6.3.2.9.4 Testing and Inspection Requirements

Refer to Subsection 5.4.6.4.

6.3.2.9.5 Instrumentation Requirements

Refer to Subsection 5.4.6.5 and 7.4.4.

6.3.2.10 Standby Liquid Control System

6.3.2.10.1 Design Bases

Refer to Subsection 9.3.5.1.

6.3.2.10.2 System Description

Refer to Subsection 9.3.5.2.

6.3.2.10.3 Safety Evaluation

SLC performance evaluation during a LOCA is covered in Subsection 6.3.3.

6.3.2.10.4 Testing and Inspection Requirements

Refer to Subsection 9.3.5.3.

6.3.2.10.5 Instrumentation Requirements

Refer to Subsection 9.3.5.4.

6.3.3 ECCS Performance Evaluation

Performance of the ECCS network is determined by evaluating the system response to an instantaneous break of a pipe. The analyses included in this subsection demonstrates the adequacy of ESBWR ECCS network performance for the entire spectrum of postulated break sizes.

The analyses are based upon the core loading shown within Section 4.3 and were performed with the TRACG model. The Maximum Linear Heat Generation Rate (MLHGR) used in the ECCS-LOCA analysis for each bundle design ensures that the criteria documented in Appendix 4B is met. These results will be provided by the utility referencing the ESBWR design to the USNRC for information. See Subsection 6.3.5.

The Chapter 15 accidents for which ECCS operation is required are:

- Feedwater Line Break;
- Spectrum of BWR Steam System Piping Failures Outside Containment; and
- Loss-of-Coolant Accidents (inside containment)

Chapter 15 provides the radiological consequences of the above listed events.

6.3.3.1 ECCS Bases for Technical Specifications

The MLHGR operating limits, used in the ECCS performance analysis, are documented in each cycle-specific Core Operating Limits Report (COLR), which is referenced to by the Technical Specifications. Minimum ECCS functional requirements are specified in Subsections 6.3.3.4 and 6.3.3.5, and testing requirements are discussed within Subsections 6.3.2 and 6.3.3.9. Limits on minimum suppression pool water level are discussed in Subsection 6.2.1.1.2 and Table 6.2-3.

6.3.3.2 Acceptance Criteria for ECCS Performance

The applicable acceptance criteria, extracted from 10 CFR 50.46, are evaluated below.

Criterion 1: Peak Cladding Temperature (PCT)

"The calculated maximum fuel element cladding temperature shall not exceed 2200°F," which is equivalent to 1204°C. Conformance to Criterion 1 is shown for the system response analyses within Subsection 6.3.3.7 and specifically in Table 6.3-5 (Summary of LOCA Analysis Results). For each plant-specific application, conformance will be re-confirmed for the limiting break. See Subsection 6.3.6 for Combined Operating License (COL) information requirements.

Criterion 2: Maximum Cladding Oxidation

"The calculated total local oxidation of the cladding shall nowhere exceed 0.17 times the total cladding thickness before oxidation." Conformation to Criterion 2 is shown in Table 6.3-5. For each plant-specific application, conformance will be re-confirmed for the limiting break. See Subsection 6.3.6 for COL information requirements.

Criterion 3: Maximum Hydrogen Generation

"The calculated total amount of hydrogen generated from the chemical reaction of the cladding with water or steam shall not exceed 0.01 times the hypothetical amount that would be generated if all the metal in the cladding cylinder surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react." Conformance to Criterion 3 is addressed in Table 6.3-5.

Criterion 4: Coolable Geometry

"Calculated changes in core geometry shall be such that the core remains amenable to cooling." As described in Reference 6.3-2, Section III.A, conformance to Criterion 4 is demonstrated by conformance to Criteria 1 and 2.

Criterion 5: Long-Term Cooling

"After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core." Conformance to Criterion 5 is assured for any LOCA where the water level can be restored and maintained at a level above the top of the core. For ESBWR, the core never uncovers during a design basis LOCA event due to flow from the GDCS pools. The water level in the vessel remains above the core for 72 hours (refer to section 6.2.1.1.3).

6.3.3.3 Single-Failure Considerations

Subsections 6.3.2 and 6.3.3 discuss the functional consequences of potential operator errors and single failures (including those that might cause any manually controlled electrically operated

valve in the ECCS to move to a position which could adversely affect the ECCS). Because the Isolation Condensers and the Standby Liquid Control system are single failure proof, it was shown that all potential single failures are no more severe than one of the single failures identified in Table 6.3-6.

It is therefore only necessary to consider each of these single failures in the ECCS performance analyses.

As shown in Table 6.3-6, the worst single failure following a LOCA is the failure of either 1 DPV (or 1 SRV) or 1 GDCS injection valve. The failure of a DPV or SRV results in the greatest reduction in the depressurization rate from ADS actuation and results in a delay in GDCS injection. The failure of one GDCS injection valve results in the greatest reduction in the GDCS reflooding rate. Each break location is evaluated assuming each failure to determine the most limiting single failure for that LOCA event.

6.3.3.4 System Performance During the Accident

In general, the system response to an accident can be described as:

- receiving an initiation signal;
- a small lag time (to open all valves and depressurize the vessel); and
- finally, the GDCS flow entering the vessel.

Key ECCS actuation setpoints and time delays for all the ECCS systems are provided in Table 6.3-1.

The ADS actuation logic includes a delay time to confirm the presence of a low water level (Level 1) initiation signal.

The GDCS flow delivery rates are addressed within Subsection 6.3.3.7 for the various breaks analyzed. Piping and instrumentation for the GDCS and ADS are addressed within Subsection 6.3.2. The operational sequence of ECCS for the limiting case is shown in Table 6.3-9 (GDCS Injection Line Break with failure of one GDCS Injection Valve).

Operator action is not required for 72 hours, except as a monitoring function, following any LOCA.

6.3.3.5 Use of Dual Function Components for ECCS

The systems of the ECCS (specifically, the ADS and the GDCS) are designed to accomplish only one function; to cool the reactor core following a LOCA. To this extent, components or portions of these systems (except for the pressure relief function of SRVs) are not required for operation of other systems. Because the SRV opens either on ADS initiating signal or by spring-actuated pressure relief in response to an overpressure condition, no conflict exists.

6.3.3.6 Limits on ECCS Parameters

Subsections 6.3.3.1 and 6.3.3.7.1 and the tables referenced in those sections provide limits on ECCS parameters. Any number of components in any given system may be out of service, up to the entire system. The maximum allowable out-of-service time is a function of the level of redundancy and the specified test intervals.

6.3.3.7 ECCS Performance Analysis for LOCA

6.3.3.7.1 LOCA Analysis Procedures and Input Variables

For the system response analysis, the TRACG model was used. The input variables are based on nominal values. A conservative assumption made in the analysis is that all preferred power is lost simultaneously with the initiation of the LOCA. The significant input variables used for the response analysis are listed in Table 6.3-1. Figures 6.2-6 to 6.2-8 show the TRACG nodalization of the RPV, the containment, and the steam line system. Refer to Subsection 6.2.1.1.3.1 for the discussion of the TRACG nodalization.

6.3.3.7.2 Accident Description

The sequence of events for the 4 representative break locations are shown in Tables 6.3-7 through 6.3-10.

6.3.3.7.3 Break Spectrum Calculations

A representative set of cases was analyzed to evaluate the spectrum of postulated break sizes and locations to demonstrate ECCS system performance. A summary of results of these calculations is shown in Table 6.3-5 and graphically in Figure 6.3-6.

Conformance to the 10 CFR 50.46 acceptance criteria [PCT ≤ 1204°C (2200°F), local oxidation ≤ 17% and core-wide metal-water reaction ≤ 1%] is demonstrated for the fuel parameters listed in Table 6.3-1. Results for the limiting break for each bundle design in a plant will be supplied by the COL Holder (see Subsection 6.3.6). Details of calculations for specific breaks are included in subsequent paragraphs.

6.3.3.7.4 Large Line Breaks Inside Containment

Because the ESBWR design has no recirculation lines, the maximum DPV stub tube break, the maximum inside steam line break, the maximum feedwater line break, and the maximum RWCU/SDC suction line break are the largest area break locations. The total stub tube break flow includes back flow from the IC through the IC return line. Similarly, the total RWCU/SDC suction line break flow includes flow through the bottom head drain line. The maximum inside steam line break and the maximum feedwater line break were analyzed as representative cases for this group of breaks. Important output variables from these cases are shown in Table 6.3-5 and Figures 6.3-7 through 6.3-22.

The variables are:

- minimum critical power ratio (MCPR) as function of time;
- chimney water level as a function of time;
- downcomer water level as a function of time;
- system pressures as a function of time;
- steamline and break flow as a function of time;
- ADS flow as a function of time;
- flow into vessel as a function of time; and

- PCT as a function of time.

6.3.3.7.5 Intermediate Line Breaks Inside Containment

The only case in this group of breaks is the IC return line break. Since the ESBWR response to this LOCA event is rapid depressurization through the ADS valves, the results for this case are similar to the large steam line break case previously discussed.

6.3.3.7.6 Small Line Breaks Inside Containment

For these cases the GDCS injection line break and the bottom head drain line break were analyzed. Important variables from these analyses are shown in Table 6.3-5 and Figures 6.3-23 through 6.3-38.

6.3.3.7.7 Line Breaks Outside Containment

This group of breaks is characterized by a rapid isolation of the break. Because the isolation condenser system is part of the ECCS network, once the break is isolated the isolation condensers, High Pressure Control Rod Drive flow and/or the ADS/GDCS systems will control the vessel pressure and level thereby terminating the transient.

6.3.3.7.8 Summary of ECCS-LOCA Performance Analysis Results

From the results presented in the above subsections it is concluded that for the ESBWR there is no core uncovery or heatup for any design basis LOCA. Also, the system response to both large and small break LOCAs is similar, i.e., rapid vessel depressurization followed by GDCS injection to maintain the vessel water level. Thus the key LOCA result of minimum chimney static head above vessel zero is similar for all LOCA events (see Table 6.3-5). The results for maximum GDCS injection line break with 1 GDCS valve failure and maximum inside steam line break with 1 DPV failure are slightly more limiting than the other LOCA cases.

The results of the limiting case for each bundle design will be provided by the COL Holder to the USNRC for information.

6.3.3.7.9 Bounding LOCA Evaluations

Consistent with previous LOCA model application methodology, LOCA evaluations in the previous sections are compared to a bounding result. Table 6.3-11 presents the significant plant variables that were considered in the determination of the bounding LOCA result. Because the ESBWR LOCA results have large margins to the acceptance criteria, a conservative LOCA evaluation was performed which bounds the 95% probability LOCA results. This bounding LOCA result was calculated by varying all significant plant parameters in the conservative direction simultaneously. The maximum inside steam line break cases (refer to Subsection 6.3.3.7.8) and the GDCS injection line break (the most limiting break location, refer to Table 6.3-5) were evaluated. The results of these calculations are given in Table 6.3-5. The GDCS injection line break with a GDCS injection valve failure results in the lowest minimum chimney static head level above vessel zero. Because the ESBWR results have large margins to the 10 CFR 50.46 licensing acceptance criteria, the ESBWR licensing LOCA results can be based on this bounding LOCA case.

6.3.3.8 ECCS-LOCA Performance Analysis Conclusions

The ECCS-LOCA perforemance analyses are performed according to the key parameters listed in Table 6.3-11. Results of these analyses demonstrate the compliance with all the applicable acceptance criteria. It is concluded that the ECCS would perform its function in an acceptable manner.

6.3.4 ECCS Performance Tests

All systems of the ECCS are tested for their operational ECCS function during the preoperational and/or startup test program. As applicable, each component is tested for power source, range, setpoint, limit switch setting, torque switch setting, etc. Subsection 6.3.2.7.4 contains additional details on GDCS testing, and Subsection 6.3.2.8.4 contains additional details on ADS testing. See Chapter 14 for a thorough discussion of preoperational testing for these systems.

6.3.4.1 Reliability Tests and Inspections

The average reliability of a standby (non-operating) safety system is a function of the duration of the interval between periodic functional tests. The factors considered in determining the periodic test interval of the ECCS are:

- The desired system availability (average reliability);
- The number of redundant functional system success paths;
- The failure rates of the individual components in the system; and
- The schedule of periodic tests (simultaneous versus uniformly staggered versus randomly staggered)

All ECCS safety-related valves are tested during plant initial power ascension per Regulatory Guide 1.68, Appendix A, except that the mechanical components of the ECCS squib type valves will be fully tested by the manufacturer prior to delivery to the site.

Logic system functional test and simulated automatic operation of all ADS logic channels are to be performed at least once per plant operating interval between reactor refuelings. Instrumentation channels are demonstrated operable by the performance of a channel functional test and a trip unit calibration at least once per month and a transmitter calibration at least once per operating interval.

All SRVs, which include those used for ADS, and DPVs are bench tested to establish lift settings in compliance with ASME Code Section XI.

Testing of the initiating instrumentation and controls portion of the ECCS is discussed in Subsection 7.3.1. The emergency power system, which supplies electrical power to the ECCS is tested as described in Subsection 8.3.1. The frequency of testing is specified in the plant-specific Technical Specifications. Components inside the drywell can be visually inspected only during periods of access to the drywell.

6.3.5 Instrumentation Requirements

Design details including redundancy and logic of the ECCS instrumentation are discussed in Section 7.3.

All instrumentation required for automatic and manual initiation of the GDCS and ADS is discussed in Subsection 7.3.1, and is designed to meet the requirements of IEEE-279 and other applicable regulatory requirements. The GDCS and ADS can be manually initiated from the control room.

The ECCS initiating signals are shown in Table 6.3-1.

6.3.6 COL Information

6.3.6.1 ECCS Performance Results

The initial core specific peak cladding temperature and oxidation fraction for each fuel bundle design, based on the limiting break size will be provided by the COL Holder to the USNRC for information as per section 6.3.3.2.

6.3.6.2 ECCS Testing Requirements

In accordance with the plant-specific Technical Specifications, the COL Holder will perform a test every refueling in which each ECCS subsystem is actuated through the emergency operating sequence.

6.3.6.3 Limiting Break Results

For the initial core, the results for the limiting break for each bundle design as per Subsection 6.3.3.7 will be provided to the USNRC by the COL Holder.

6.3.7 References

6.3-1 GE Nuclear Energy, “Depressurization Valve Development Test Program Final Report,” GEFR-00879, October 1990.

6.3-2 GE Nuclear Energy, “TRACG Application for ESBWR,” NEDC-33083P-A, Class III (Proprietary), March 2005 and NEDO-33083-A, Class I (non-proprietary), October 2005.

Table 6.3-1

Significant Input Variables to the ECCS-LOCA Performance Analysis

A. Plant Parameters		
Variable	**Units**	**Value**
Core thermal Power	MWt	4500
Vessel Steam Output	kg/hr [lbm/hr]	8.76×10^6 [19.31×10^6]
Vessel Steam Dome Pressure	MPa (absolute) [psia]	7.17 [1040]
Scram Initiating Signal	---	Loss of power to two feedwater pump buses
Maximum Sensor Response Time	sec	2
B. Emergency Core Cooling System Parameters		
B.1 ECCS Initiation Signal		
Variable	**Units**	**Value**
Initiating Signal:Level 1	meters (above TAF) [ft] (above TAF)	4.05 [13.28]
Maximum Allowable Time Delay to Confirm ECCS-LOCA Signal	sec	10
B.2 Gravity-Driven Core Cooling System		
Variable	**Units**	**Value**
Initiating Signal	—	ECCS-LOCA confirmed initiating signal (See B.1)
GDCS Injection valve timer delay	sec	150

Table 6.3-1

Significant Input Variables to the ECCS-LOCA Performance Analysis

Minimum drainable inventory per GDCS pool		See Table 6.3-2
Minimum elevation of GDCS pool surfaces above the RPV nozzles		See Table 6.3-2
GDCS drain line loss coefficient (k/A2)	$1/m^4$ [$1/ft^4$]	$12.587*10^3$ [$1.458*10^6$]
B.3 Isolation Condenser System		
Variable	**Units**	**Value**
Initiating Signal	—	Loss of feedwater
Maximum Sensor Response Time	sec	2
Heat Removal Capacity per Unit	MW	33.75
Minimum Drainable Liquid Volume per System	m^3 [ft^3]	13.88 [490.1]
B.4 Standby Liquid Control System		
Variable	**Units**	**Value**
Initiating Signal	—	DPV actuation (See B.5)
Liquid Volume per Tank	m3 [ft3]	7.8 [275.4]
B.5 Automatic Depressurization Subsystem		
Variable	**Units**	**Value**
Initiating Signal	—	ECCS-LOCA confirmed initiating signal (See B.1)

Table 6.3-1

Significant Input Variables to the ECCS-LOCA Performance Analysis

Valve Actuation Sequence:		
5 ADS	sec	0
5 ADS	sec	10
3 DPVs	sec	50
2 DPVs	sec	100
2 DPVs	sec	150
1 DPVs	sec	200
Total Number of Safety Relief Valves With ADS Function	—	10
Total Min. ADS Flow Capacity at Vessel Pressure	kg/hr MPa (gauge) [lbm/hr] [psig]	4.356×10^6 8.618 [9.61×10^6] [1250]
Total Number of Depressurization Valves	—	8
Total min. DPV flow capacity at vessel pressure	kg/hr MPa (gauge) [lbm/hr] [psig]	6.89×10^6 7.481 [15.2×10^6] [1085]
Total max. DPV flow capacity at vessel pressure	kg/hr MPa (gage) [lbm/hr] [psig]	8.47×10^6 7.481 [18.7×10^6] [1085]

Table 6.3-1

Significant Input Variables to the ECCS-LOCA Performance Analysis

C. Fuel Parameters *		
Variable	**Units**	**Value**
Fuel type	—	See Chapter 4
Peak Linear Heat Generation Rate (Bounding))	kW/m [kW/ft]	44 [13.4]
Initial Minimum Critical Power Ratio (Bounding)	—	1.12

Table 6.3-2

GDCS Design Basis Parameters

Parameter	Value
Number of separate/independent GDCS divisions	4
Per division, number of (short-term core cooling injection) lines from its GDCS pool	1
Per division, number of injection line RPV nozzles	2
Per division, number of equalizing line RPV nozzles	1
Total inventory (for 3 GDCS pools) at GDCS pool low water level	1830 m^3 (64626 ft^3)
Minimum total drainable inventory (for 3 GDCS pools) at GDCS pool low water level of 6.5 meters	1746 m^3 (61659 ft^3)
Minimum elevation of GDCS pool surfaces above the RPV nozzles, at GDCS pool low water level	13.5 m (44.3 ft)
Minimum long-term core cooling flow delivered by the GDCS equalizing lines for a minimum ΔP of 9.12 kPa (1.32 psid) across the equalizing lines	22.7 m^3/hr (100 gpm)
Minimum flow through the deluge lines required to flood the lower drywell region	70 kg/sec (154 lb/sec)*
Minimum available suppression pool water inventory 1 meter above TAF with 1.0 m of equalizing line driving head	799 m^3 (28216 ft^3)
Minimum GDCS equalizing line driving head	1.0 m (3.3 ft)

* Core melt scenario instead of ECCS performance evaluation scenarios.

Table 6.3-3

GDCS Surveillance Testing

Component	Type of Test	Component to be aligned
Check Valves	Functional tests: flushing the line from dedicated test connection	Opening of test line isolation valves
Squib Valve Initiators	Explosive tests	Each initiator is tested in laboratory after replacement
Flushing of injection line to remove any possible plugging	Flushing during refueling outage	Alignment of test connection lines
Venturi within GDCS-RPV injection nozzles	Flushing during refueling outage	Alignment of test connection lines
Deluge Line Flushing	Flushing lines from dedicated connection to prevent crud build up during refueling outage	Alignment of flushing connection lines

Table 6.3-4

DPV Design and Performance Parameters

Parameter	Value/Description
Inlet side design pressure	10.34 MPa gauge (1500 psig) at a design temperature of 313°C (595°F)
Outlet-side design pressure	4.97 MPa gauge (720 psig) at a design temperature of 264°C (508°F)
Material of valve bodies	See Table 5.2-4
Design life	60 yrs
Design operating fluid conditions	Saturated steam flow ranging from 95% quality to 2.8°C (5°F) superheat
Rated flow capacity of each DPV (based on dry saturated steam conditions and a flow-induced backpressure of up to 50% of the inlet pressure)	Between 8.62×10^5 and 1.06×10^6 kg/hr (1.90×10^6 to 2.33×10^6 lbm/hr) at an inlet pressure of 7.48 MPa gauge (1085 psig)
Specified response times (opening time to full rated capacity) of the DPVs, with a static backpressure of up to 50% of the inlet pressure	• 0.45 second or less with an inlet pressure of 6.89 MPa gauge (1000 psig) or greater • 5 seconds or less with an inlet pressure between 6.89 MPa gauge (1000 psig) and 0.69 MPa gauge (100 psig). • 30 seconds or less with an inlet pressure below 0.69 MPa gauge (100 psig).

Table 6.3-5

Summary of ECCS-LOCA Performance Analyses

Break Location	Break Size+ m^2 (ft^2)	Minimum Chimney Static Head* Level Above Vessel Zero Per Active Single Failure m (ft)			PCT **	Maximum Local and Core Wide Oxidations (%) ***	Minimum Downcomer Collapsed Water Level Above Vessel Zero Per Active Single Failure m (ft)			Change in MCPR From Start of Event	Change in RPV Press. From Start of Event
		1 SRV	1 GDCS	1 DPV			1 SRV	1 GDCS	1 DPV		
Based on standard TRACG evaluation model:											
Steam Line Inside Containment	0.09832 (1.058)	9.00 (29.53)	9.15 (30.02)	8.90 (29.20)	No heatup	<1.0	7.66 (25.13)	7.85 (25.75)	7.68 (25.20)	Increases	Decreases
Feedwater Line++	0.07420 (0.7986)	9.48 (31.10)	9.48 (31.10)	9.34 (30.64)	No heatup	<1.0	8.41 (27.59)	8.29 (27.20)	8.39 (27.53)	Increases	Decreases
GDCS Injection Line	0.004561 (0.04910)	9.24 (30.31)	9.08 (29.77)	9.34 (30.64)	No heatup	<1.0	6.30 (20.68)	6.47 (21.24)	6.43 (21.11)	Increases	Decreases
Bottom Head Drain Line	0.004052 (0.04361)	9.45 (31.00)	9.30 (30.52)	9.46 (31.02)	No heatup	<1.0	6.87 (22.53)	6.80 (22.32)	6.71 (22.01)	Increases	Decreases
Based on bounding values:											
Steam Line Inside Containment	0.09832 (1.058)	9.49 (31.14)	9.37 (30.74)	9.31 (30.54)	No heatup	<1.0	7.25 (23.79)	7.11 (23.33)	7.16 (23.49)	Increases	Decreases
GDCS Injection Line	0.004561 (0.04910)	8.81 (28.89)	8.61 (28.25)	8.94 (29.34)	No heatup	<1.0	5.70 (18.70)	5.78 (18.96)	5.69 (18.67)	Increases	Decreases

+ The break area is from the RPV side of the break.

++ For the feedwater line break, the total break area from the turbine building side is limited at the two parallel ventrui sections, with flow area of 0.04997 m^2 each.

* Chimney static head is calculated by adding the static head in the chimney to the elevation of bottom of chimney.

** No break results in core uncovery, and thus, there is no cladding heatup and PCT remains < 316°C (600°F).

*** Maximum local oxidation values are provided. The local oxidation values are calculated using TRACG. This results in a fraction of total cladding volume of fueled rods and water rods of <1.0%. The core-wide metal-water reaction is also <0.1%.

