scenarios with CMTs

Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
Vessel/Core (Cont.) Wall Stored Energy	-	-	**H**	**H**	Downcomer The stored energy in the vessel wall can impact the pressure of the RCS during the IRWST gravity injection phase. The stored energy is a potential source of additional steam generation, which may provide additonal challenges to RCS venting capacity.	RCS Pressure Downcomer Mass Inventory
Downcomer / Lower Plenum Stored Energy Release / Boiling	-	-	**H**	**H**		
Level	-	-	H	H	This is highly ranked since it provides the gravity driving head for flow into the core. It is specifically of greatest interest during the IRWST injection period.	Downcomer Level
Flashing	-	-	-	-	--	--
Loop Asymmetry Effects	-	-	-	-	--	--
Hot Legs Countercurrent Flow	-	-	-	-	--	--
Entrainment	-	-	-	-	--	--
Flashing	-	-	-	-	--	--
Horizontal Fluid Stratification	-	-	**H**	**H**	ADS-4 ADS-4 is a key component for the PRA success criteria. The reduced venting capacity (compared to DBA) is the reason for the increased importance. The flow regime in the hot leg determines the mixture that is entrained into the ADS stage 4 lines. The ADS stage 4 lines are the primary venting path to reduce system pressure to achieve / maintain IRWST gravity injection.	Integrated ADS-4 water Integrated ADS-4 vapor RCS pressure Hot leg water level
Phase Separation in Tees (Flow Region)	-	-	**H**	**H**		
ADS 4 Critical Flow	-	-	H	**H**		
Subsonic Flow	-	-	-	**H**		
Two-Phase Pressure Drop	-	-	-	**H**		

TABLE 1A PIRT for PRA Scenarios with CMTs						
Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
ADS Stages 1 - 3 Critical Flow	O	O	H	-	ADS 1-3 In PRA full depressurization scenarios (to IRWST gravity injection), ADS stage 1 to 3 are only used in high pressure scenarios to reduce the pressure below the 4th stage interlock. ADS 1 - 3 do not have a controlling influence on the event progression.	Integrated ADS 1-3 water Integrated ADS 1-3 vapor RCS pressure
Two-Phase Pressure Drop	-	-	I			
Valve Loss Coefficient	-	-	O	-		
Single-Phase Pressure Drop	-	-	-	-	--	--
IRWST Pool Level	-	-	-	H	IRWST The IRWST injection provides core cooling. The pool level is a boundary condition that provides the elevation head to drive the inventory injection. Gravity draining also depends on the primary system pressure, pressure drops in the vent paths, and line resistances in the injection lines.	IRWST flow rate IRWST level IRWST temperature RCS pressure
Gravity Draining	-	-	-	H		
Temperature	-	-	-	H		
DVI Line Pressure Drop (Flow Resistance)	-	-	-	-	--	--
Discharge Line Flashing	-	-	-	-	--	--
Flow and Temperature Distribution in PRHR Bundle Region	-	-	-	-	--	--
Vapor Condensation	-	-	-	-	--	--

TABLE 1A
PIRT for PRA Scenarios with CMTs

Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
Pressurizer Surge Line Pressure Drop	-	-	-	-	--	--
Flooding / CCFL	-	I	I	-	Pressurizer The pressurizer of high interest because it can impact the redistribution of mass in the RCS. Once ADS-4 is actuated, the pressurizer drains.	Pressurizer level Pressurizer mass inventory
Pressurizer Flashing	I	-	-	-		
Level (Inventory)	-	I	I	-		
Level Swell	-	I	I	-		
CCFL	-	-	-	-	--	--
Entrainment / De-entrainment	-	-	-	-	--	--
Stored Energy Release	-	-	-	-	--	--
Vapor Space Behavior	-	-	-	-	--	--
Steam Generator 2Φ Natural Circulation	I	I	-	-	Steam Generator The steam generators are the only source of energy removal except the CMTs and the break flow. For breaks too small to remove the decay heat, the steam generators play a role in the timing of the event.	SG Mass Inventory SG Heat Transfer
Secondary Mass Inventory	I	I	-	-		
Steam Generator Heat Transfer	-	-	-	-	--	--
Secondary Conditions	-	-	-	-	--	--
U-tube Condensation	-	-	-	-	--	--
Secondary Pressure	-	-	-	-	--	--
Steam Generator Tube Draining	-	-	-	-	--	--