Table 6.3-6

Single Failure Evaluation

Assumed Failure*	Systems Remaining**
One Depressurization Valve	10 SRVs, 7 DPVs, 4 ICs***, 2 SLC system and 4 GDCS with 8 Injection Lines
One Safety/Relief Valve	9 SRVs, 8 DPVs, 4 ICs***, 2 SLC system and 4 GDCS with 8 Injection Lines
One GDCS Injection Valve	10 SRVs, 8 DPVs, 4 ICs***, 2 SLC system and 4 GDCS with 7 Injection Lines

* Single, active failures are considered in the ECCS performance analysis. Other postulated failures are not specifically considered, because they all result in at least as much ECCS capacity as one of the above failures.

** Systems remaining, as identified in the table, are applicable to all non-ECCS line breaks. For the LOCA from an ECCS line break, the systems remaining are those listed, less the specific ECCS in which the break is assumed.

*** A sensitivity study was performed to determine the impact of assuming only 3 ICs available at the start of the LOCA event. The results of this studied showed that the minimum water levels identified in Table 6.3-5 and Figure 6.3-6 would be affected by <10cm. Because a change of this magnitude is minimal compared to the level margins above the top of the active fuel identified in Figure 6.3-6, it is concluded that the assumption of only 3 ICs available for the ECCS-LOCA performance analysis would not invalidate the ECCS-LOCA performance analysis results presented in Section 6.3.3.

Table 6.3-7

Operational Sequence of ECCS For A Feedwater Line Break with Failure of One GDCS Injection Valve (Nominal Calculation)

Time (sec)	**Events**
0	Guillotine break of Feedwater line inside containment; normal auxiliary power assumed to be lost; Feedwater tripped.
~ 1	High Drywell pressure setpoint reached; Scram signal not credited in this analysis.
2	Loss of normal auxiliary power confirmed; reactor scram initiated; rod insertion started at 0.25 second later.
	Main Vent Clearing, 1.94 sec. (Top), 2.34 sec. (Mid) and 3.00 sec. (Bottom)
3	IC initiated, drain valves started to open at 15 seconds later.
5	Level 3 is reached (no additional trip credited in this analysis).
13	Level 2 is reached (no additional trip credited in this analysis).
14	Low main steamline pressure setpoint reached; MSIV closure initiated in 0.7 second later.
18	Reactor is isolated on low MSL pressure set point.
314	Level 1 is reached.
324	Level 1 confirmed; ADS/GDCS/SLC timer initiated; SRV actuation begins.
375	DPV actuation begins; SLC flow starts.
474	GDCS timer runs out; GDCS injection valves open.
524	Vessel pressure decreases below the maximum injection pressure of GDCS. GDCS flow into the vessel begins.
564	Minimum chimney water level (9.48 m) is reached.
675	SLC flow depleted.
From 600 to 2000	RPV water level remains higher than Level 0.5. Therefore, equalizing line valves are not expected to open.

Table 6.3-8

Operational Sequence of ECCS For a Main Steam Line Break with Failure of One GDCS Injection Valve (Nominal Calculation)

Time (sec)	**Events**
0	Guillotine break of main steam line inside containment; normal auxiliary power assumed to be lost; Feedwater tripped.
~ 1	High Drywell pressure setpoint reached, Scram signal not credited in this analysis.
2	Loss of normal auxiliary power confirmed; reactor scram initiated; rod insertion started at 0.25 second later.
	Main Vent Clearing, 1.74 sec. (Top), 2.14 sec. (Mid) and 2.83 sec. (Bottom)
3	IC initiated, drain valves started to open at 15 seconds later.
7	Low main steamline pressure setpoint reached; MSIV closure initiated at 0.7 second later.
8	Level 3 is reached (no additional trip credited in this analysis).
11	Reactor is isolated on low MSL pressure set point.
18	Level 2 is reached (no additional trip credited in this analysis).
487	Level 1 is reached.
497	Level 1 signal confirmed; ADS/GDCS/SLC timer initiated; SRV actuated.
548	DPV actuation begins; SLC flow starts.
647	GDCS timer timed out; GDCS injection valves open.
647	Vessel pressure is below the maximum injection pressure of GDCS. GDCS flow into the vessel begins.
848	SLC flow depleted.
1050	Minimum chimney water level (9.15 m) is reached.

From 800 to 2000	RPV water level remains higher than Level 0.5. Therefore, equalizing line valves are not expected to open.

Table 6.3-9

Operational Sequence of ECCS For a GDCS Line Break with Failure of One GDCS Injection Valve (Nominal Calculation)

Time (sec)	**Events**
0	Guillotine break of GDCS Injection line inside containment; normal auxiliary power assumed to be lost; Feedwater tripped.
2	Loss of normal auxiliary power confirmed; reactor scram initiated; rod insertion started at 0.25 second later.
3	IC initiated, drain valves started to open at 15 seconds later.
4	High drywell pressure setpoint reached; Scram signal not credited in this analysis.
6	Level 3 is reached (no additional trip credited in this analysis).
13	Main Vent Clearing, 13.19 sec. (Top), 231.5 sec. (Middle) and no vent clearing (Bottom)
15	Level 2 is reached; MSIV closure to be initiated at 30 seconds later.
17	Low main steamline pressure setpoint reached; MSIV closure initiated in 0.7 second later.
21	Reactor is isolated on low MSL pressure set point
168	Level 1 is reached.
178	Level 1 signal confirmed; SRV actuation begins; ADS/GDCS/SLC timer initiated.
228	DPV actuation begins; SLC flow starts.
328	GDCS timer timed out; GDCS injection valves open.
446	Vessel pressure decreases below maximum injection pressure of GDCS. GDCS flow into the vessel begins.
526	SLC flow depleted.
539	Minimum chimney water level (9.08 m) is reached.

From 900 to 2000	RPV water level remains higher than Level 0.5. Therefore equalizing line valves are not expected to open for this event.

Table 6.3-10

Operational Sequence of ECCS For a Bottom Drain Line Break with Failure of One GDCS Injection Valve (Nominal Calculation)

Time (sec)	**Events**
0	Guillotine break of GDCS Injection line inside containment; normal auxiliary power assumed to be lost; Feedwater tripped.
2	Loss of normal auxiliary power confirmed; reactor scram initiated; rod insertion started at 0.25 second later.
3	IC initiated, drain valves started to open at 15 seconds later.
6	High drywell pressure setpoint reached; Scram signal not credited in this analysis.
6	Level 3 is reached (no additional trip credited in this analysis).
13	Main Vent Clearing, 12.94 sec. (Top), 343. 9 sec. (Middle) and no vent clearing (Bottom)
15	Level 2 is reached; MSIV closure to be initiated at 30 seconds later.
17	Low main steamline pressure setpoint reached; MSIV closure initiated in 0.7 second later.
21	Reactor is isolated on low MSL pressure set point
280	Level 1 is reached.
290	Level 1 signal confirmed; SRV actuation begins; ADS/GDCS/SLC timer initiated.
340	DPV actuation begins; SLC flow starts.
440	GDCS timer timed out; GDCS injection valves open.
573	Vessel pressure decreases below maximum injection pressure of GDCS. GDCS flow into the vessel begins.
641	SLC flow depleted.

1221	Minimum chimney water level (9.3 m) is reached.
From 900 to 2000	RPV water level remains higher than Level 0.5. Therefore equalizing line valves are not expected to open for this event.

Table 6.3-11

Plant Variables with Nominal and Bounding Calculation Values

Plant Variable	Nominal Value	Bounding Calculation Value*
1. Vessel Steam Dome Pressure	7.17 MPa (1040 psia)	7.274 MPa (1055 psia)
2. Decay Heat	1979 ANS (Figure 6.3-39)	+ 2σ
3. Core Power	Rated	+ 2%
4. PLHGR	44.0 kW/m (13.4 kW/ft)	44.8 kW/m (13.7 kW/ft)
5. Initial MCPR	1.12	1.10
6. Initial Downcomer Level	NWL	NWL – 0.3m
7. Significant TRACG Modeling Parameters**	Nominal	Bounding

* Represents upper 95% or higher probability value.

** Reference 6.3-2, Table 2.5-2.

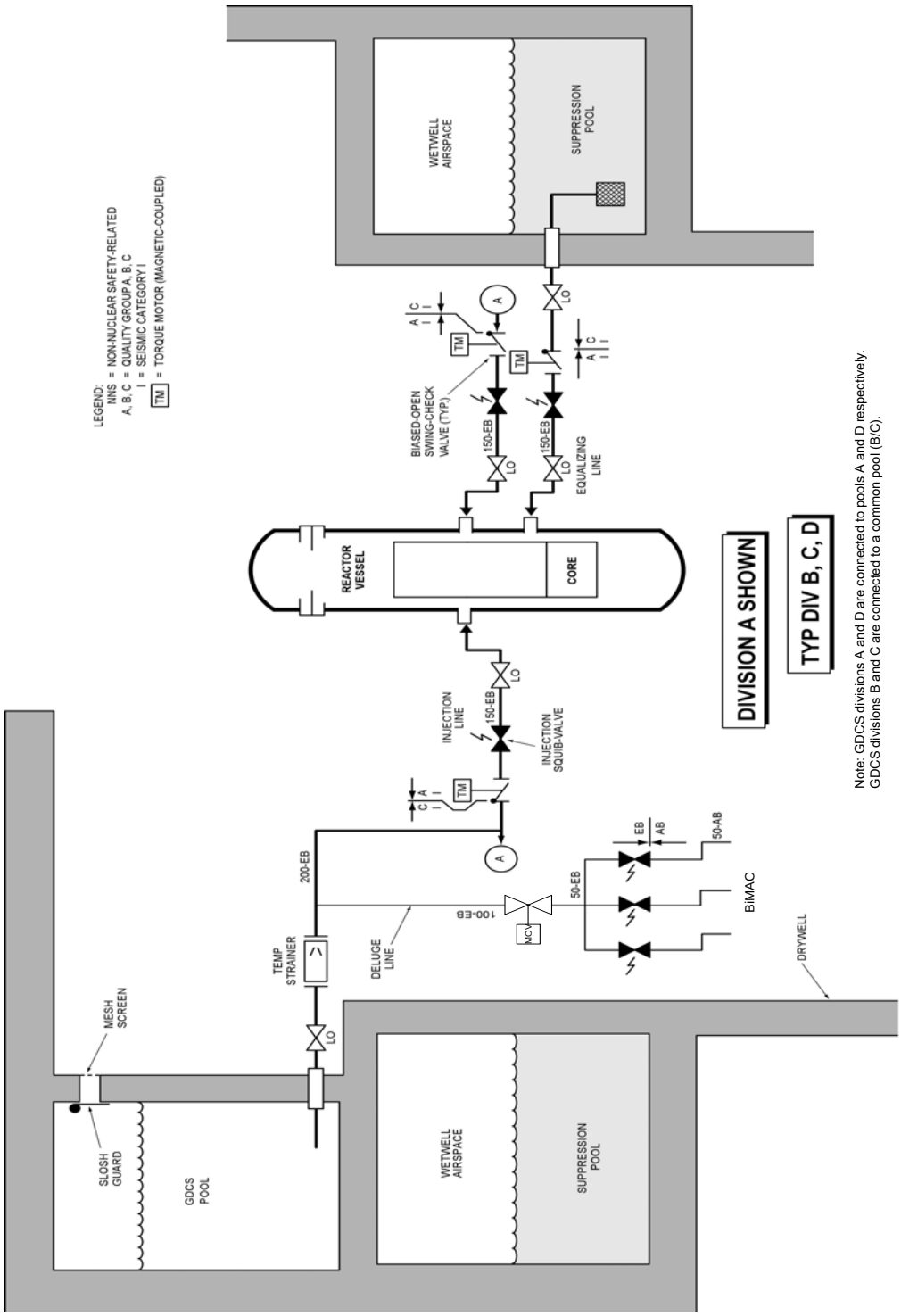

Figure 6.3-1. GDCS Configuration

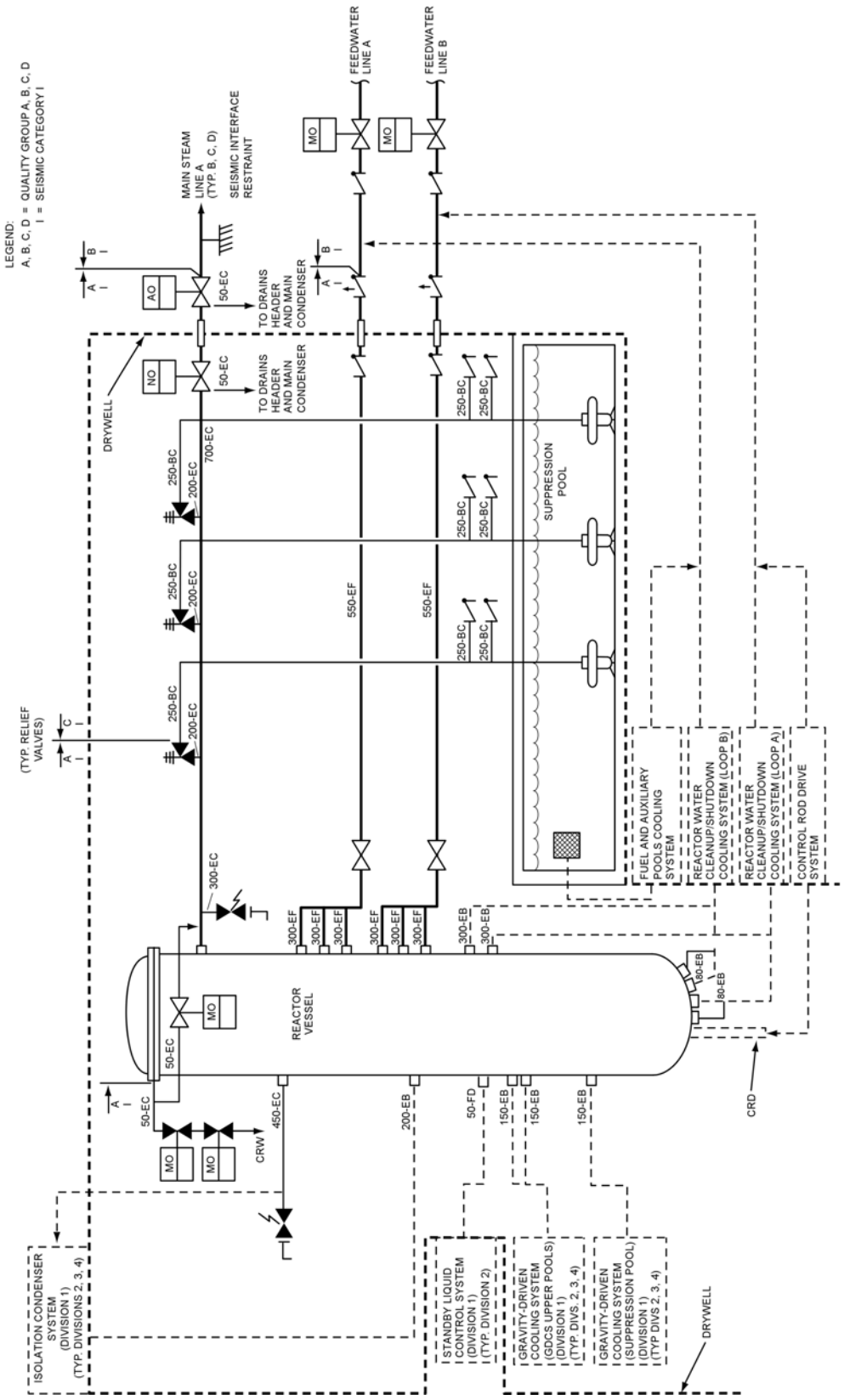

Figure 6.3-4. ADS Component Schematic Diagram

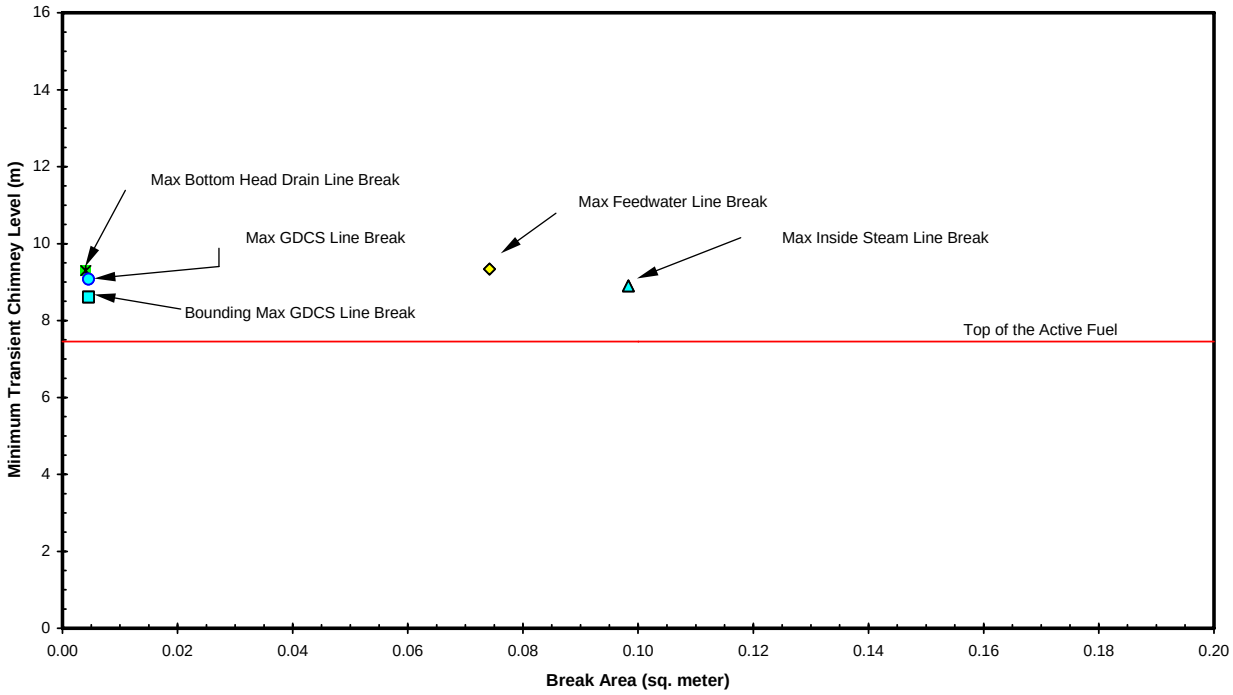

Figure 6.3-6. Minimum Transient Chimney Water Level vs. Break Area

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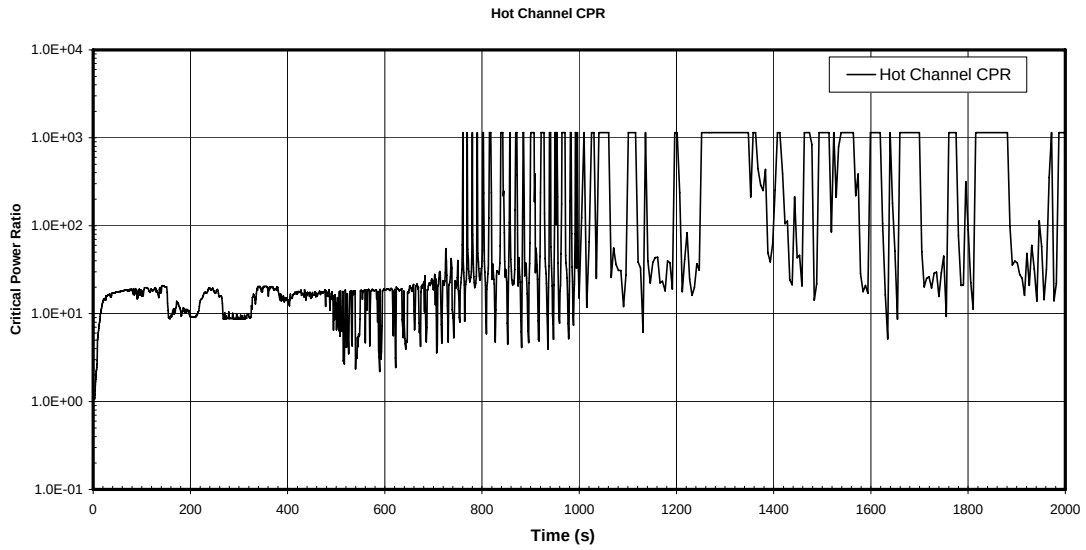

Figure 6.3-7a. MCPR, Feedwater Line Break, 1 GDCS Valve Failure

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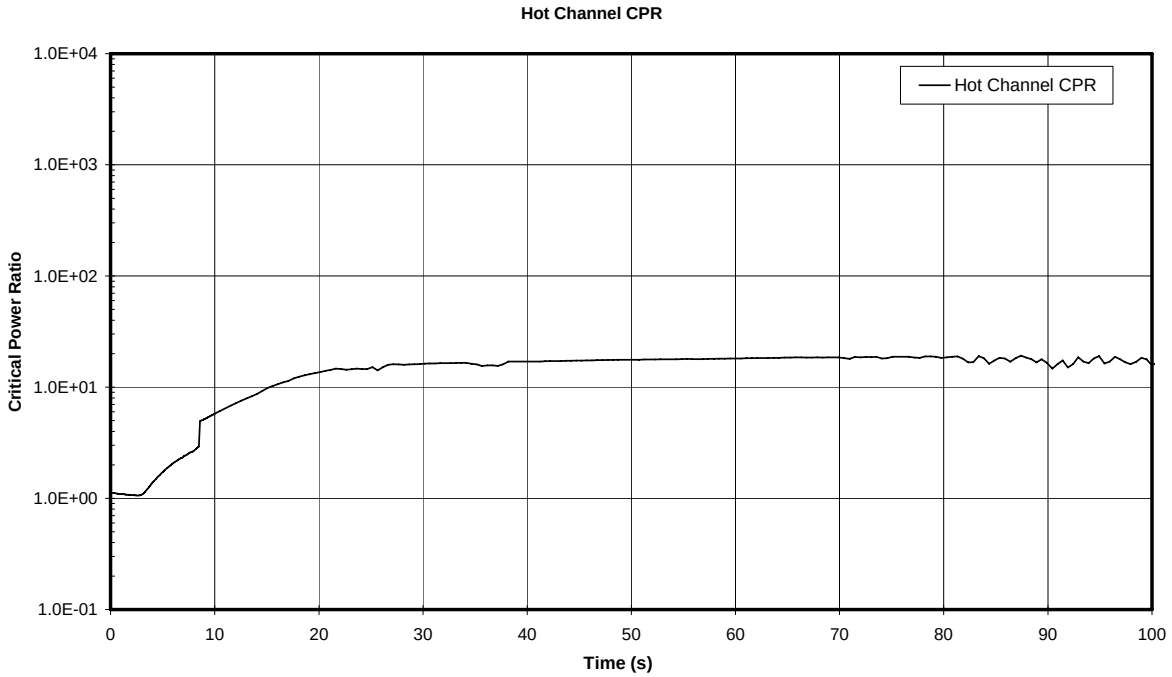

Figure 6.3-7b. MCPR, Feedwater Line Break, 1 GDCS Valve Failure

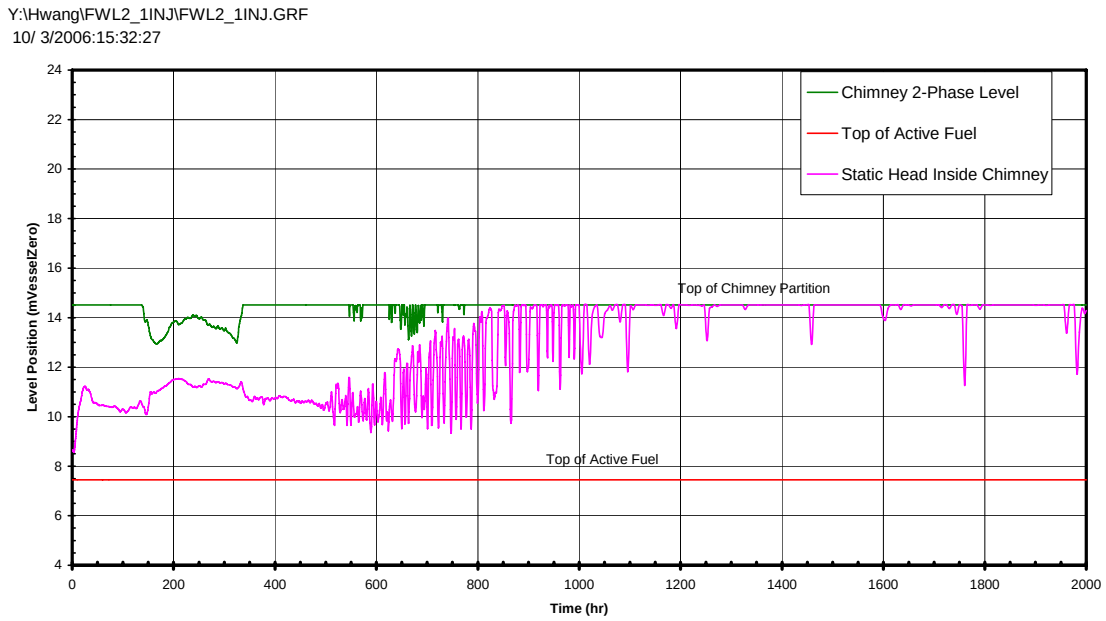

Figure 6.3-8a. Chimney Water Level, Feedwater Line Break, 1 GDCS Valve Failure

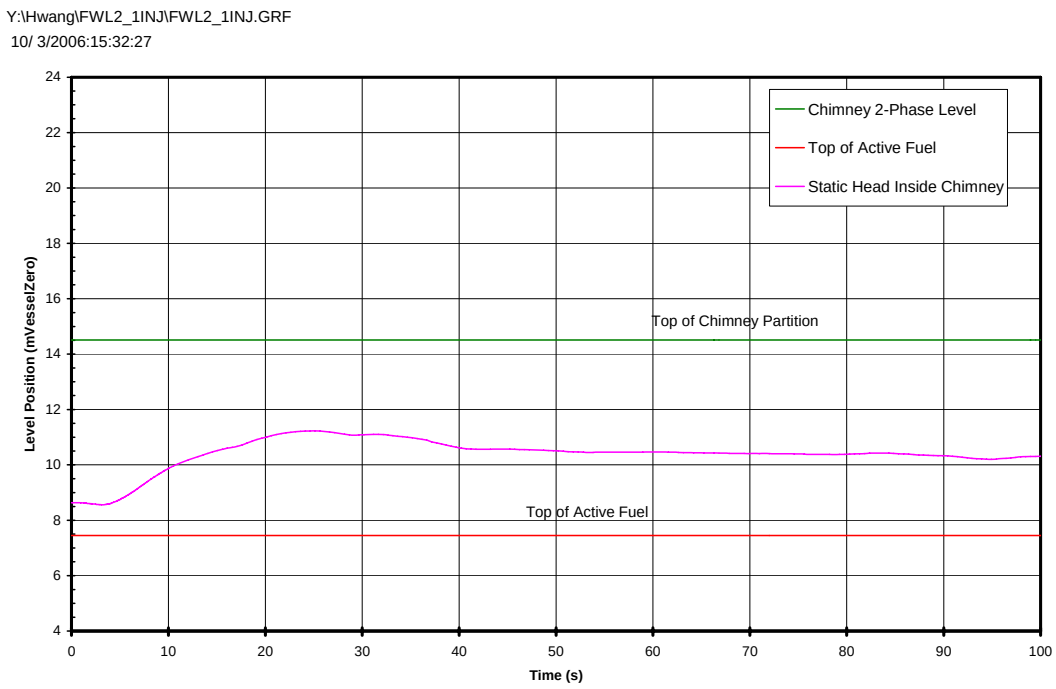

Figure 6.3-8b. Chimney Water Level, Feedwater Line Break, 1 GDCS Valve Failure

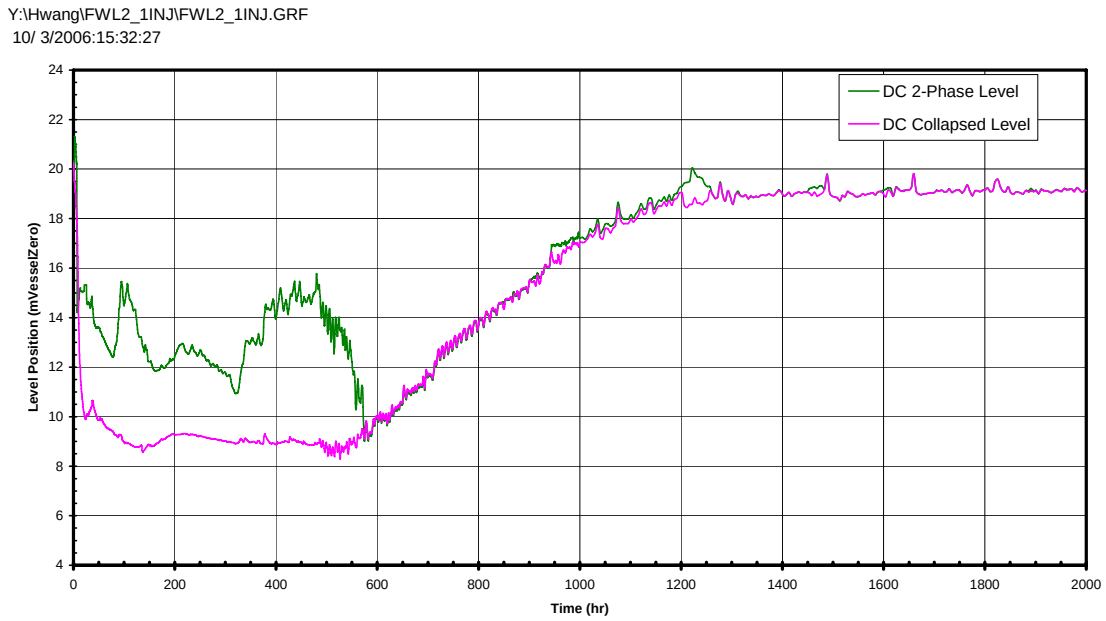

Figure 6.3-9a. Downcomer Water Level, Feedwater Line Break, 1 GDCS Valve Failure

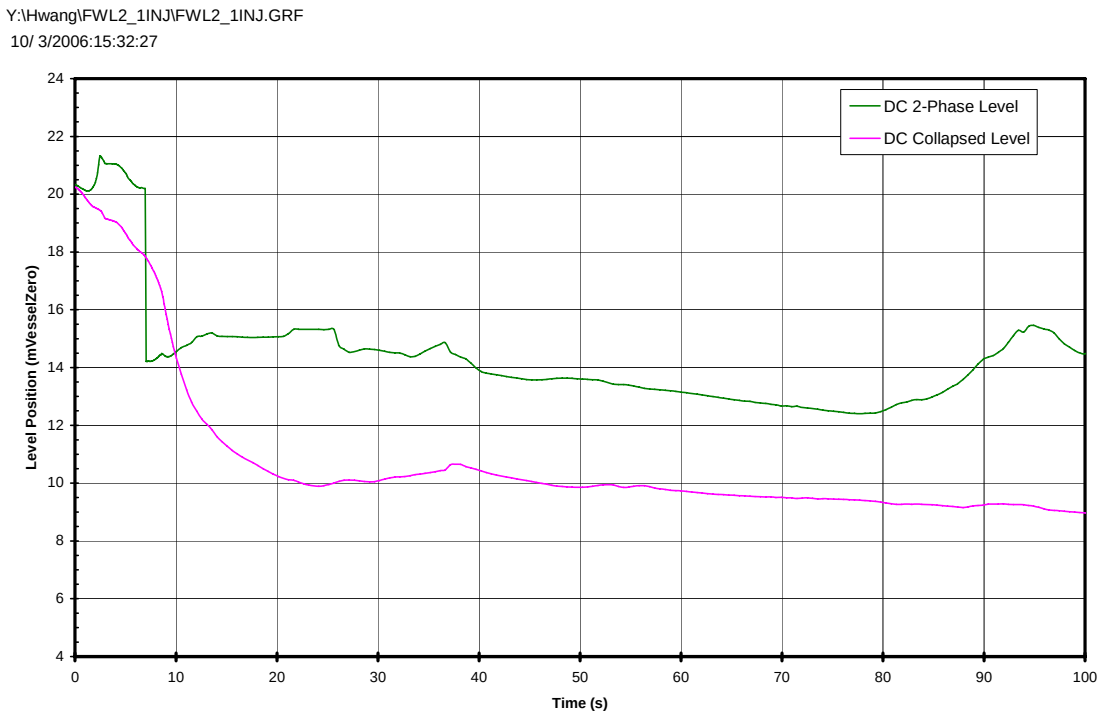

Figure 6.3-9b. Downcomer Water Level, Feedwater Line Break, 1 GDCS Valve Failure

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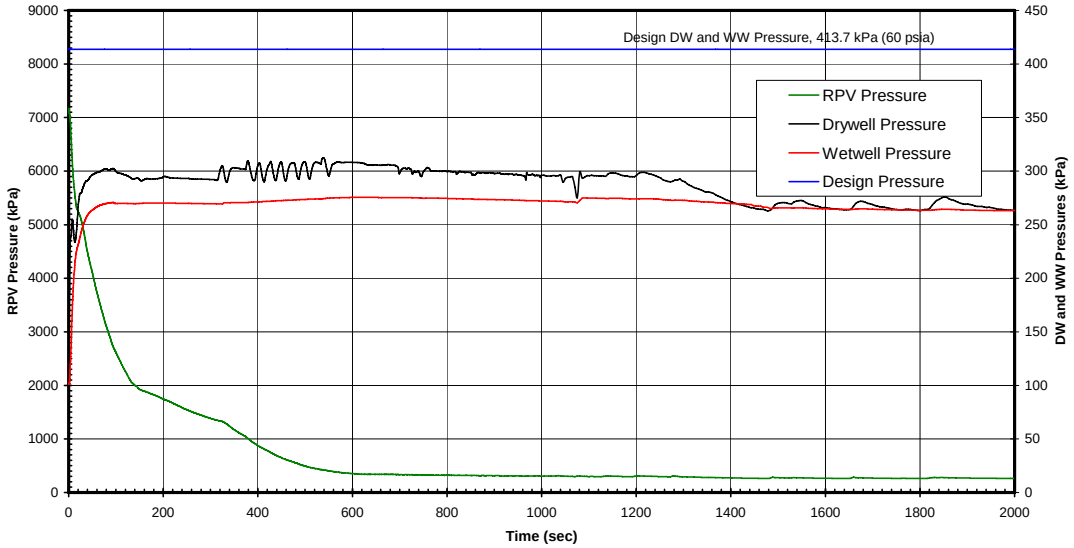

Figure 6.3-10a. System Pressures, Feedwater Line Break, 1 GDCS Valve Failure

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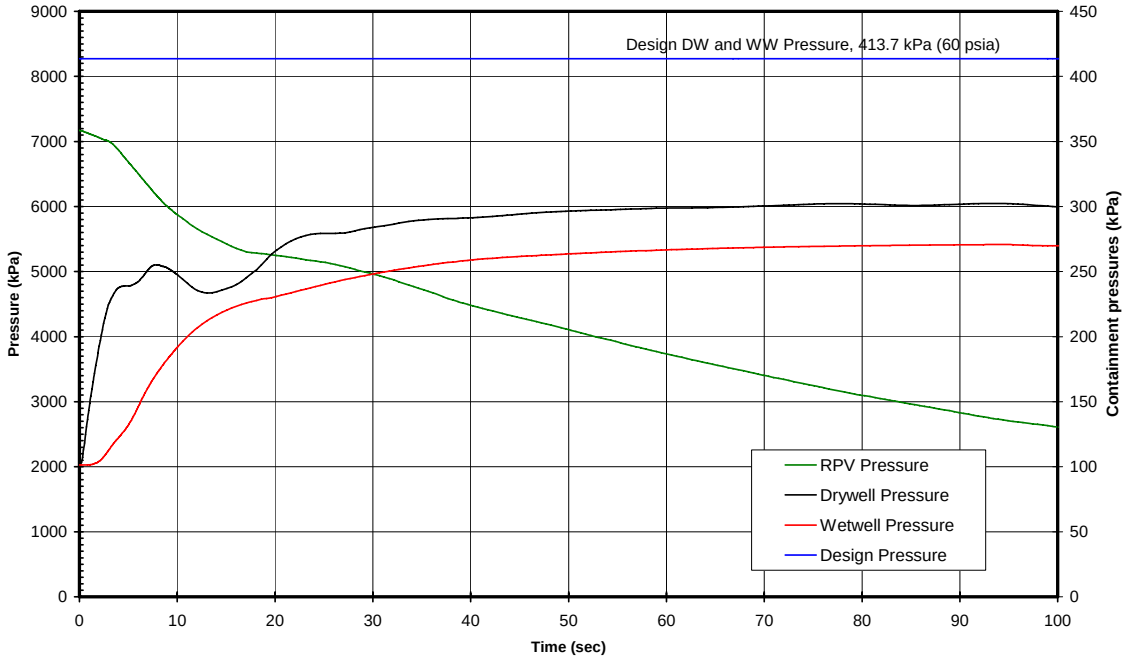

Figure 6.3-10b. System Pressures, Feedwater Line Break, 1 GDCS Valve Failure

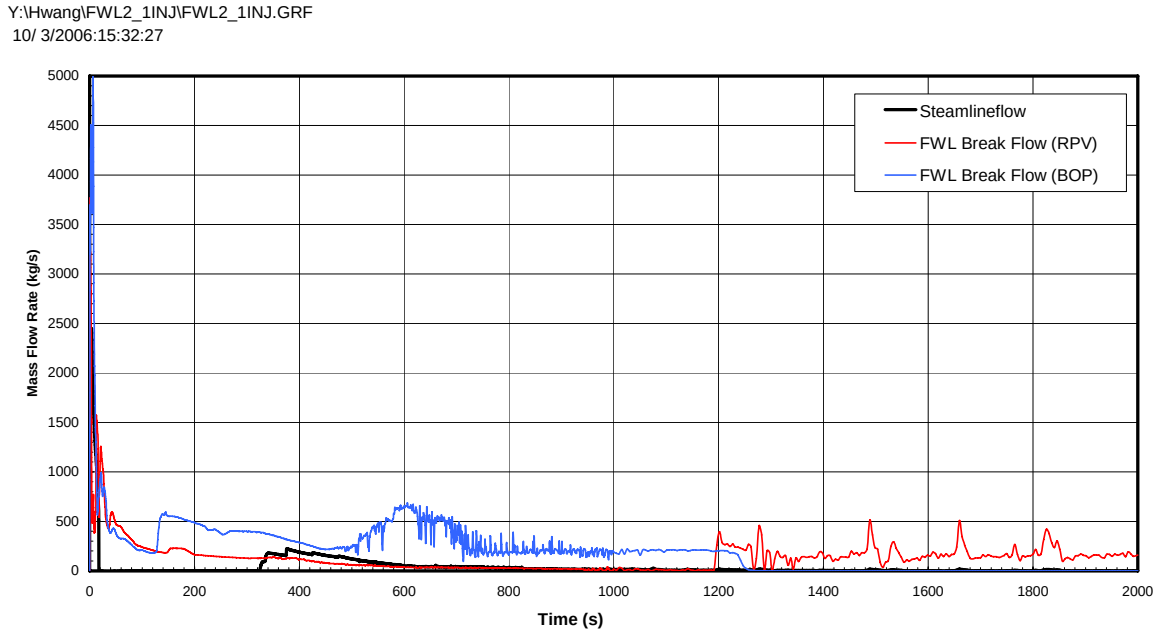

Figure 6.3-11a. Steam Line and Break Flow, Feedwater Line Break, 1 GDCS Valve Failure

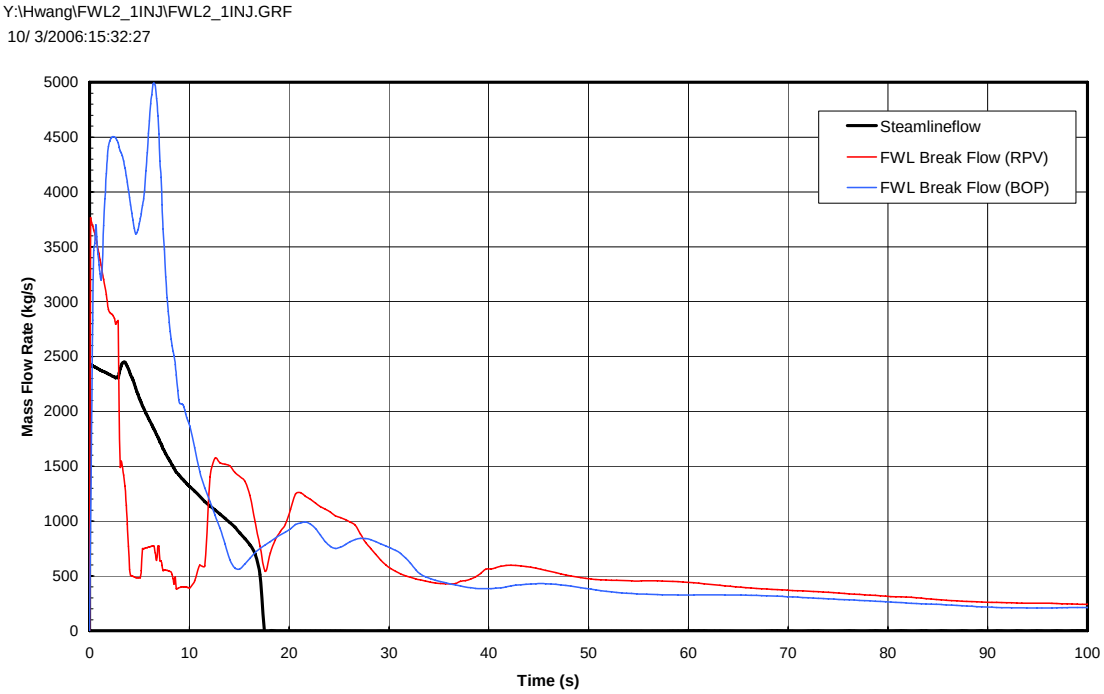

Figure 6.3-11b. Steam Line and Break Flows, Feedwater Line Break, 1 GDCS Valve Failure

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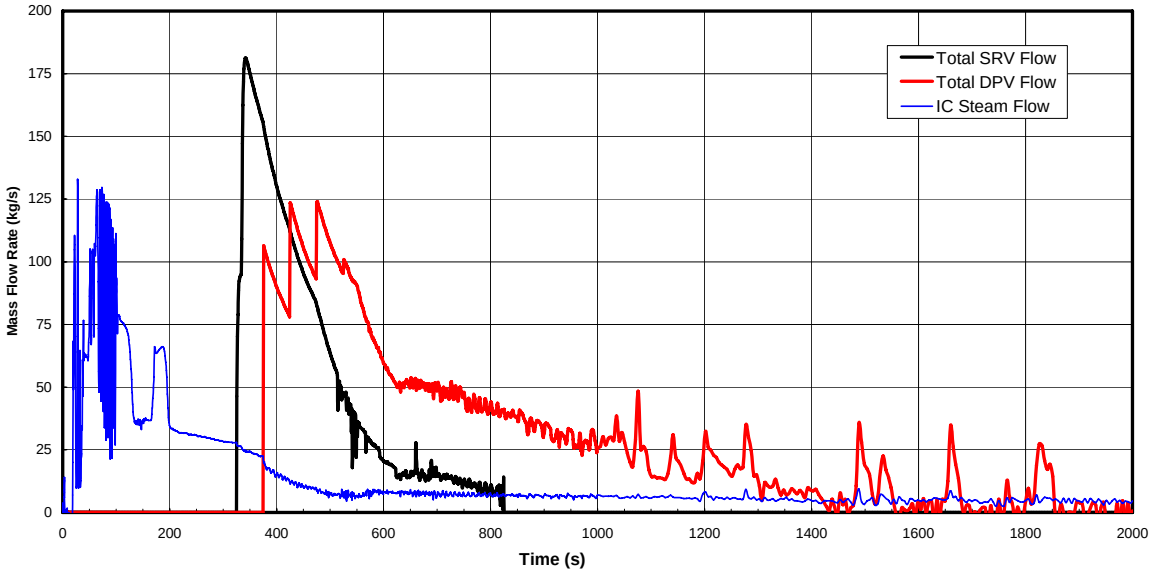

Figure 6.3-12a. ADS Flow, Feedwater Line Break, 1 GDCS Valve Failure

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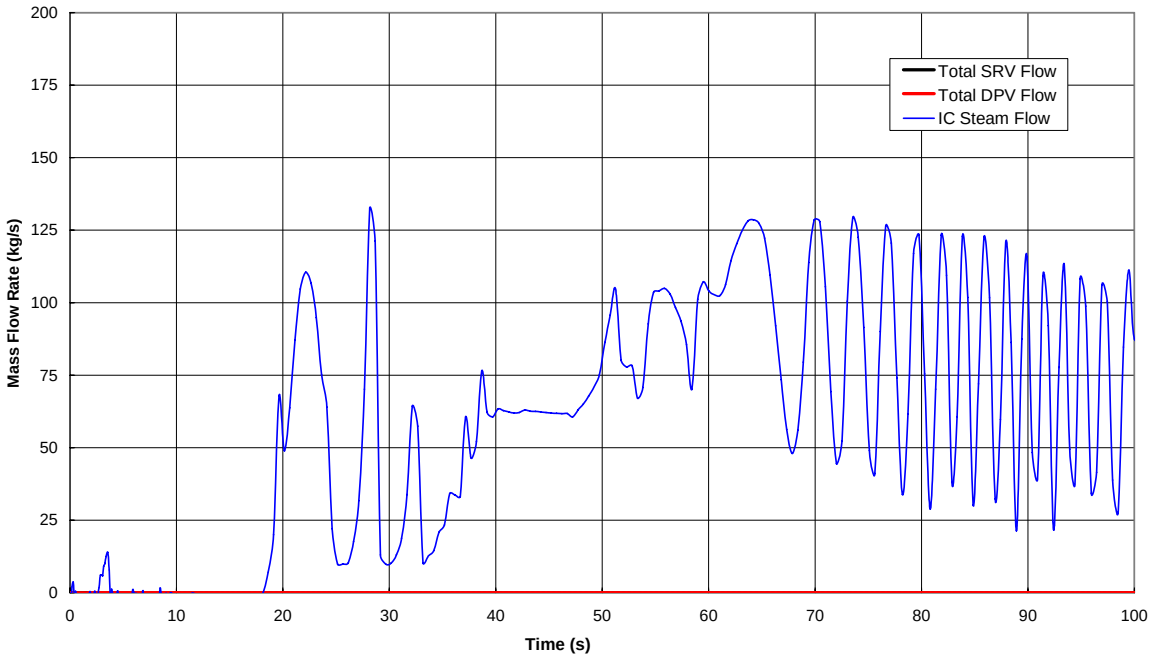