TABLE 1A
PIRT for PRA Scenarios with CMTs

Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
RCP Coast Down	-	-	-	-	--	--
Flow Resistance	-	-	-	-	--	--
Accumulator Injection Flow Rate	-	-	-	-	--	--
Noncondensable Gas Entrainment	-	-	-	-	--	--
PRHR 1Φ Heat Transfer	-	-	-	-	--	--
2Φ Heat Transfer	-	-	-	-	--	--
Non-Condensable Gas Effects	-	-	-	-	--	--
Recirculation Flow	-	-	-	-	--	--

TABLE 1B
PIRT for PRA Scenarios without CMTs

Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
Break Critical Flow (in complex geometries)	H	H	H	-	<u>Break</u> Critical break flow occurs when the break is the main vent path from the reactor system. The break flow rate determines the rate of inventory loss, the system depressurization, and the timing of the accident progression. For larger breaks, the prediction of break flow and depressurization is most important during the blowdown phase because it can impact coolant inventory in the core region. For smaller breaks, inaccuracies in break flow predictions may have a cumulative effect, impacting the timing of the accident progression.	Integrated break water Integrated break vapor RCS pressure
Subsonic Flow	-	-	-	-	--	--
Line Resistance	-	-	-	-	--	--
Discharge Coefficient	-	-	-	-	--	--
Accumulators Injection Flow Rate	H	H	H	-	<u>Accumulators</u> The accumulators provide the only source of reactor coolant make-up prior to ADS actuation. The rate of delivery can play a key role in the primary inventory status.	--
Noncondensible Gas Entrainment	-	-	-	-	--	--
Upper Head Draining Effects	-	-	-	-	--	--
Upper Head (Cont) Flashing	-	-	-	-	--	--
Mixture Level	O	O	O	O	Mixture level in the upper plenum is considered below; mixture level in the upper head is not a concern.	--
Entrainment / De-entrainment	-	-	-	-	--	--

TABLE 1B
PIRT for PRA Scenarios without CMTs

Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
Upper Plenum Draining Effects	-	-	-	-	--	--
Flashing	-	-	-	-	--	--
Entrainment / De-entrainment	-	-	-	-	--	--
Mixture Level	H	H	H	H	Core Cooling These phenomena are ranked high since the two-phase drift flux and mixture level models determine the distribution of a two-phase mixture, which determines if the core would become uncovered and experience a clad temperature heat up. These are the key phenomena for PRA success criteria.	RCS mass inventory Vessel mass inventory Core mixture level Core collapsed level
Vessel/Core Mixture Level / Mass Inventory	H	H	H	H		
Decay Heat	H	H	H	H	The decay heat to be removed is a sensitive boundary condition.	
Forced Convection	-	-	-	-	--	--
Flashing	-	-	-	-	--	--
Natural Circulation Flow and Heat Transfer	-	-	-	-	--	--
Mass Flow	-	-	-	-	--	--
Flow Resistance	-	-	-	-	--	--