Figure 6.3-12b. ADS Flows, Feedwater Line Break, 1 GDCS Valve Failure

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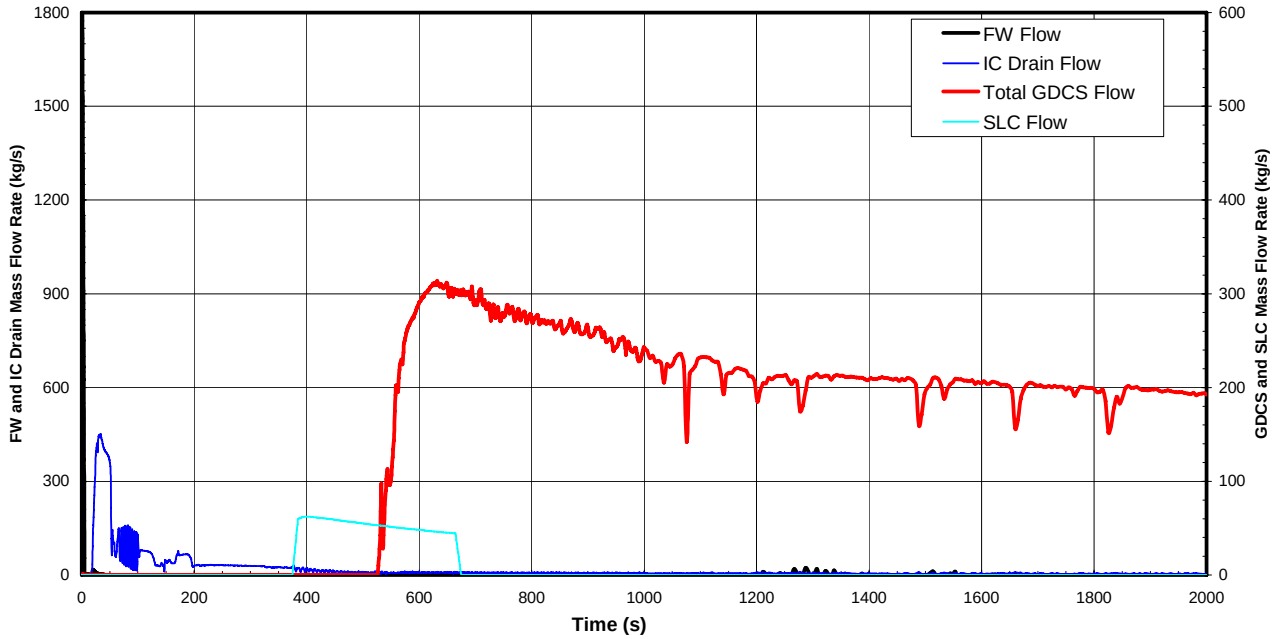

Figure 6.3-13a. Flows Into Vessel, Feedwater Line Break, 1 GDCS Valve Failure

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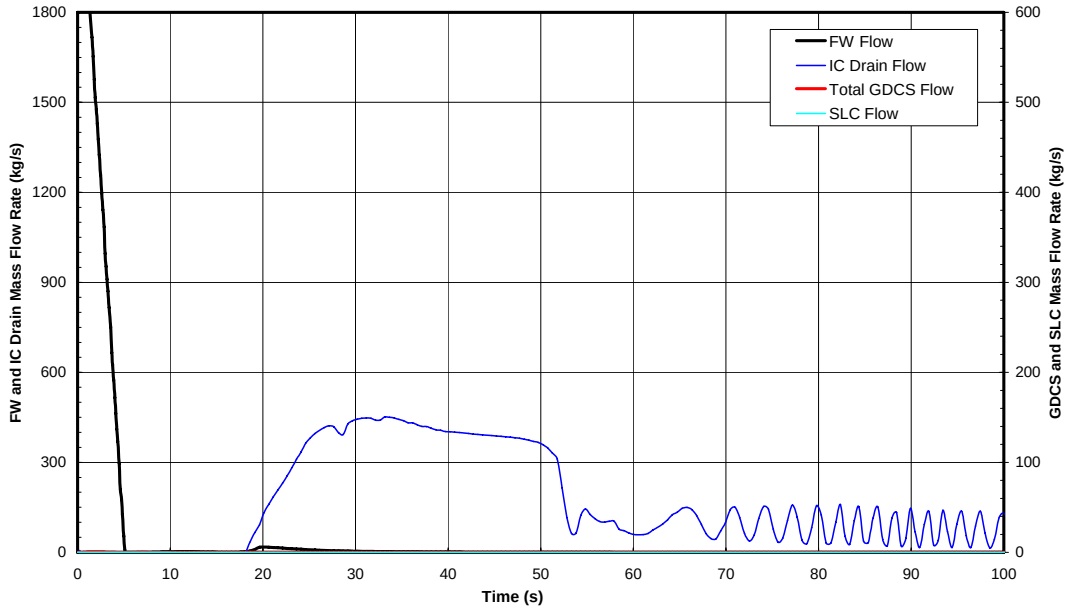

Figure 6.3-13b. Flows Into Vessel, Feedwater Line Break, 1 GDCS Valve Failure

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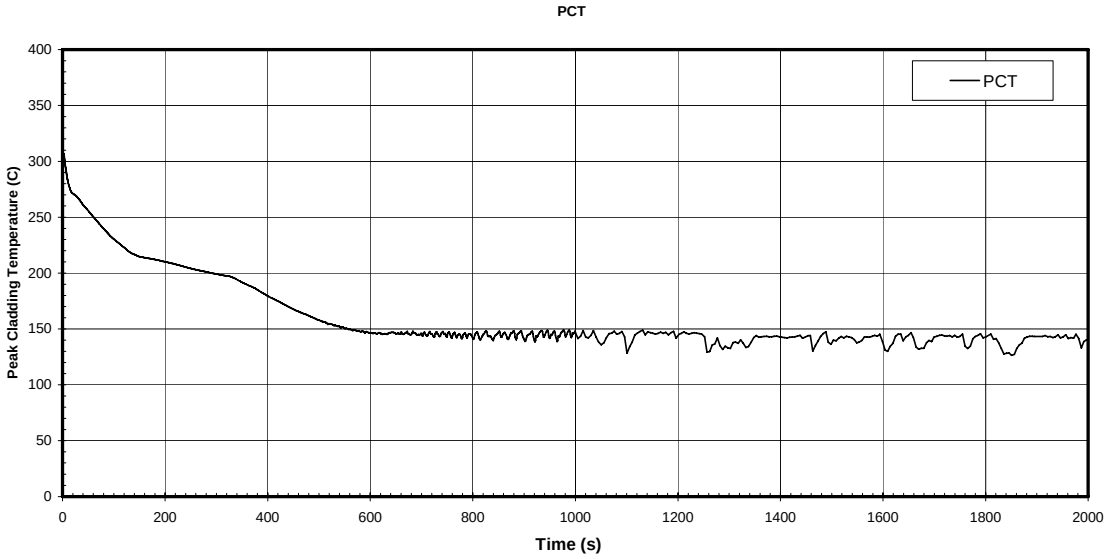

Figure 6.3-14a. PCT, Feedwater Line Break, 1 GDCS Valve Failure

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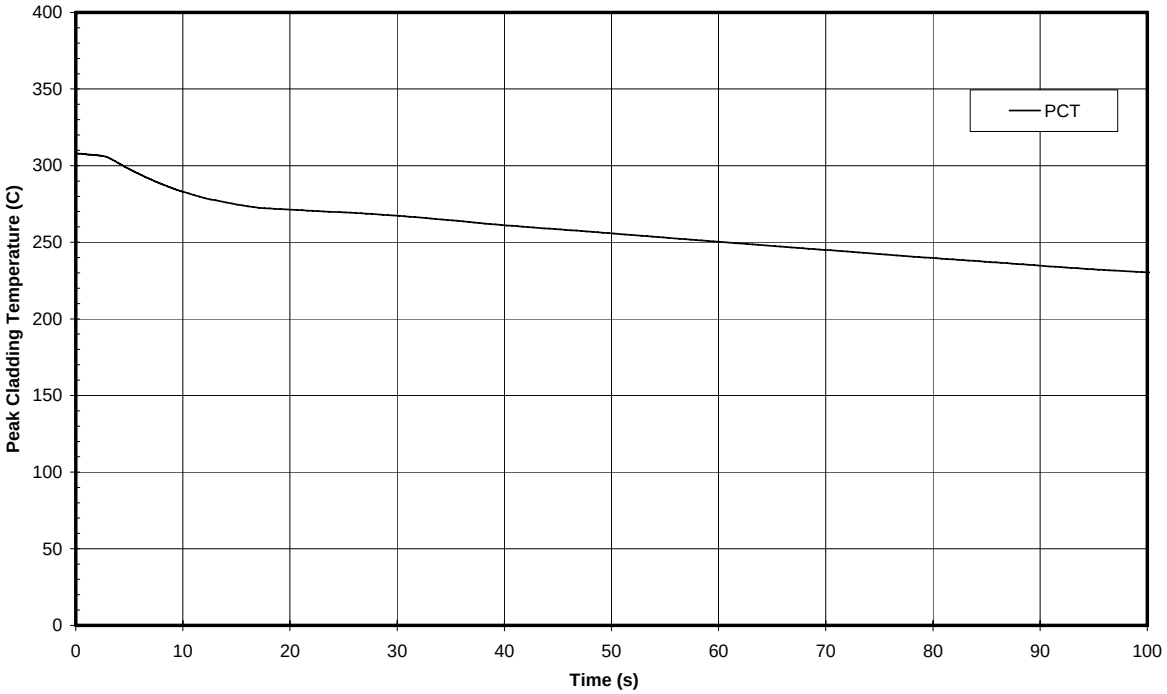

Figure 6.3-14b. PCT, Feedwater Line Break, 1 GDCS Valve Failure

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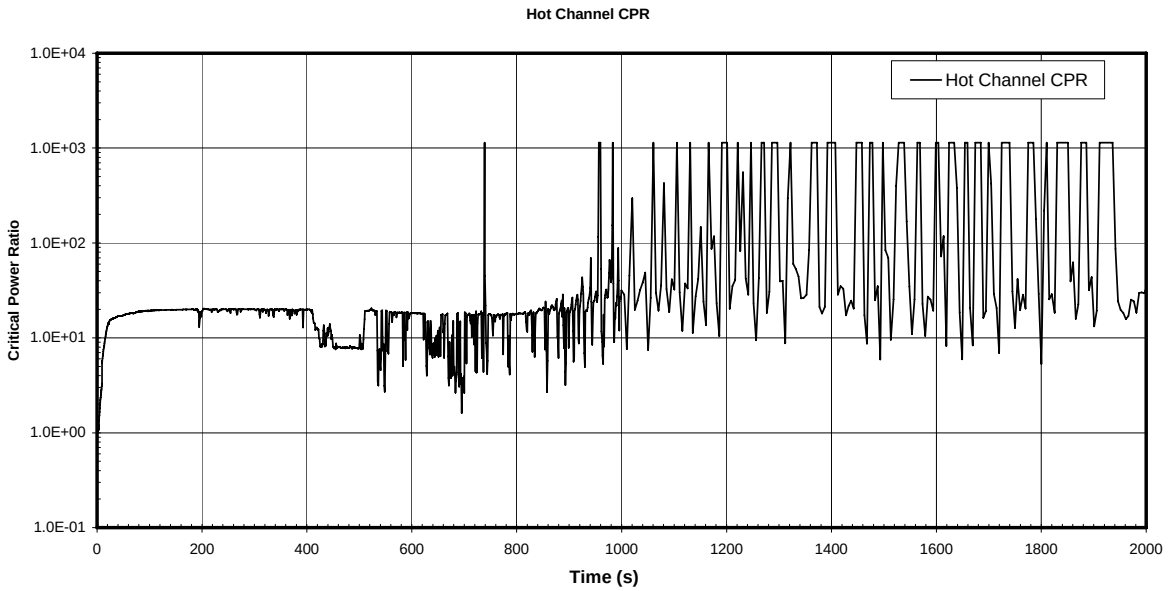

Figure 6.3-15a. MCPR, Inside Steam Line Break, 1 GDCS Valve Failure

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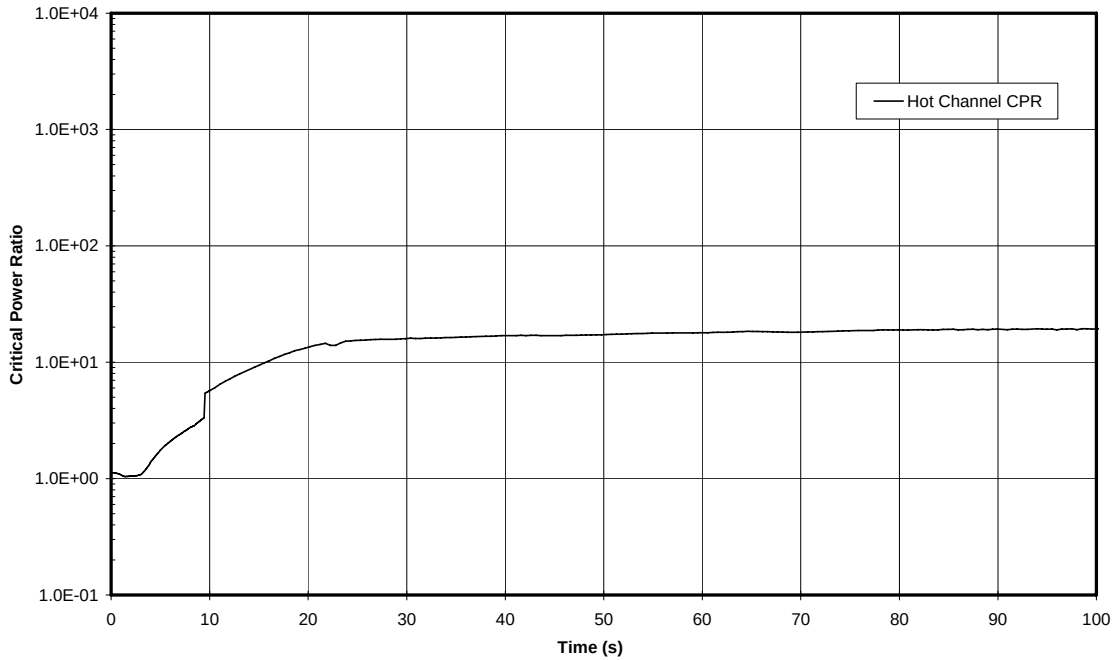

Figure 6.3-15b. MCPR, Inside Steam Line Break, 1 GDCS Valve Failure

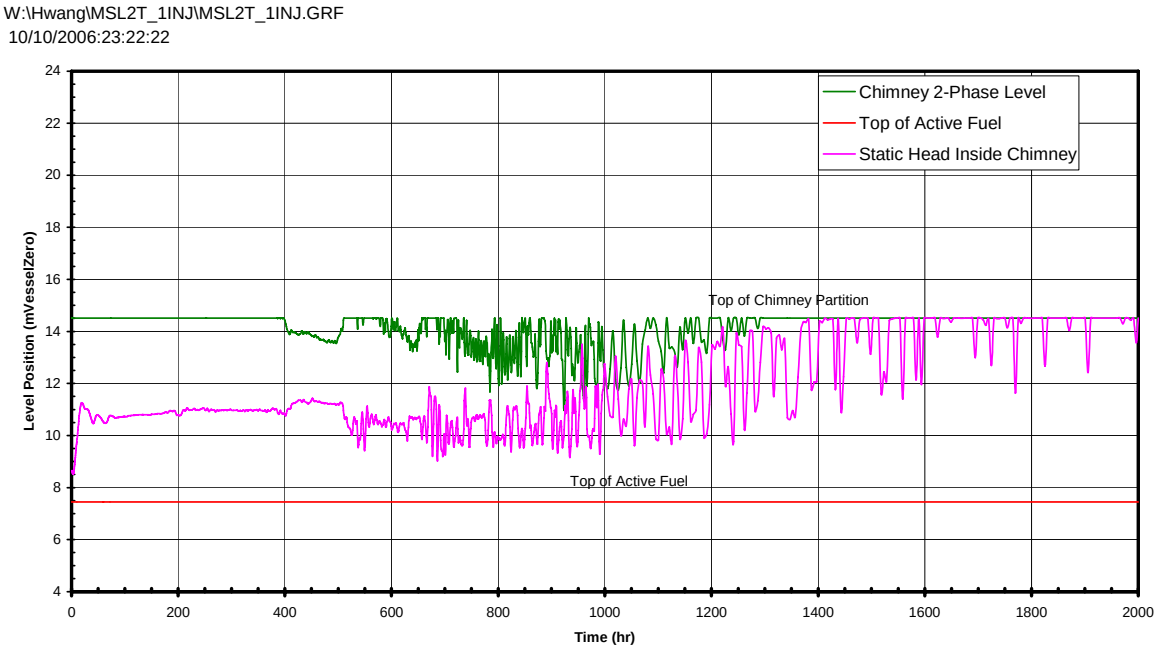

Figure 6.3-16a. Chimney Water Level, Inside Steam Line Break, 1 GDCS Valve Failure

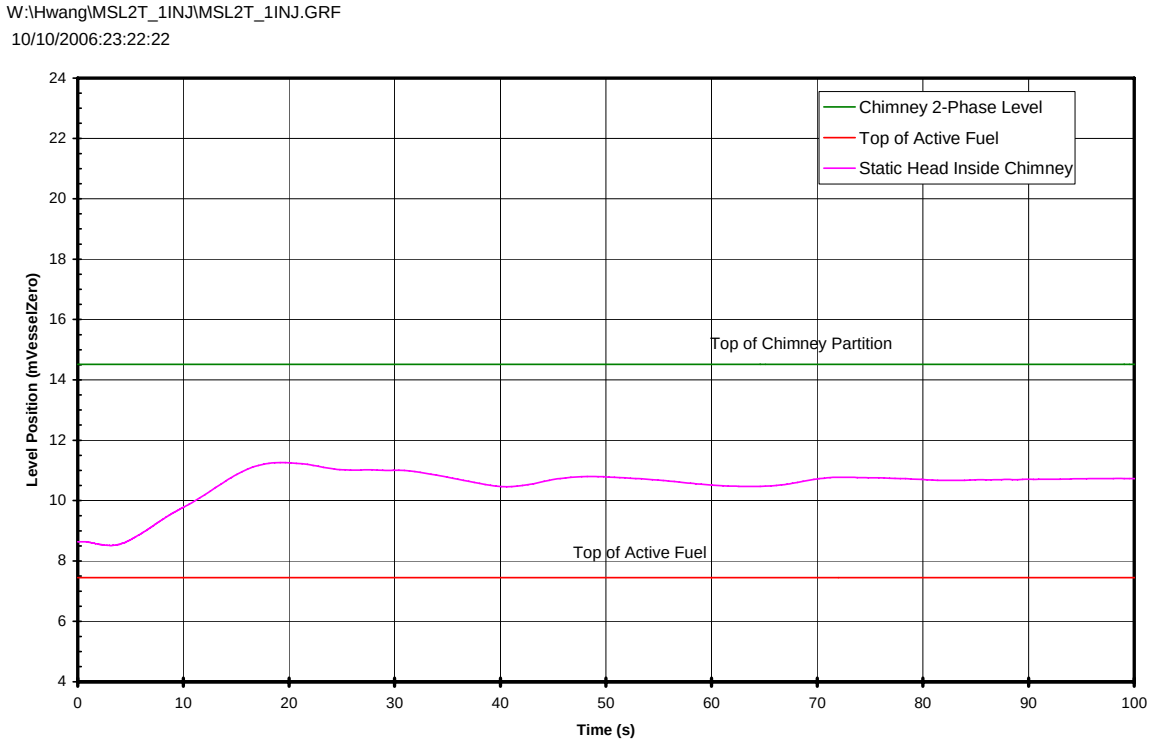

Figure 6.3-16b. Chimney Water Level, Inside Steam Line Break, 1 GDCS Valve Failure

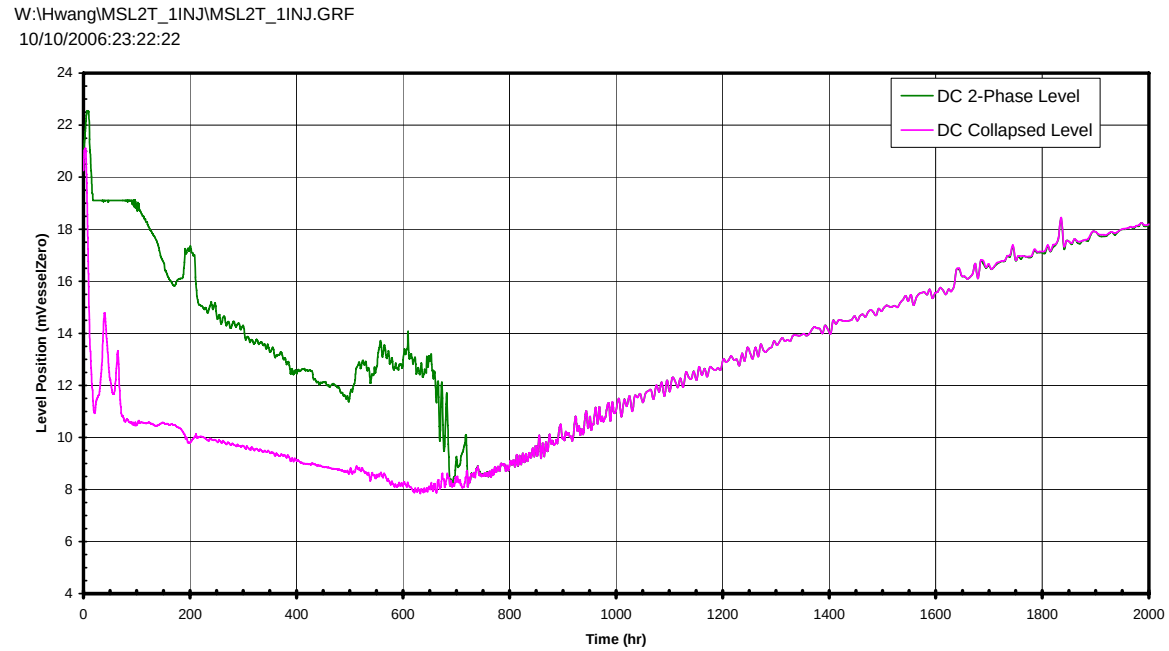

Figure 6.3-17a. Downcomer Water Level, Inside Steam Line Break, 1 GDCS Valve Failure

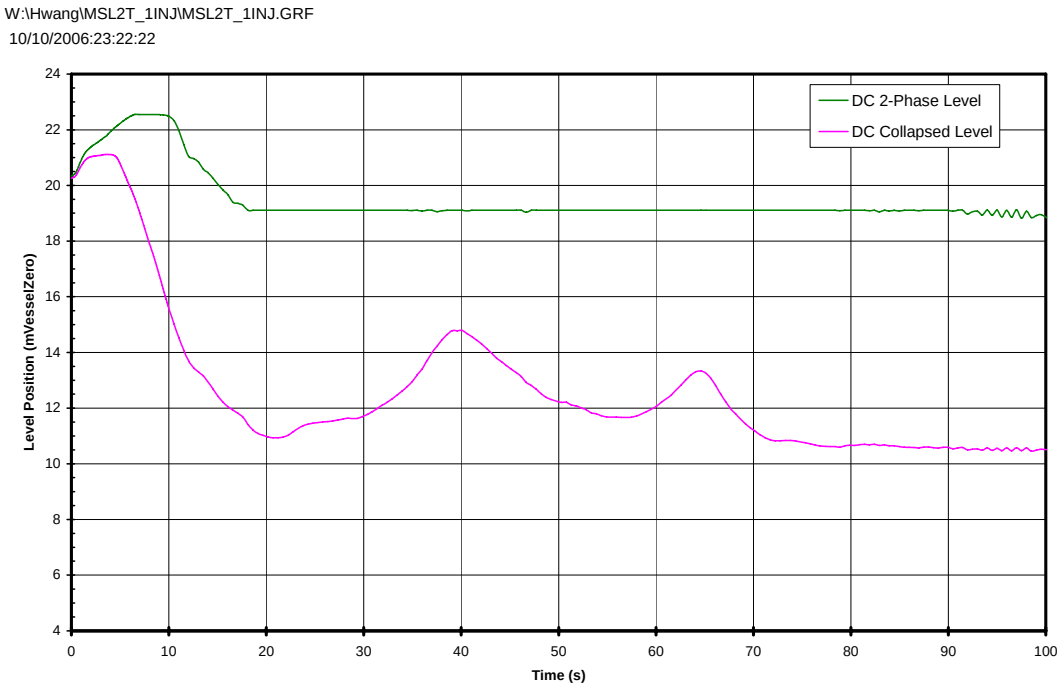

Figure 6.3-17b. Downcomer Water Level, Inside Steam Line Break, 1 GDCS Valve Failure

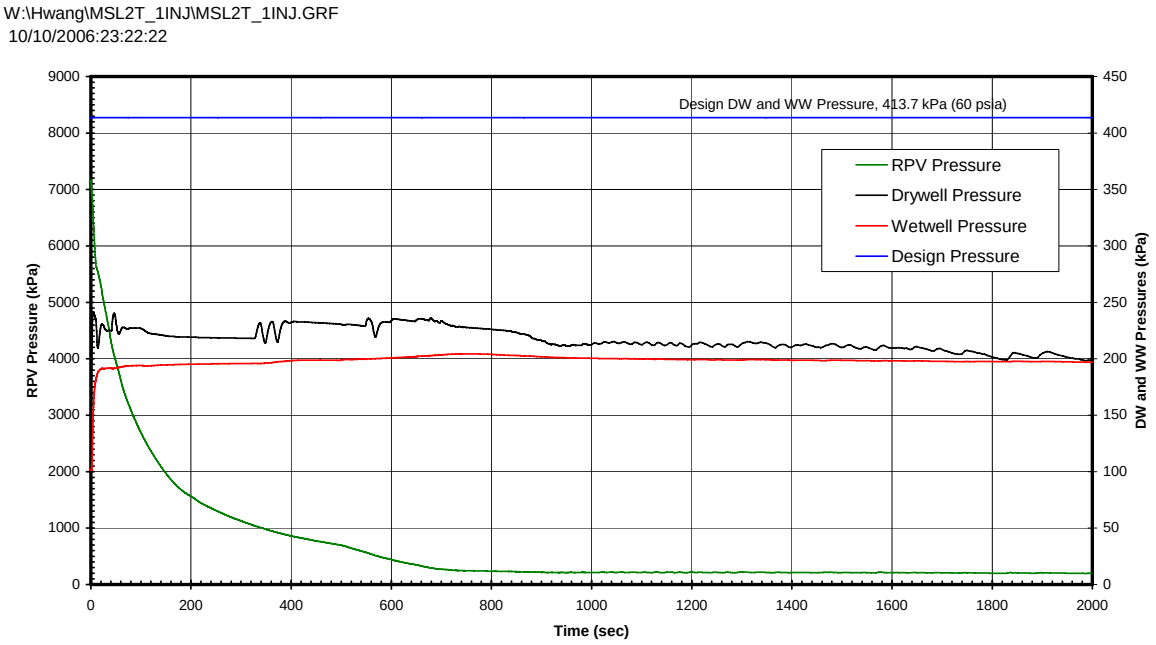

Figure 6.3-18a. System Pressures, Inside Steam Line Break, 1 GDCS Valve Failure

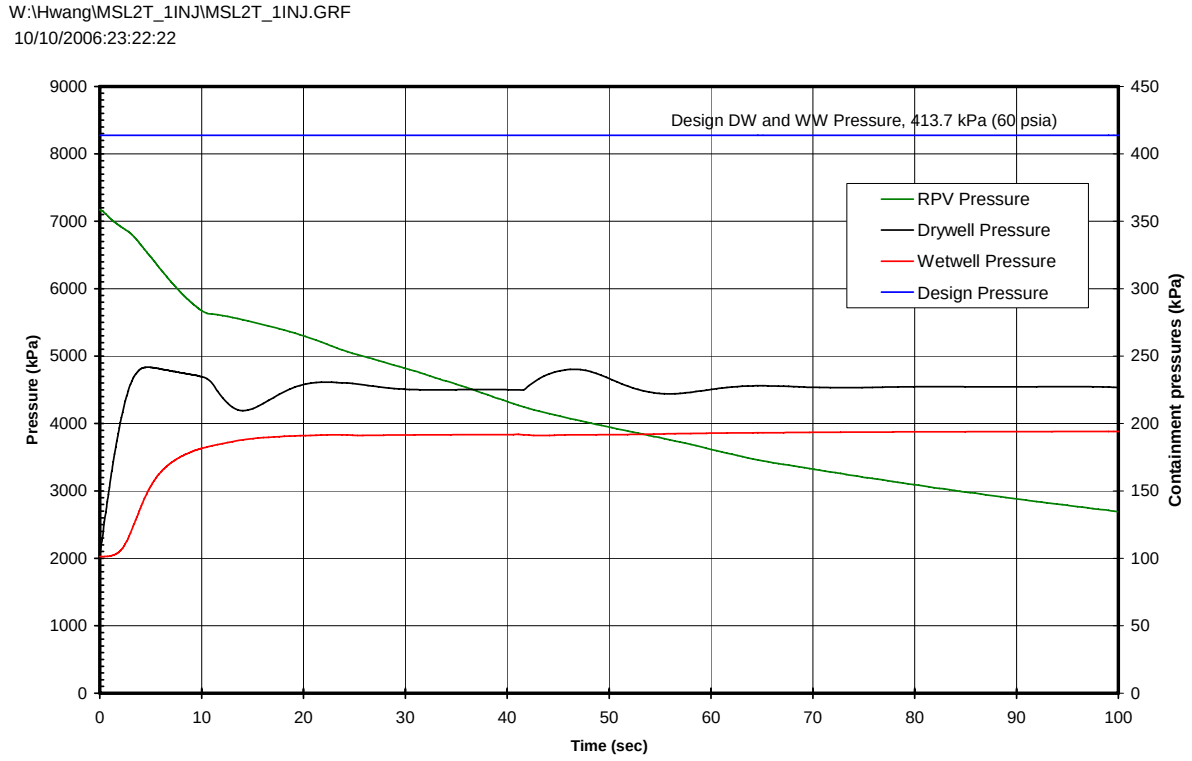

Figure 6.3-18b. System Pressures, Inside Steam Line Break, 1 GDCS Valve Failure

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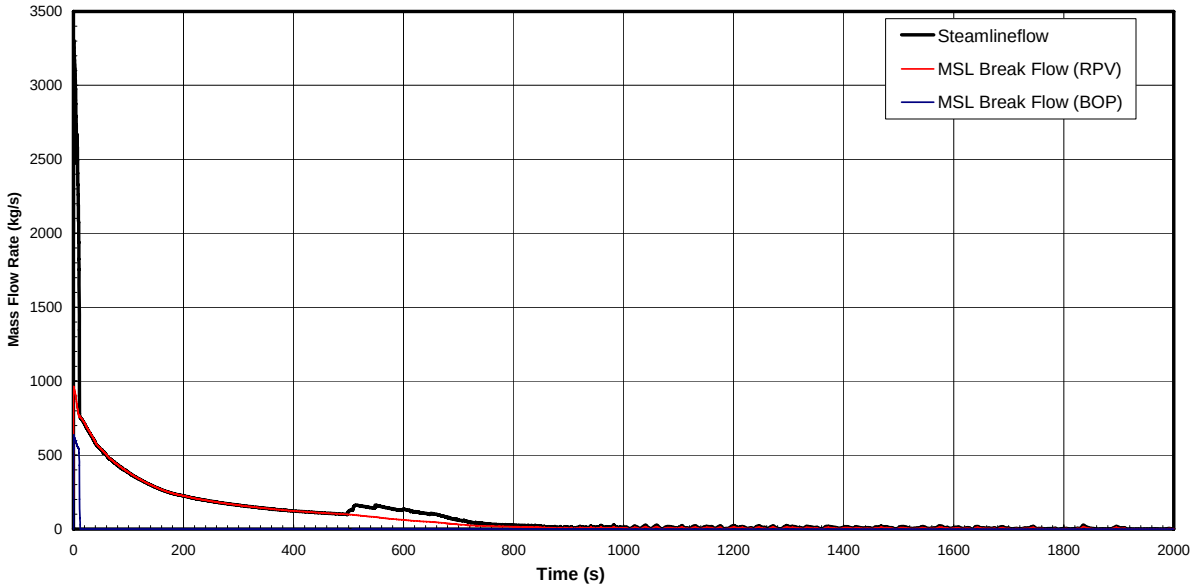

Figure 6.3-19a. Steam Line and Break Flow, Inside Steam Line Break, 1 GDCS Valve Failure

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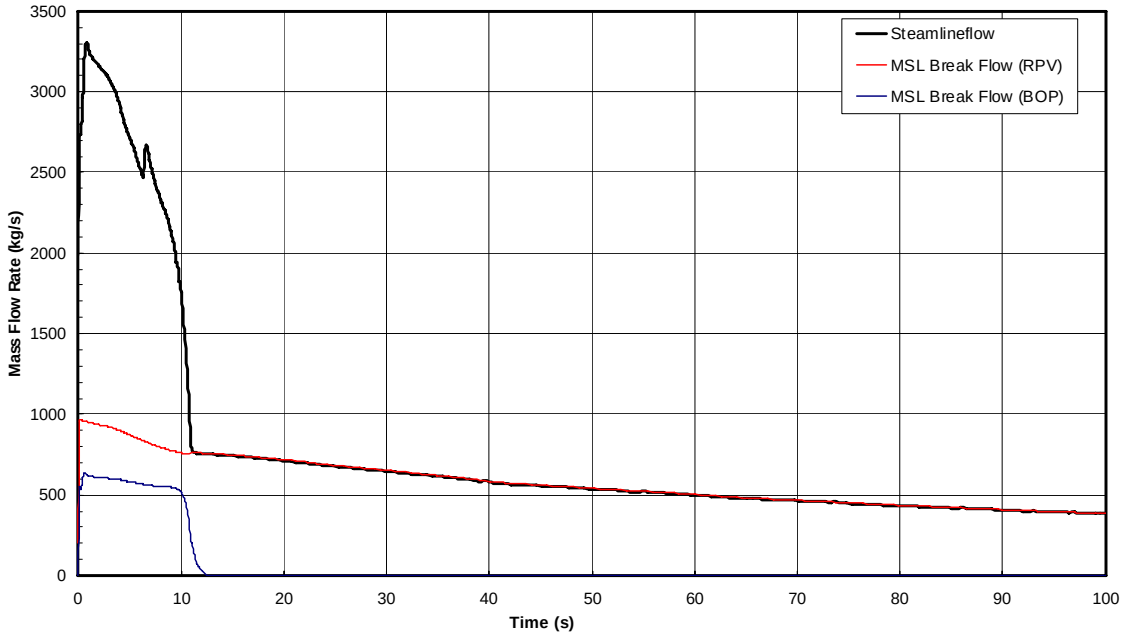

Figure 6.3-19b. Steam Line and Break Flow, Inside Steam Line Break, 1 GDCS Valve Failure

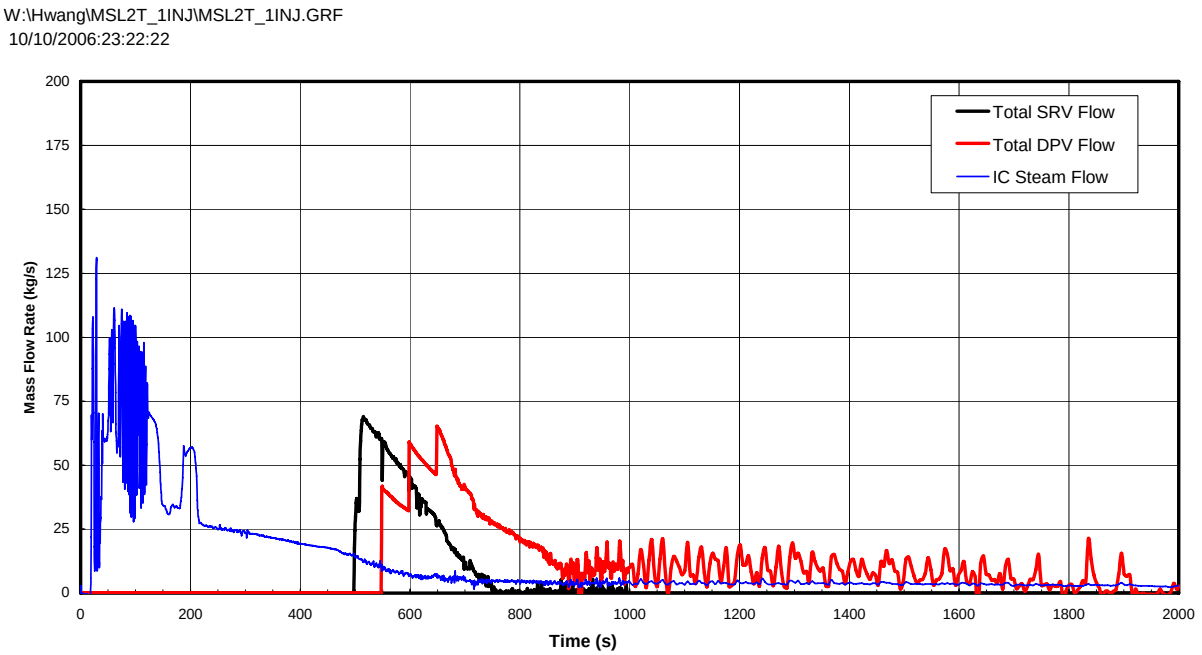

Figure 6.3-20a. ADS Flow, Inside Steam Line Break, 1 GDCS Valve Failure

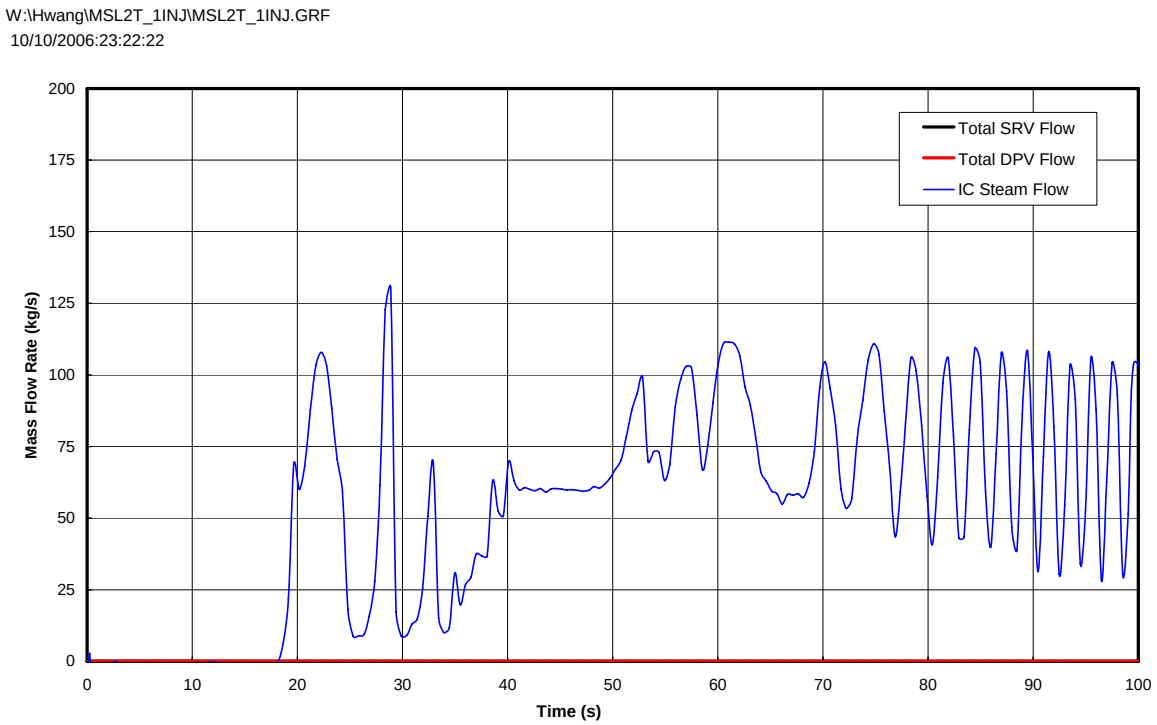

Figure 6.3-20b. ADS Flows, Inside Steam Line Break, 1 GDCS Valve Failure

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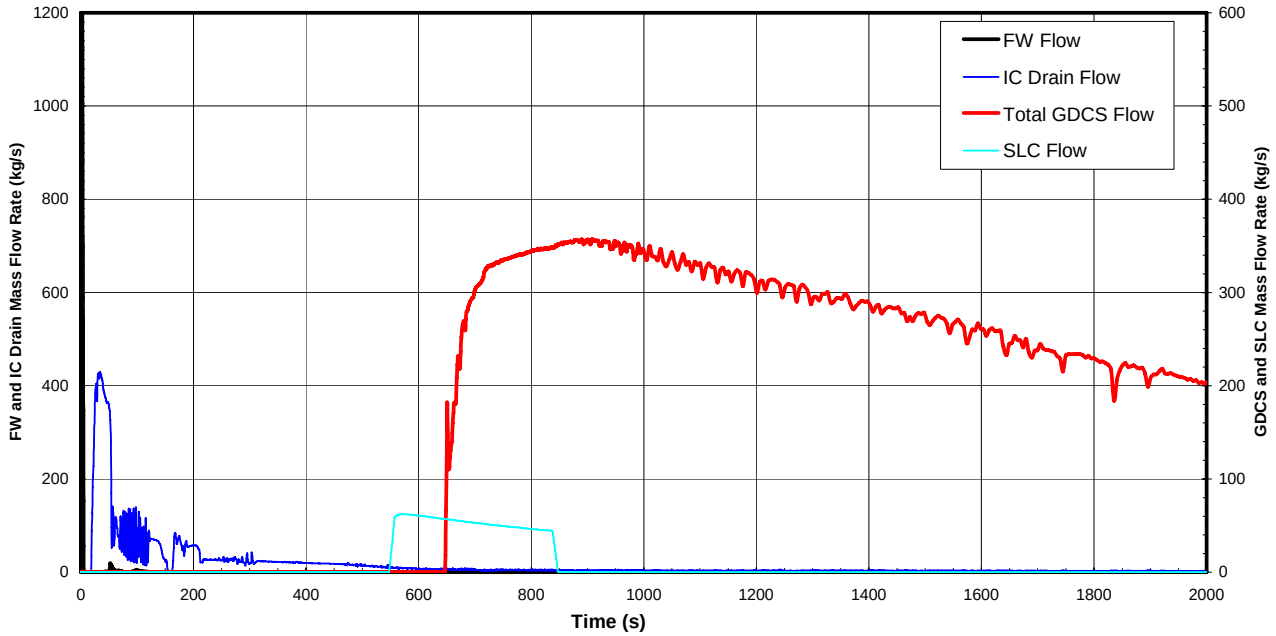

Figure 6.3-21a. Flows Into Vessel, Inside Steam Line Break, 1 GDCS Valve Failure

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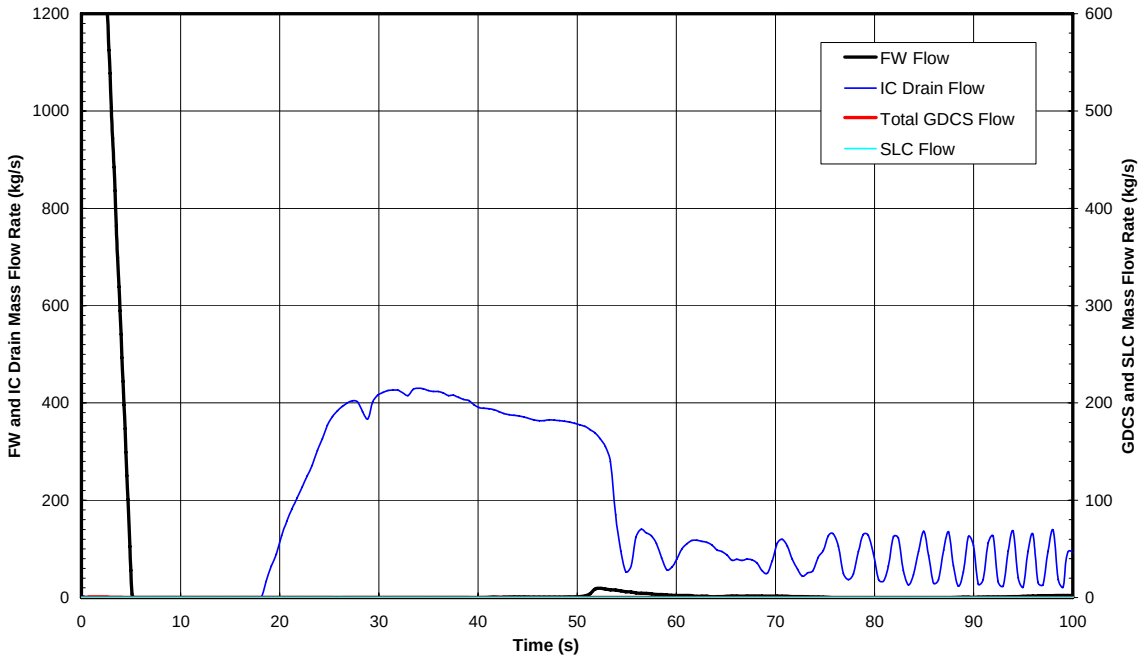

Figure 6.3-21b. Flows Into Vessel, Inside Steam Line Break, 1 GDCS Valve Failure

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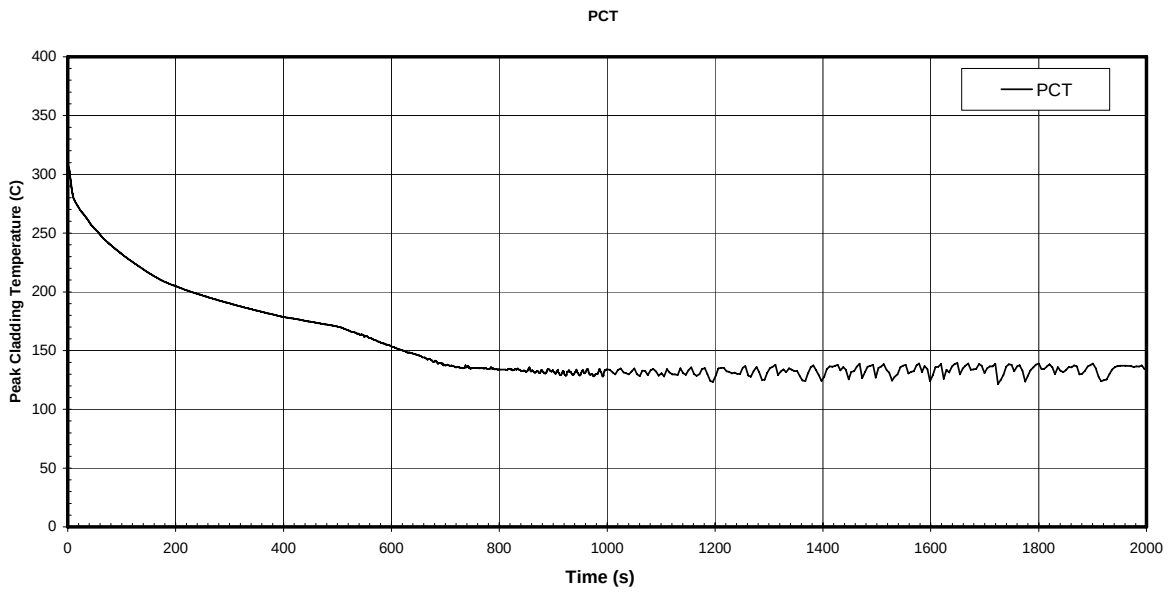