TABLE 1B
PIRT for PRA Scenarios without CMTs

Component / Phenomena	Blow-down	Nat. Circulation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
Vessel/Core (Cont.) Wall Stored Energy	-	-	**H**	**H**	<u>Downcomer</u> The stored energy in the vessel wall can impact the pressure of the RCS during the IRWST gravity injection phase. The stored energy is a potential source of additional steam generation, which may provide additonal challenges to RCS venting capacity.	RCS Pressure Downcomer Mass Inventory
Downcomer / Lower Plenum Stored Energy Release / Boiling	-	-	**H**	**H**		
Level	-	-	H	H	This is highly ranked since it provides the gravity driving head for flow into the core. It is specifically of greatest interest during the IRWST injection period.	Downcomer Level
Flashing	-	-	-	-	--	--
Loop Asymmetry Effects	-	-	-	-	--	--
Hot Legs Countercurrent Flow	-	-	-	-	--	--
Entrainment	-	-	-	-	--	--
Flashing	-	-	-	-	--	--
Horizontal Fluid Stratification	-	-	**H**	**H**	<u>ADS-4</u> ADS-4 is a key component for the PRA success criteria. The reduced venting capacity (compared to DBA) is the reason for the increased importance. The flow regime in the hot leg determines the mixture that is entrained into the ADS stage 4 lines. The ADS stage 4 lines are the primary venting path to reduce system pressure to achieve / maintain IRWST gravity injection.	Integrated ADS-4 water Integrated ADS-4 vapor RCS pressure Hot leg water level
Phase Separation in Tees (Flow Region)	-	-	**H**	**H**		
ADS 4 Critical Flow	-	-	H	**H**		
Subsonic Flow	-	-	-	**H**		
Two-Phase Pressure Drop	-	-	-	**H**		

TABLE 1B PIRT for PRA Scenarios without CMTs						
Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
ADS Stages 1 - 3 Critical Flow	O	O	H	-	ADS 1-3 In PRA full depressurization scenarios (to IRWST gravity injection), ADS stage 1 to 3 are only used in high pressure scenarios to reduce the pressure below the 4th stage interlock. ADS 1 - 3 do not have a controlling influence on the event progression.	Integrated ADS 1-3 water Integrated ADS 1-3 vapor RCS pressure
Two-Phase Pressure Drop	-	-	I	-		
Valve Loss Coefficient	-	-	O	-		
Single-Phase Pressure Drop	-	-	-	-	--	--
IRWST Pool Level	-	-	-	H	IRWST The IRWST injection provides core cooling. The pool level is a boundary condition that provides the elevation head to drive the inventory injection. Gravity draining also depends on the primary system pressure, pressure drops in the vent paths, and line resistances in the injection lines.	IRWST flow rate IRWST level IRWST temperature RCS pressure
Gravity Draining	-	-	-	H		
Temperature	-	-	-	H		
DVI Line Pressure Drop (Flow Resistance)	-	-	-	-	--	--
Discharge Line Flashing	-	-	-	-	--	--
Flow and Temperature Distribution in PRHR Bundle Region	-	-	-	-	--	--
Vapor Condensation	-	-	-	-	--	--

TABLE 1B PIRT for PRA Scenarios without CMTs						
Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
Pressurizer Surge Line Pressure Drop	-	-	-	-	--	--
Flooding / CCFL	-	I	I	-	Pressurizer The pressurizer of high interest because it can impact the redistribution of mass in the RCS. Once ADS-4 is actuated, the pressurizer drains.	Pressurizer level Pressurizer mass inventory
Pressurizer Flashing	I	-	-	-		
Level (Inventory)	-	I	I	-		
Level Swell	-	I	I	-		
CCFL	-	-	-	-	--	--
Entrainment / De-entrainment	-	-	-	-	--	--
Stored Energy Release	-	-	-	-	--	--
Vapor Space Behavior	-	-	-	-	--	--
Steam Generator 2Φ Natural Circulation	I	-	-	-	Steam Generator The steam generators are the only source of energy removal except the break flow. Since the actuation of ADS is controlled by operator action, the SGs play a smaller role in the timing of the event.	SG Mass Inventory SG Heat Transfer
Secondary Mass Inventory	I	-	-	-		
Steam Generator Heat Transfer	-	-	-	-	--	--
Secondary Conditions	-	-	-	-	--	--
U-tube Condensation	-	-	-	-	--	--
Secondary Pressure	-	-	-	-	--	--
Steam Generator Tube Draining	-	-	-	-	--	--