Figure 6.3-22a. PCT, Inside Steam Line Break, 1 GDCS Valve Failure

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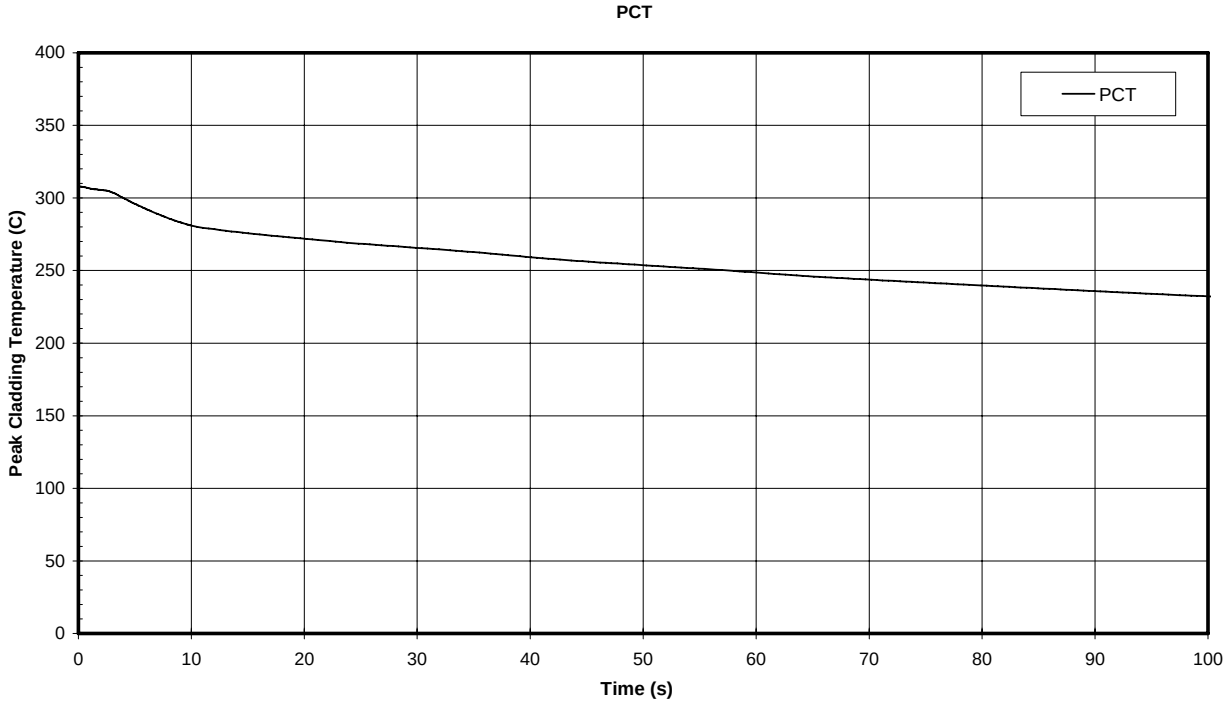

Figure 6.3-22b. PCT, Inside Steam Line Break, 1 GDCS Valve Failure

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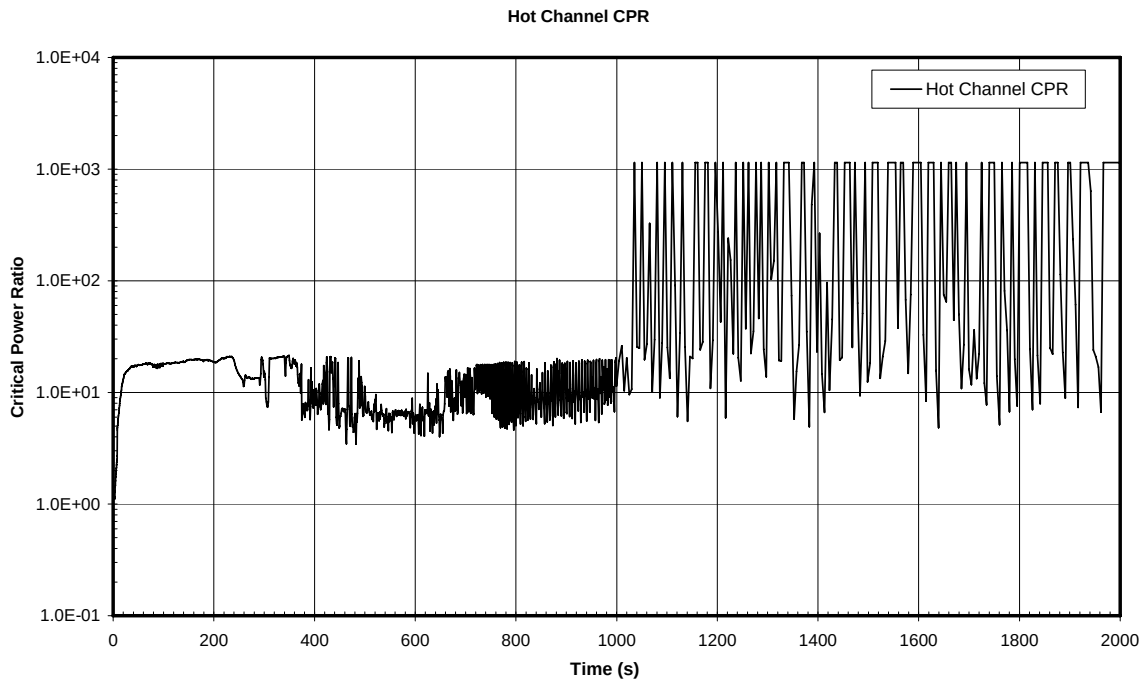

Figure 6.3-23a. MCPR, Bottom Drain Line Break, 1 GDCS Valve Failure

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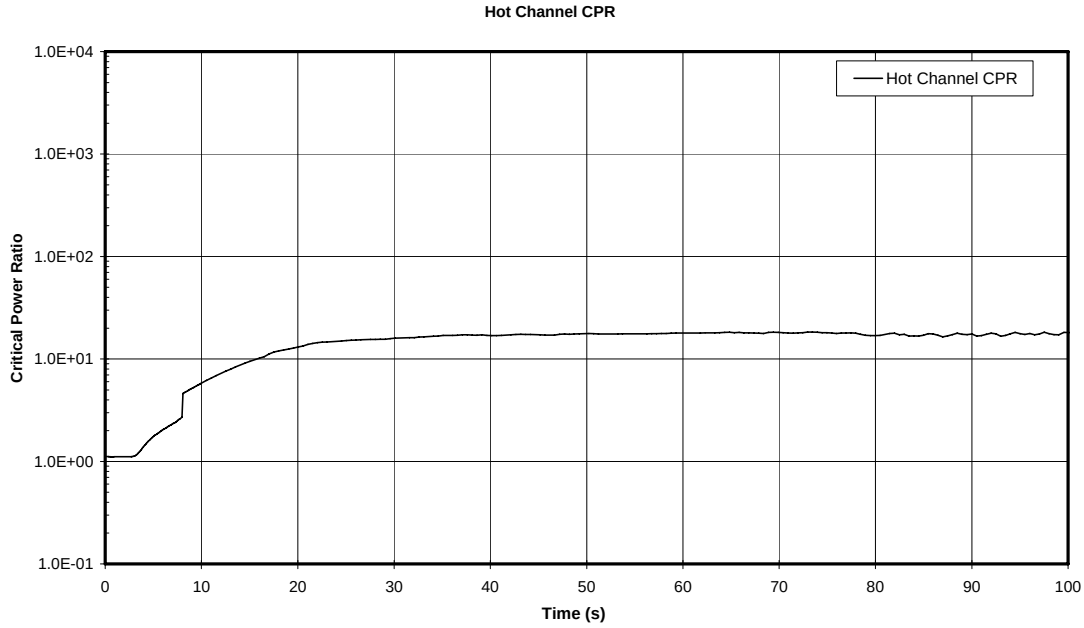

Figure 6.3.3-23b. MCPR, Bottom Drain Line Break, 1 GDCS Valve Failure

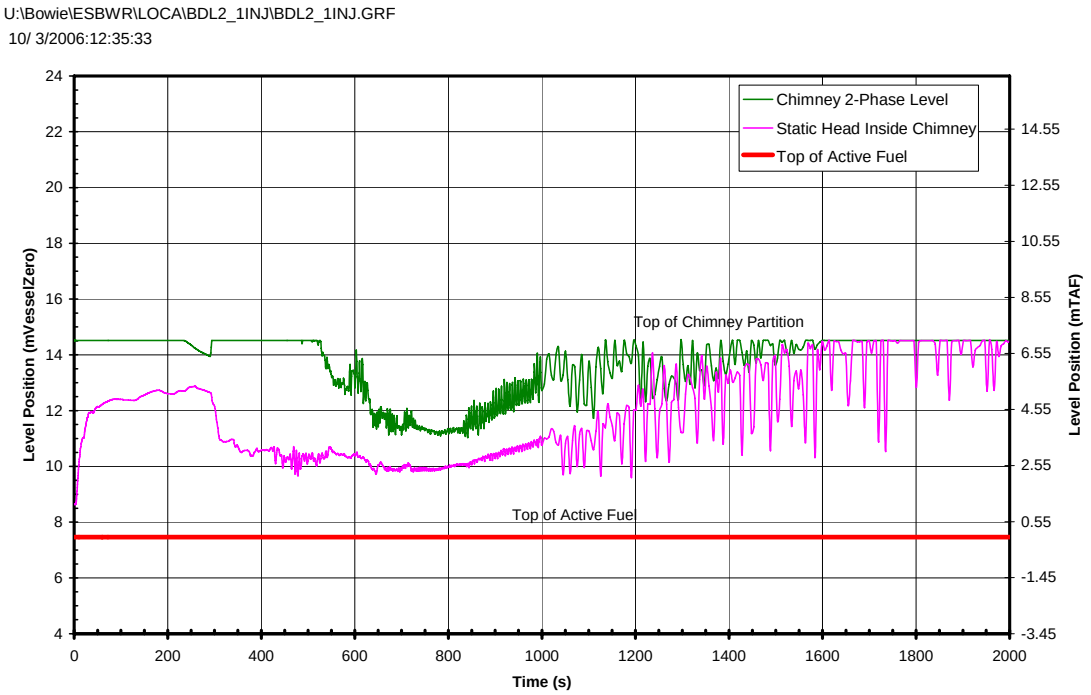

Figure 6.3-24a. Chimney Water Level, Bottom Drain Line Break, 1 GDCS Valve Failure

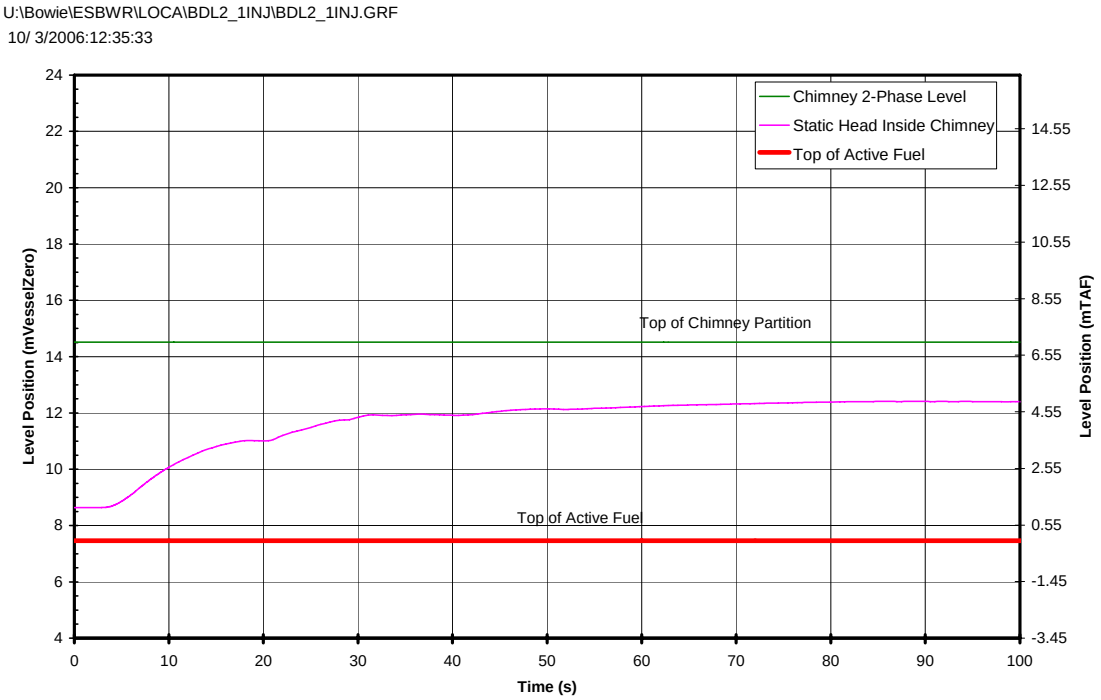

Figure 6.3-24b. Chimney Water Level, Bottom Drain Line Break, 1 GDCS Valve Failure

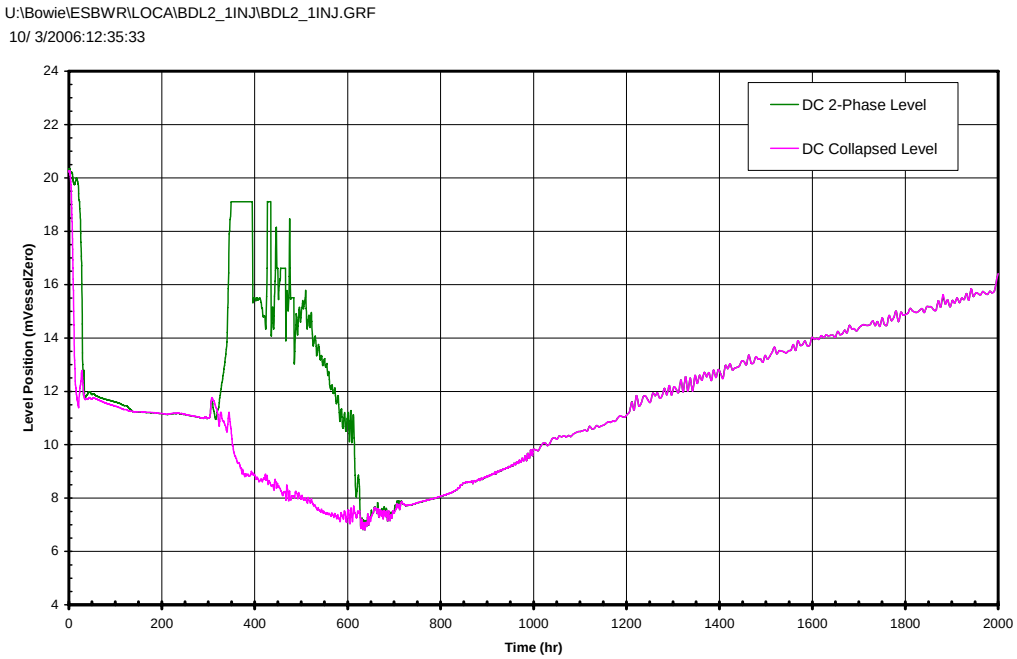

Figure 6.3-25a. Downcomer Water Level, Bottom Drain Line Break, 1 GDCS Valve Failure

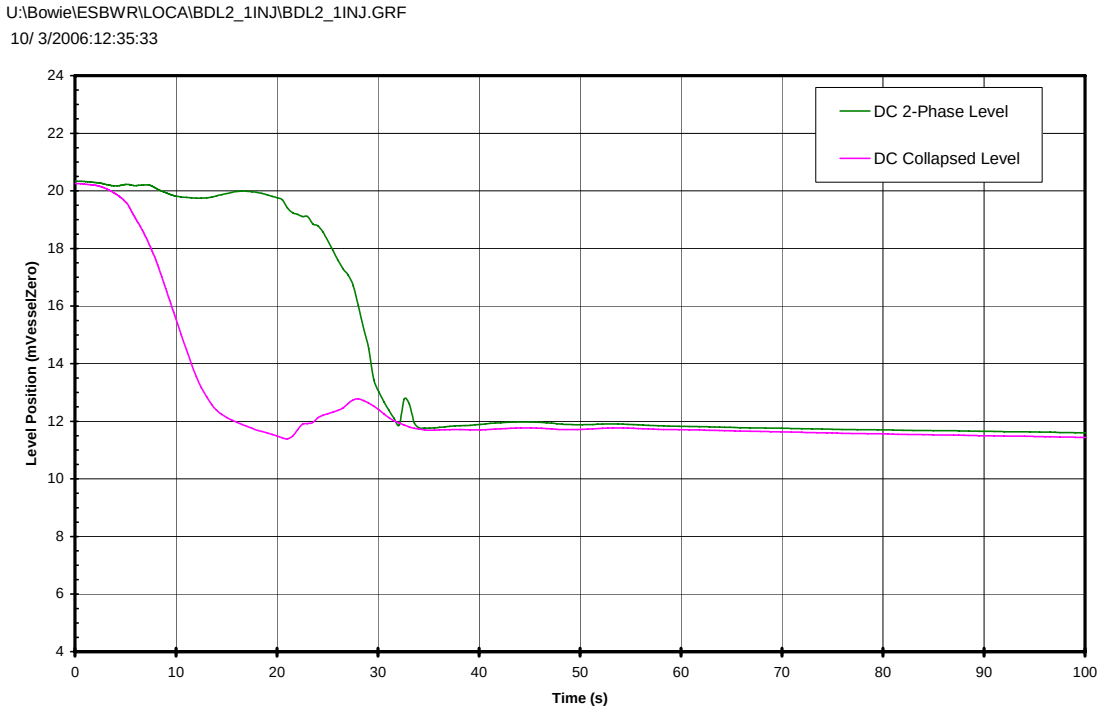

Figure 6.3.3-25b. Downcomer Water Level, Bottom Drain Line Break, 1 GDCS Valve Failure

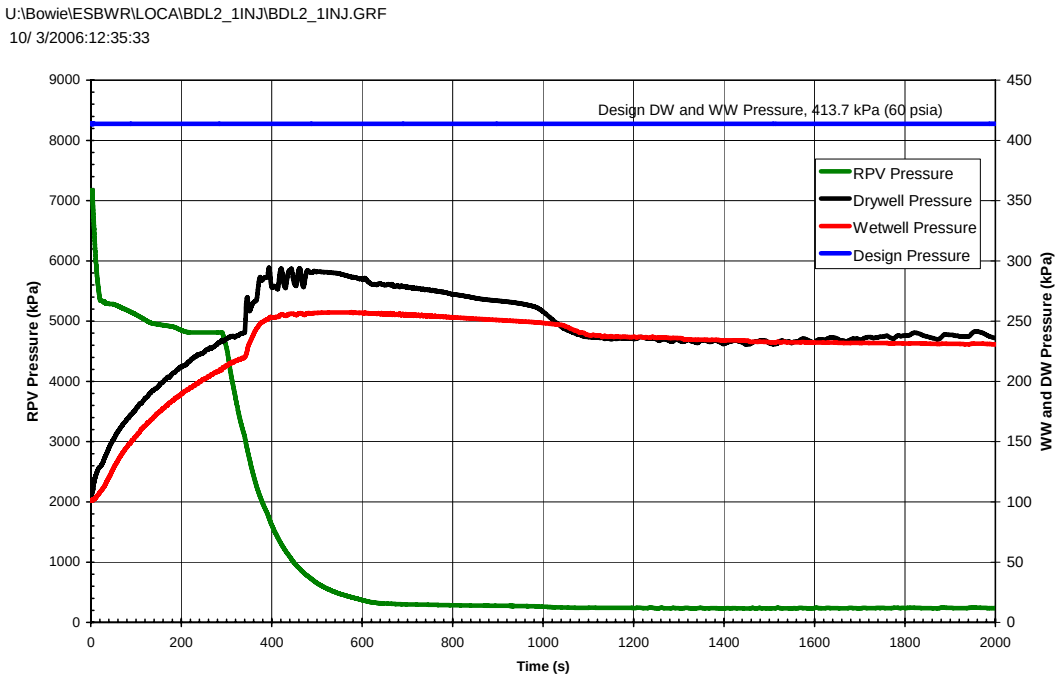

Figure 6.3-26a. System Pressures, Bottom Drain Line Break, 1 GDCS Valve Failure

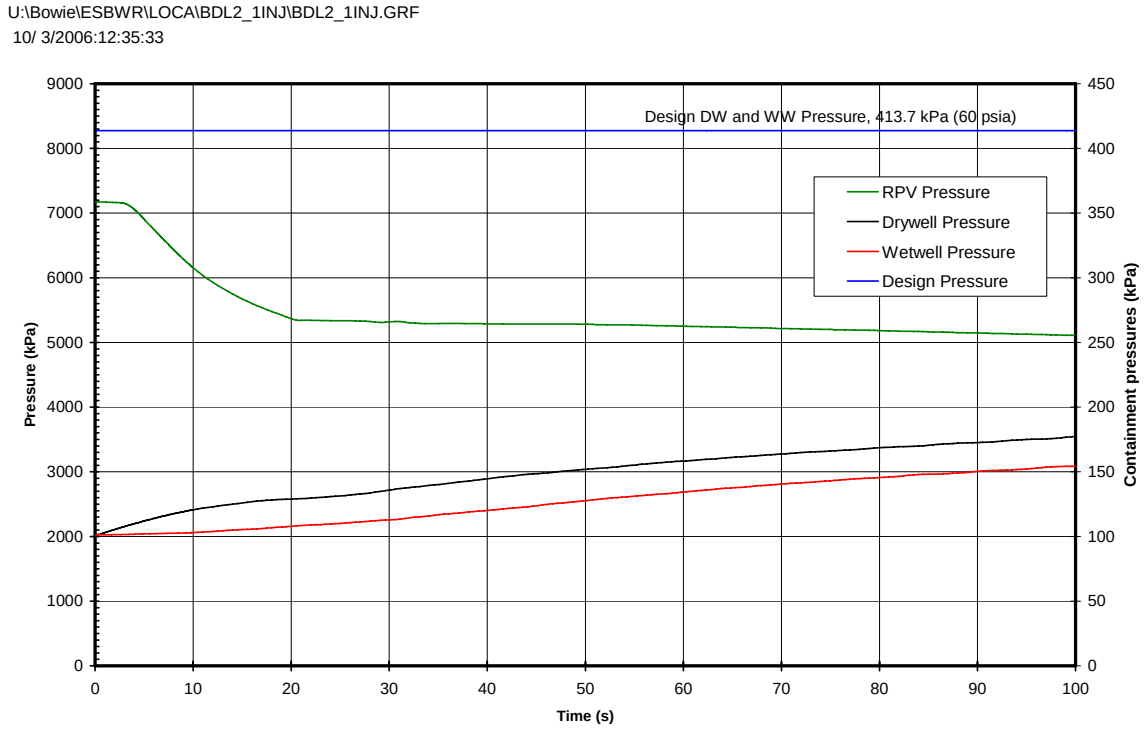

Figure 6.3-26b. System Pressures, Bottom Drain Line Break, 1 GDCS Valve Failure

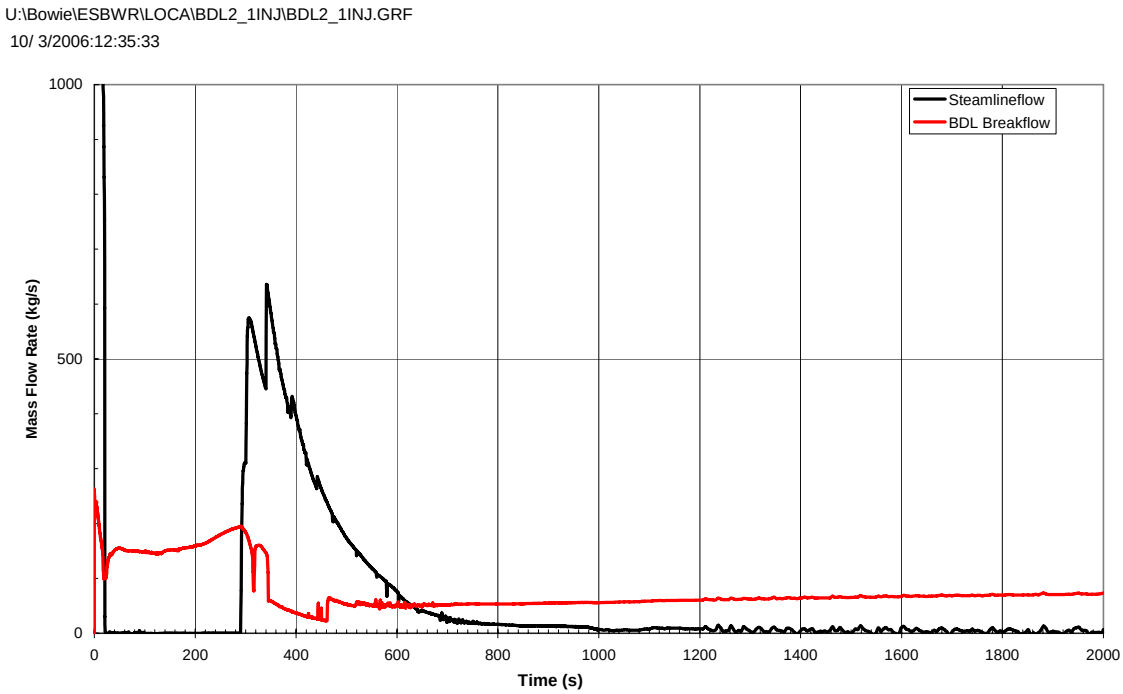

Figure 6.3-27a. Steam Line and Break Flow, Bottom Drain Line Break, 1 GDCS Valve Failure

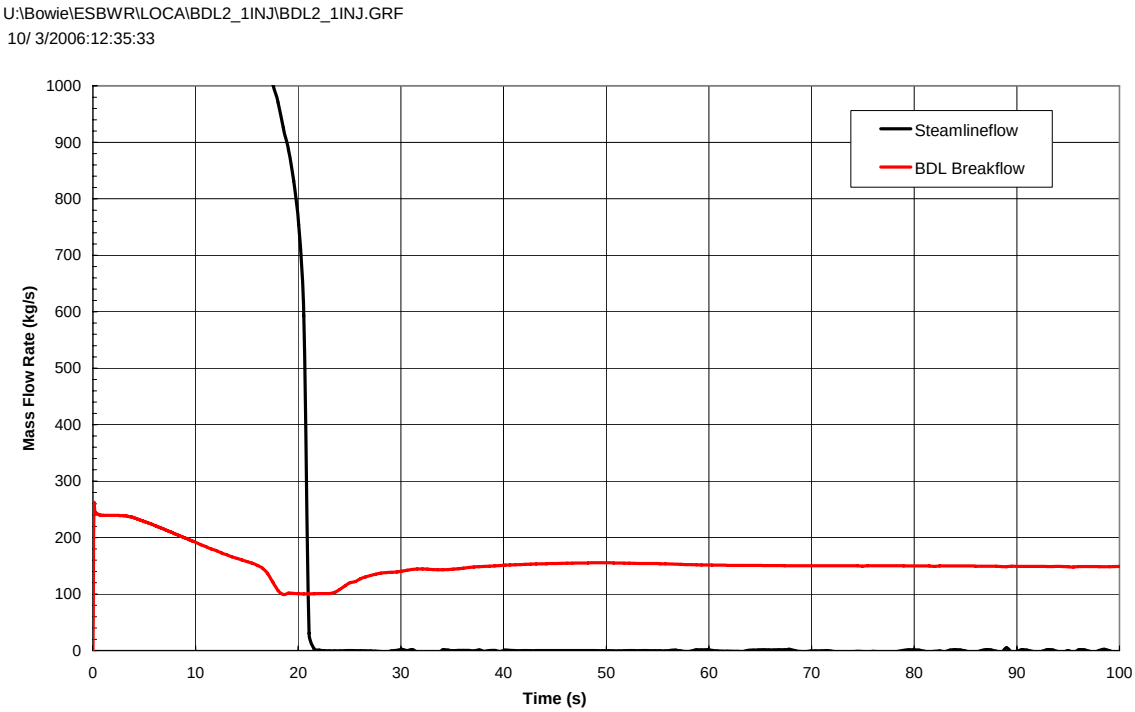

Figure 6.3-27b. Steam Line and Break Flow, Bottom Drain Line Break, 1 GDCS Valve Failure

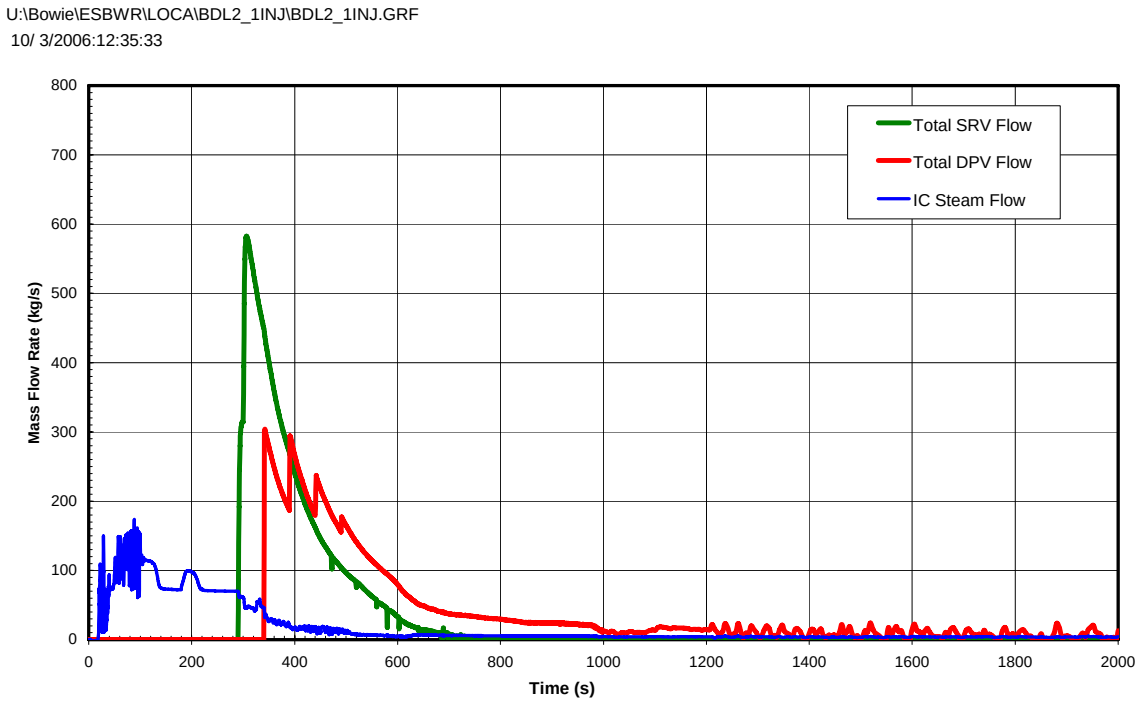

Figure 6.3-28a. ADS Flow, Bottom Drain Line Break, 1 GDCS Valve Failure

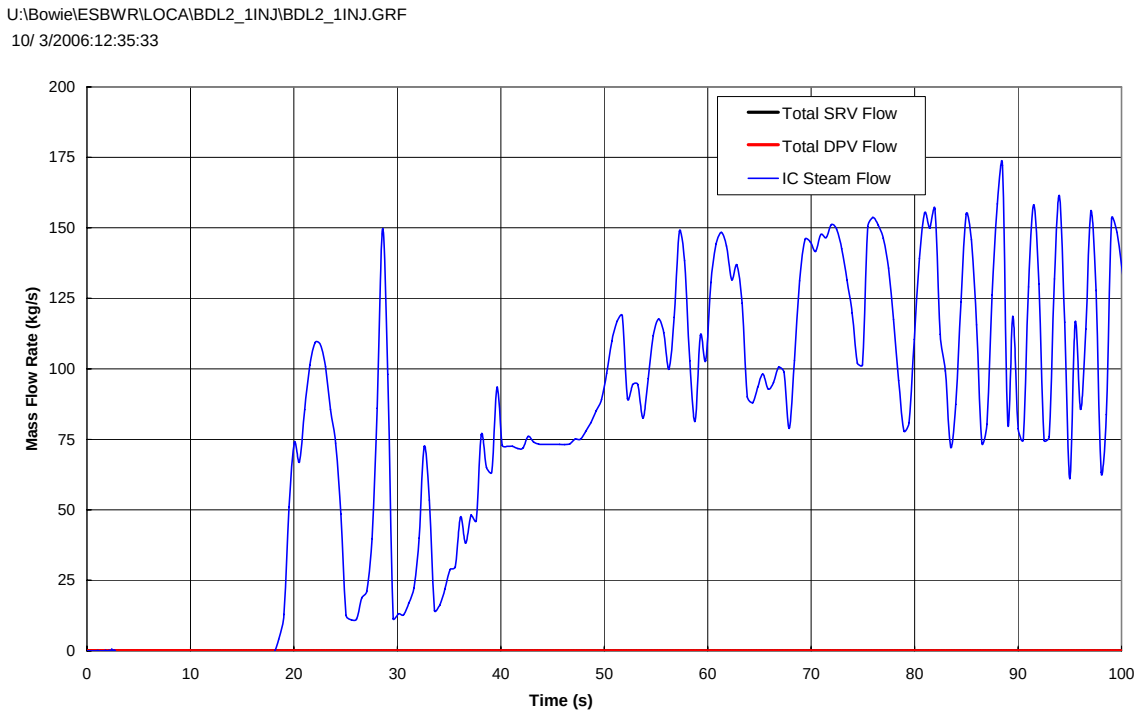

Figure 6.3-28b. ADS Flows, Bottom Drain Line Break, 1 GDCS Valve Failure

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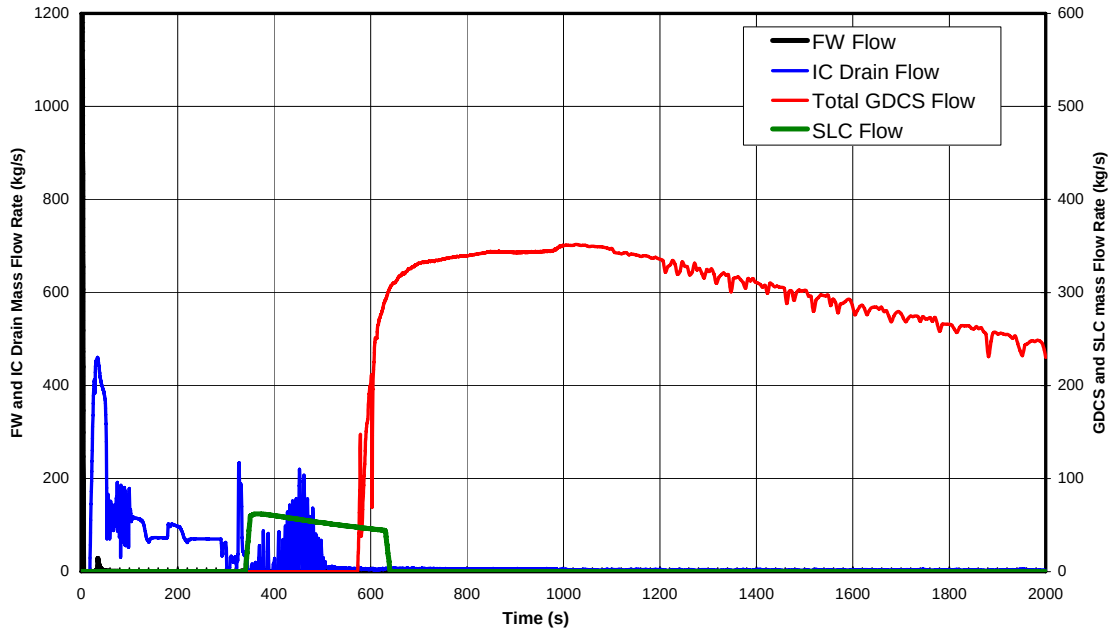

Figure 6.3-29a. Flows Into Vessel, Bottom Drain Line Break, 1 GDCS Valve Failure

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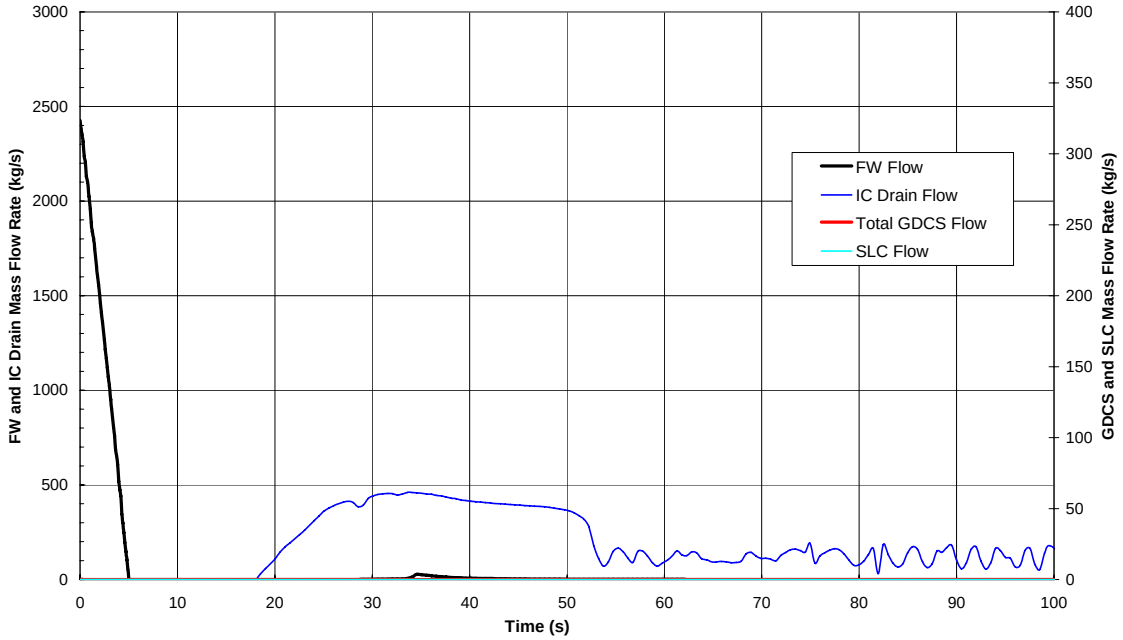

Figure 6.3-29b. Flows Into Vessel, Bottom Drain Line Break, 1 GDCS Valve Failure

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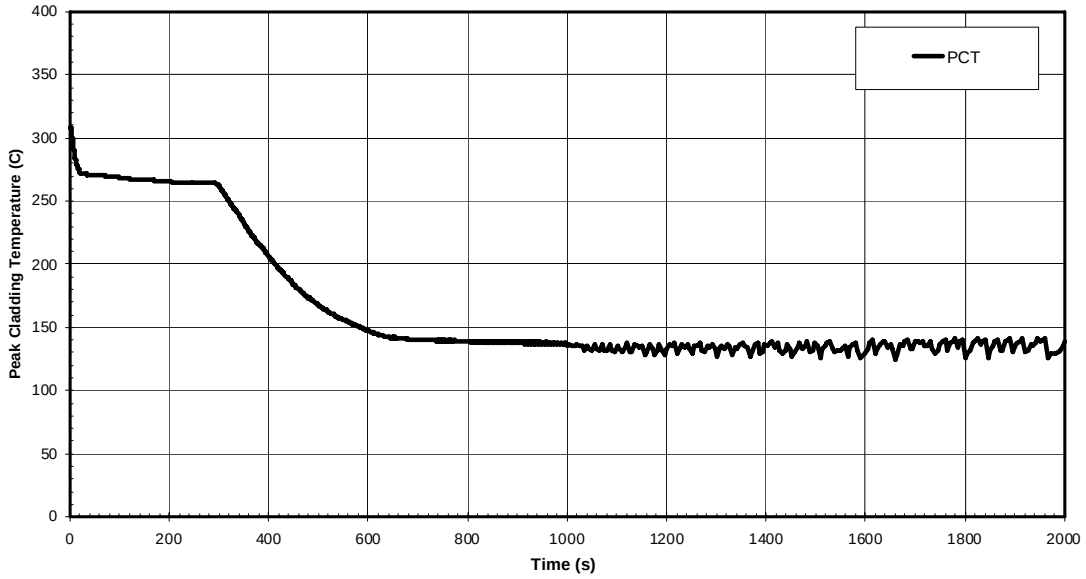

Figure 6.3-30a. PCT, Bottom Drain Line Break, 1 GDCS Valve Failure

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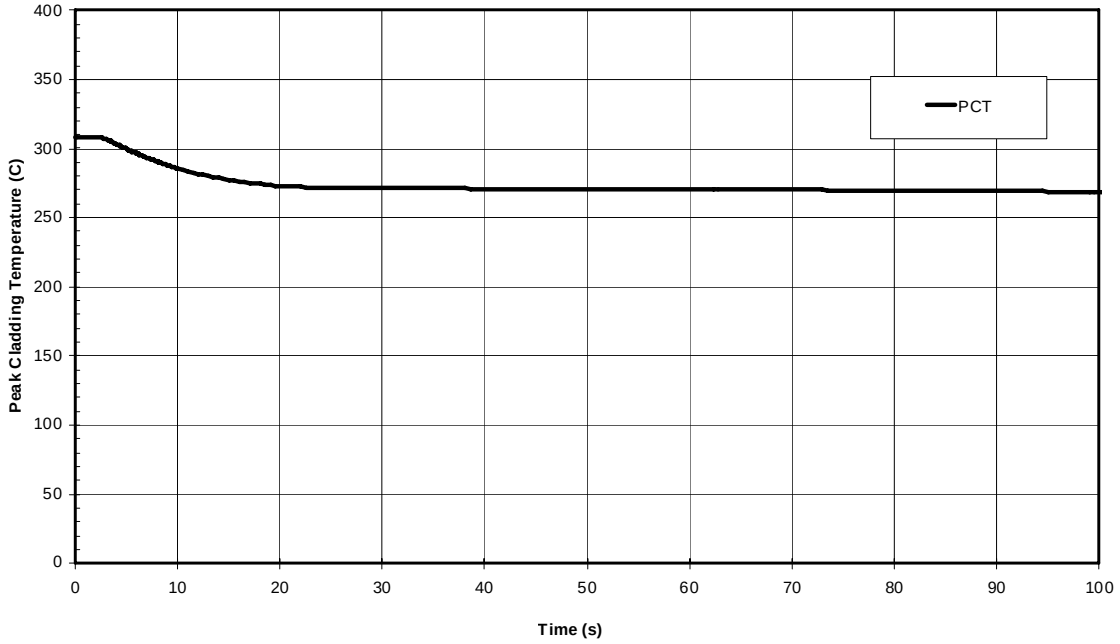

Figure 6.3-30b. PCT, Bottom Drain Line Break, 1 GDCS Valve Failure

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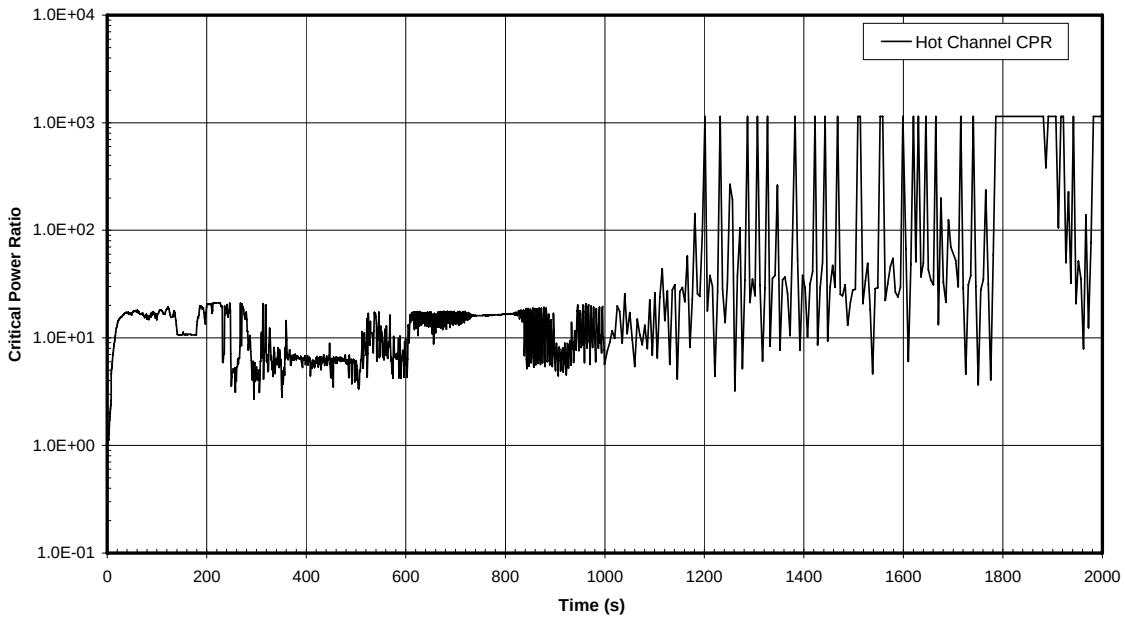

Figure 6.3-31a. MCPR, GDCS Injection Line Break, 1 GDCS Valve Failure

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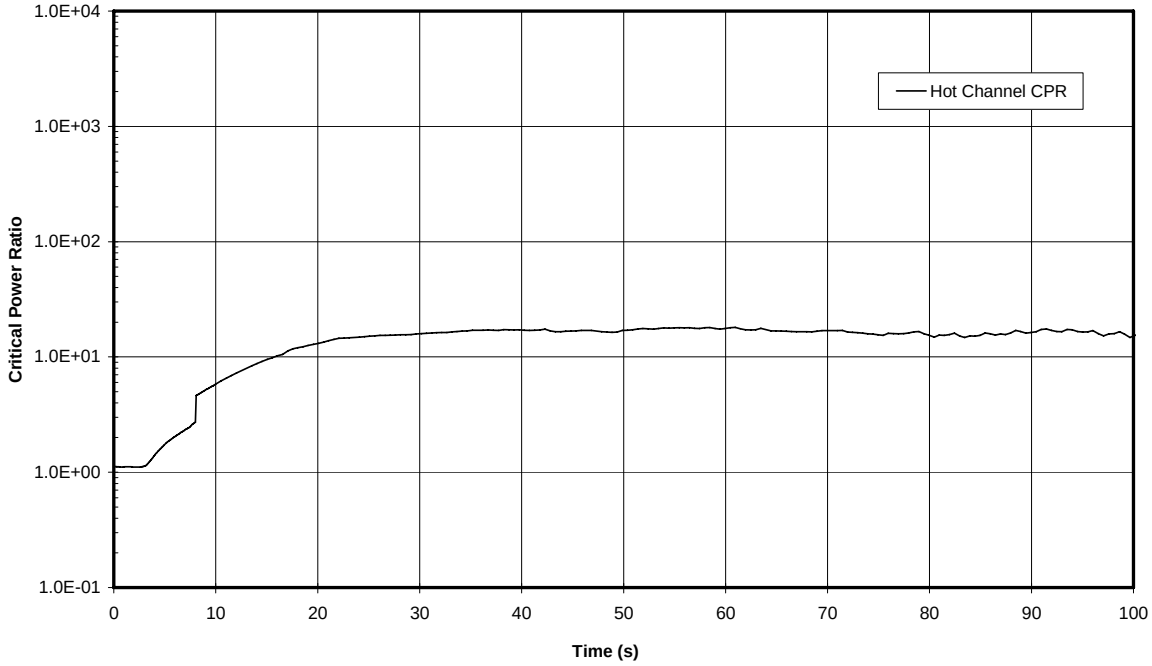