TABLE 1B PIRT for PRA Scenarios without CMTs						
Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
RCP Coast Down	-	-	-	-	--	--
Flow Resistance	-	-	-	-	--	--
CMT Recirculation Natural circulation of CMT and CL balance leg	-	-	-	-	--	--
Liquid mixing of CL balance leg, condensate, and CMT liquid	-	-	-	-	--	--
Flashing effects of hot CMT liquid layer	-	-	-	-	--	--
CMT wall heat transfer	-	-	-	-	--	--
CMT Balance Lines Pressure Drop	-	-	-	-	--	--
Flow Composition	-	-	-	-	--	--
Cold Legs PBL-to-Cold Leg Tee	-	-	-	-	--	--
Phase Separation	-	-	-	-	--	--
Flashing	-	-	-	-	--	--
Stored Energy Release	-	-	-	-	--	--
CMT Draining Effects Thermal stratification and mixing of warmer condensate with colder CMT water	-	-	-	-	--	--
Interfacial condensation on CMT water surface	-	-	-	-		

TABLE 1B PIRT for PRA Scenarios without CMTs						
Component / Phenomena	Blow-down	Nat. Circu-lation	ADS Blow-down	IRWST Gravity Drain	Discussion of High Importance and High Interest Items	Benchmarking Focus
Condensation on cold [illegible] surfaces	-	-	-	-	--	--
Transient conduction in CMT walls	-	-	-	-	--	--
Dynamic effects of steam injection and mixing with CMT liquid and condensate	-	-	-	-	--	--
PRHR 1Φ Heat Transfer	-	-	-	-	--	--
2Φ Heat Transfer	-	-	-	-	--	--
Non-Condensible Gas Effects	-	-	-	-	--	--
Recirculation Flow	-	-	-	-	--	--

Selection of Benchmarking Cases

Table 2

Cases for MAAP4 Benchmarking

Case	Break	CMT			Accum.	Core Cooling	Down-comer	ADS-4	ADS 1-3	IRWST	Press'zer	Steam Gen.
		Recirc.	Trans.	Drain.								
<u>With 1 CMT (Auto ADS)</u> 0.5" HL	x	x	x			x	x	x	x	x	x	x
2.0" HL	x	x	x			x	x	x		x		x
5.0" HL	x	x	x	x		x	x	x		x		
8.75" HL	x			x		x	x	x		x		
<u>With 1 Accum. (Man ADS)</u> 3.0" HL	x				x	x	x	x		x		x
6.0" HL	x				x	x	x	x		x		
8.75" HL	x				x	x	x	x		x		
<u>Sensitivities with Auto ADS</u> 2.0" HL with 2 CMTs		x	x			x						
2.0" HL with all ADS						x		x	x			
2.0" HL with delayed ADS						x		x				
2.0" HL with higher IRWST temp						x				x		
2.0" CL with 1 stage 3 ADS for RNS injection	x					x			x		x	
5.0" HL with 1 CMT, 1 Acc		x	x		x	x						
DVI line break	x					x						
<u>Sensitivities with Man ADS</u> 8.75" CL with 1 Acc	x					x						

Summary / Open Items

Summary

- PRA scenarios have been discussed by a panel of experts to develop the PRA PIRTs
- The key phenomena which significantly affect the core inventory have been identified for a range of break sizes and avaiiable passive safety system equipment
- Benchmarking cases have been selected which capture the key phenomena
- Benchmarking process between NOTRUMP and MAAP4 will verify the AP600 PRA success criteria
  - NOTRUMP and MAAP4 will confirm successful core cooling for a spectrum of PRA scenarios that have been chosen to fully demonstrate the phenomena of interest
  - MAAP4 will be used for additional sensitivities to support the PRA

OPEN ITEMS

NRC Actions

- Feedback on 2/29/96 plan
- Review PRA PIRTs
- Review selection of benchmarking cases
- Further clarification of T&H uncertainty concerns

Westinghouse Actions

- Continue with benchmarking activities
- Plan for resolution of long-term recirculation issues

Joint Actions

- Next meeting