Figure 6.3-31b. MCPR, GDCS Injection Line Break, 1 GDCS Valve Failure

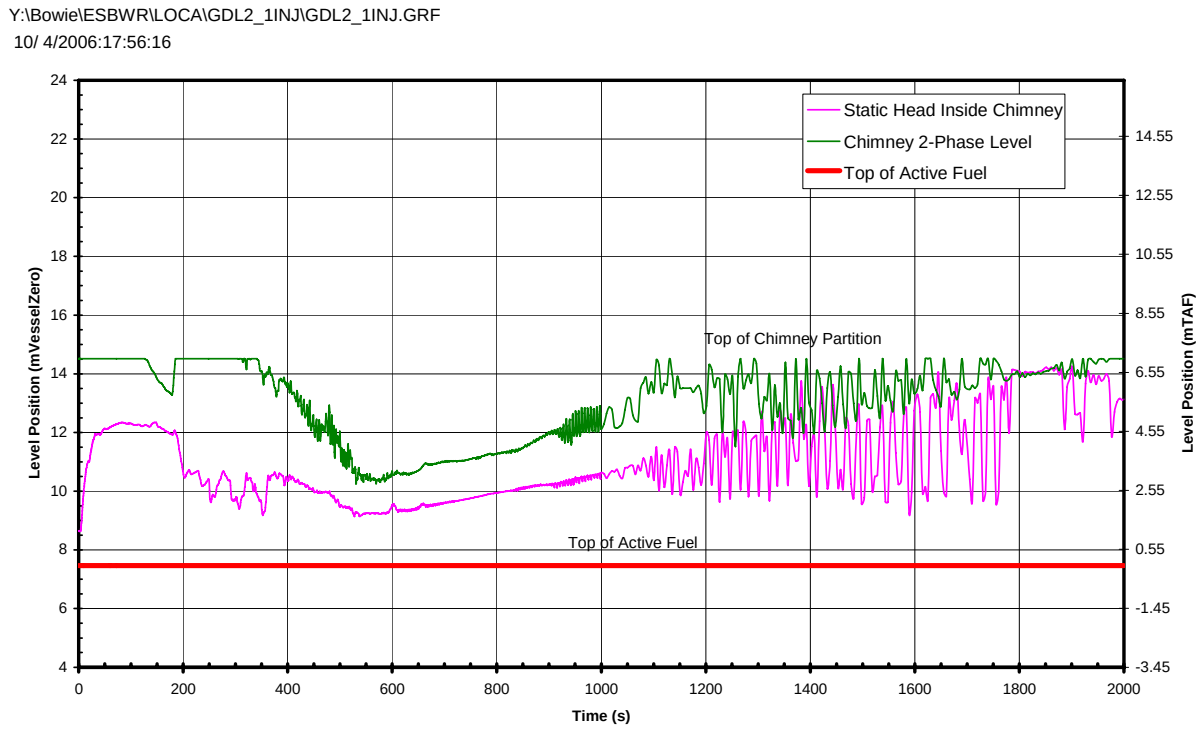

Figure 6.3-32a. Chimney Water Level, GDCS Injection Line Break, 1 GDCS Valve Failure

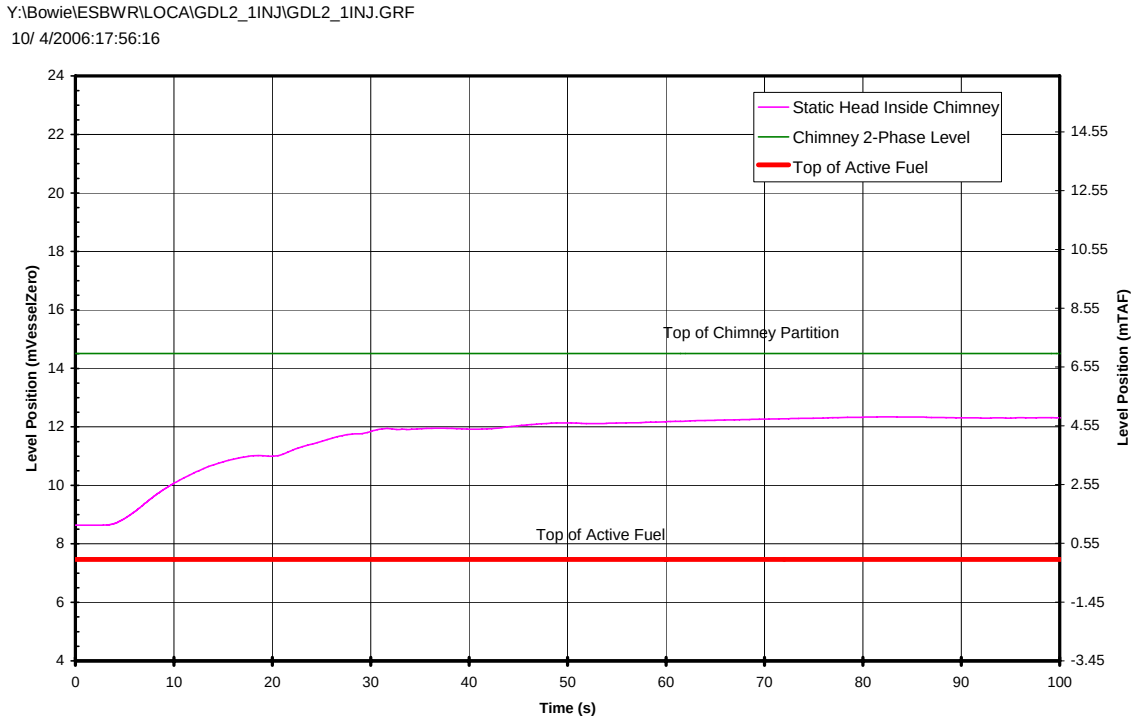

Figure 6.3-32b. Chimney Water Level, GDCS Injection Line Break, 1 GDCS Valve Failure

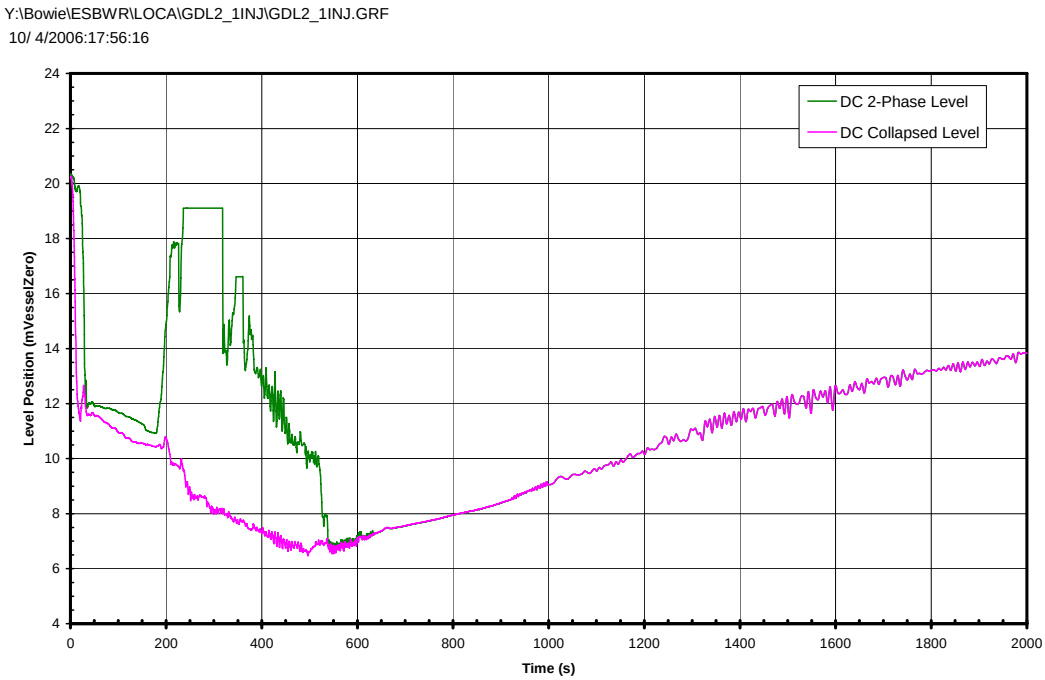

Figure 6.3-33a. Downcomer Water Level, GDCS Injection Line Break, 1 GDCS Valve Failure

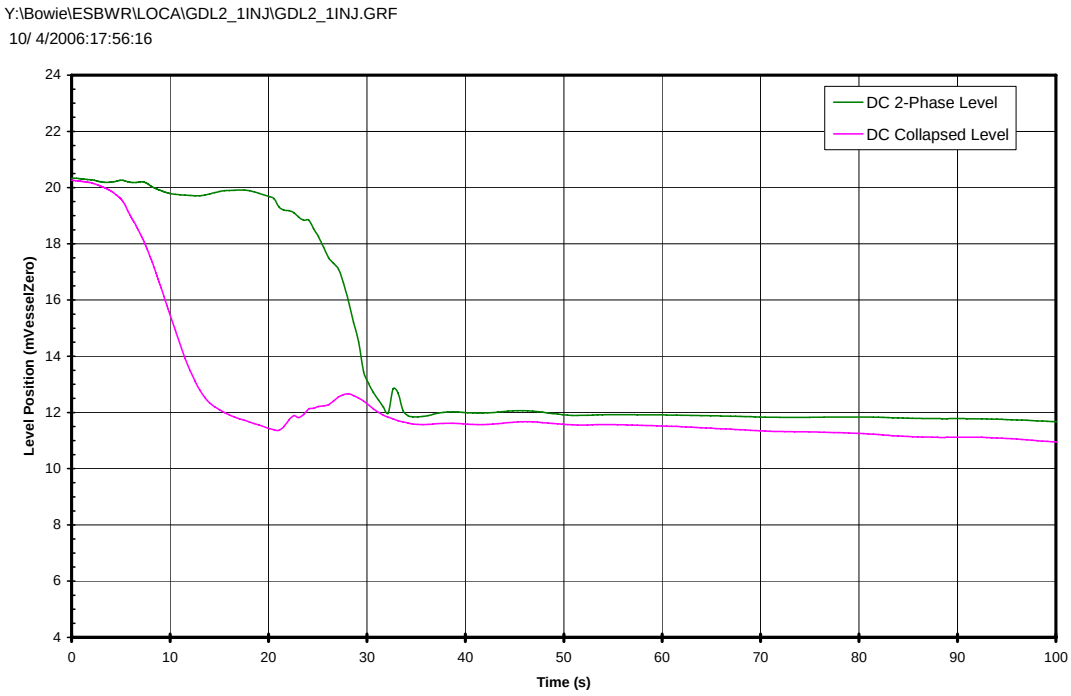

Figure 6.3-33b. Downcomer Water Level, GDCS Injection Line Break, 1 GDCS Valve Failure

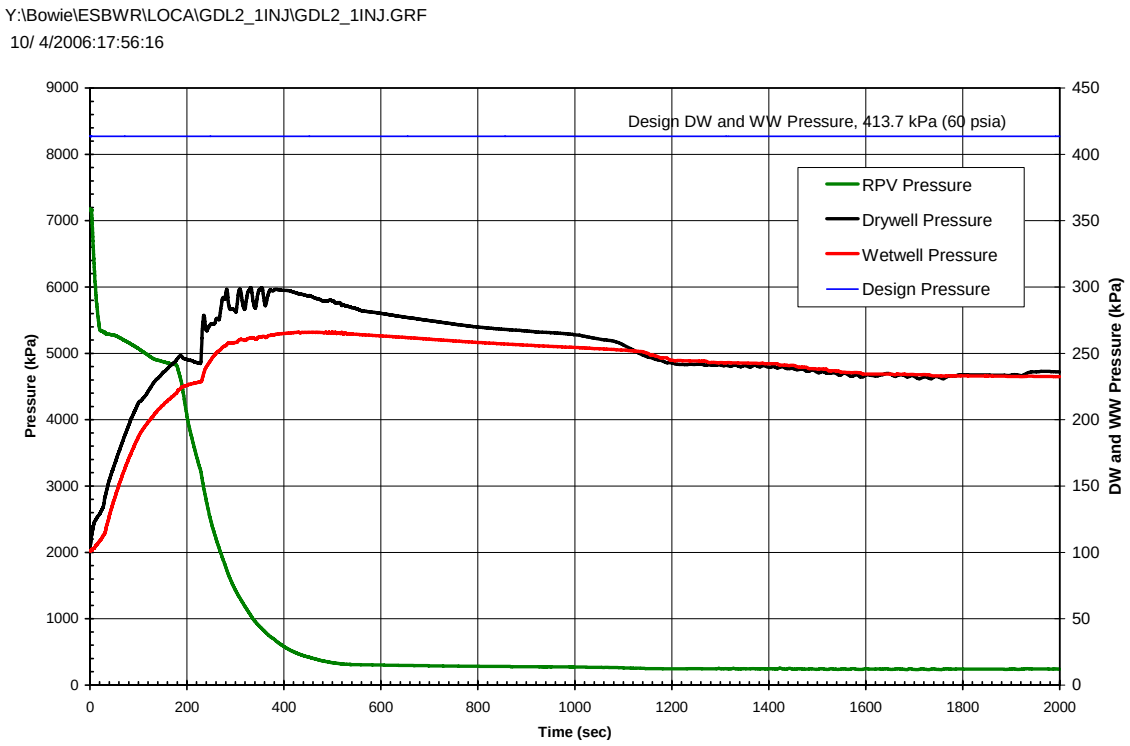

Figure 6.3-34a. System Pressures, GDCS Injection Line Break, 1 GDCS Valve Failure

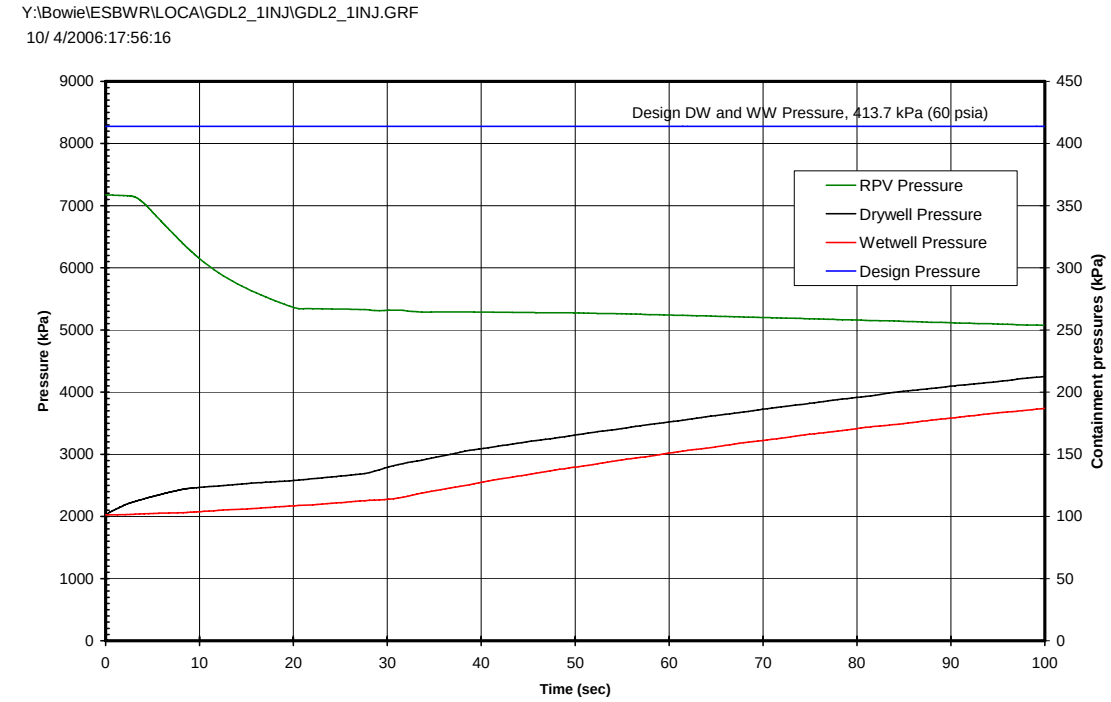

Figure 6.3-34b. System Pressures, GDCS Injection Line Break, 1 GDCS Valve Failure

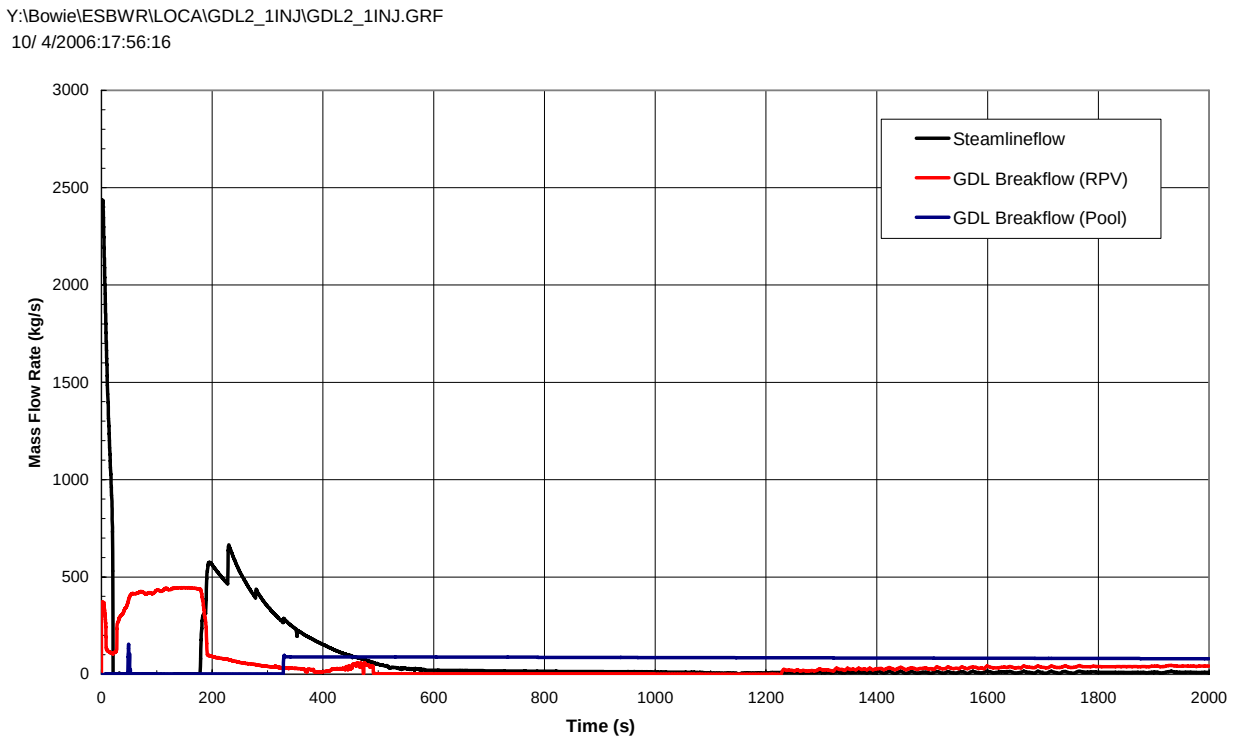

Figure 6.3-35a. Steam Line and Break Flow, GDCS Injection Line Break, 1 GDCS Valve Failure

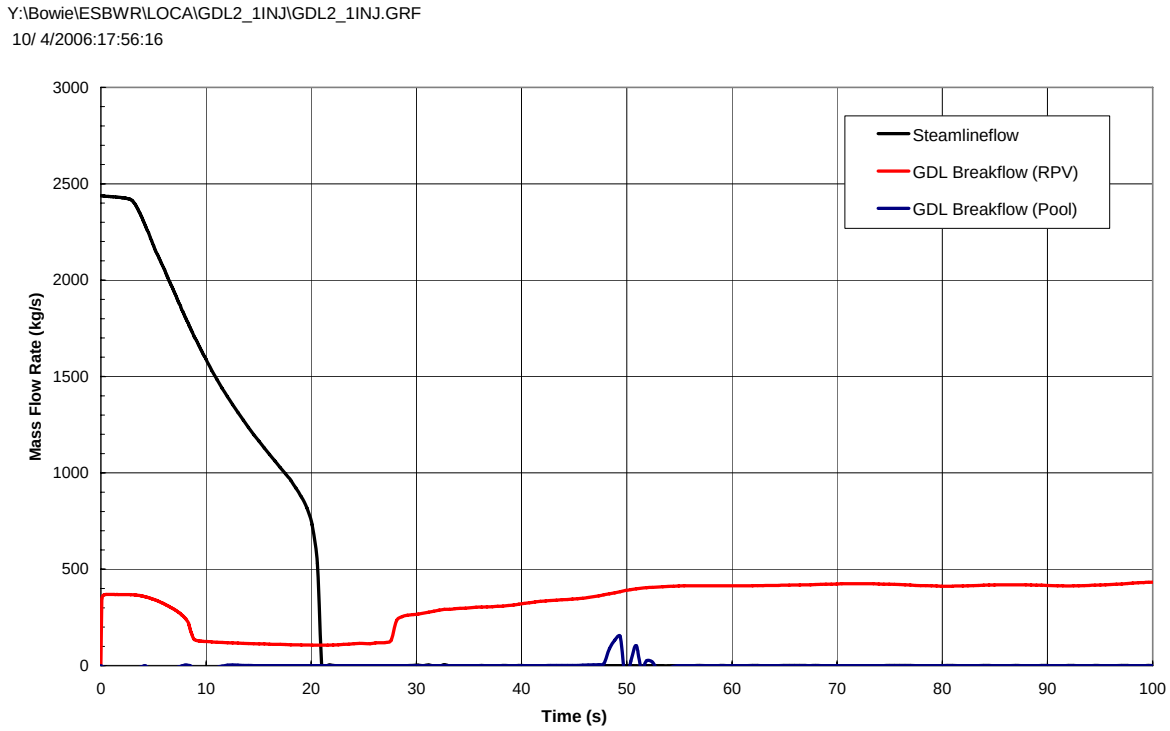

Figure 6.3-35b. Steam Line and Break Flow, GDCS Injection Line Break, 1 GDCS Valve Failure

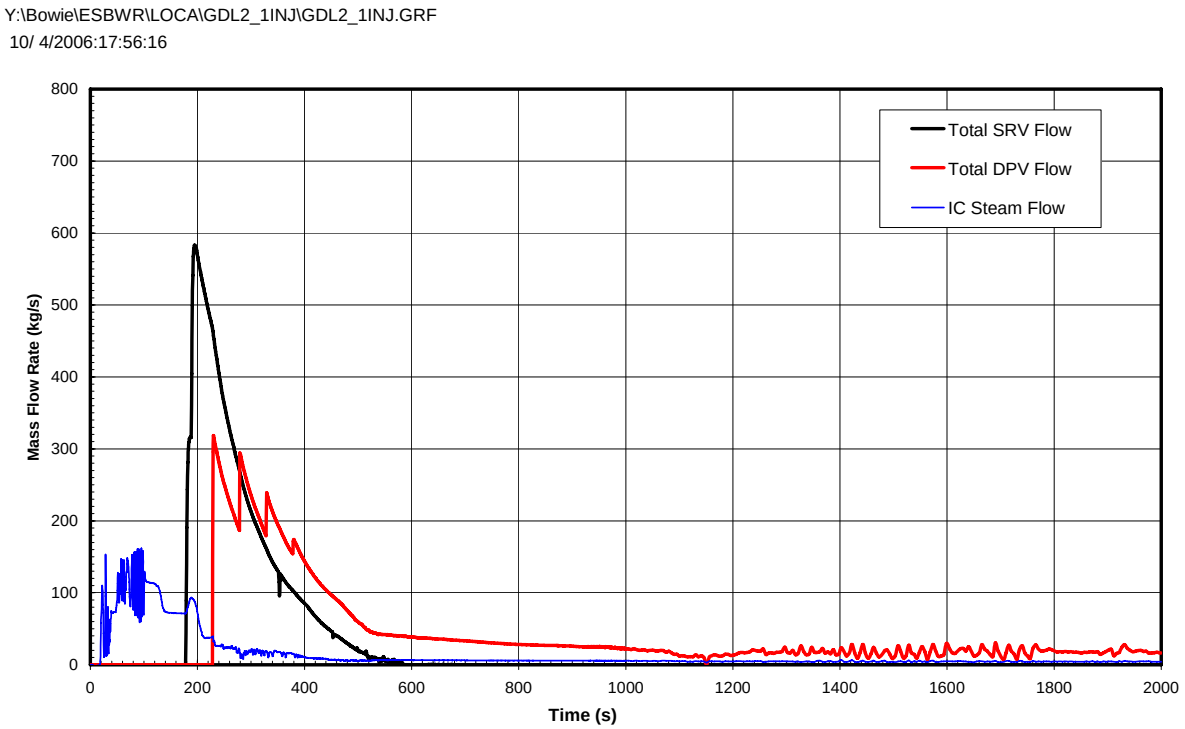

Figure 6.3-36a. ADS Flow, GDCS Injection Line Break, 1 GDCS Valve Failure

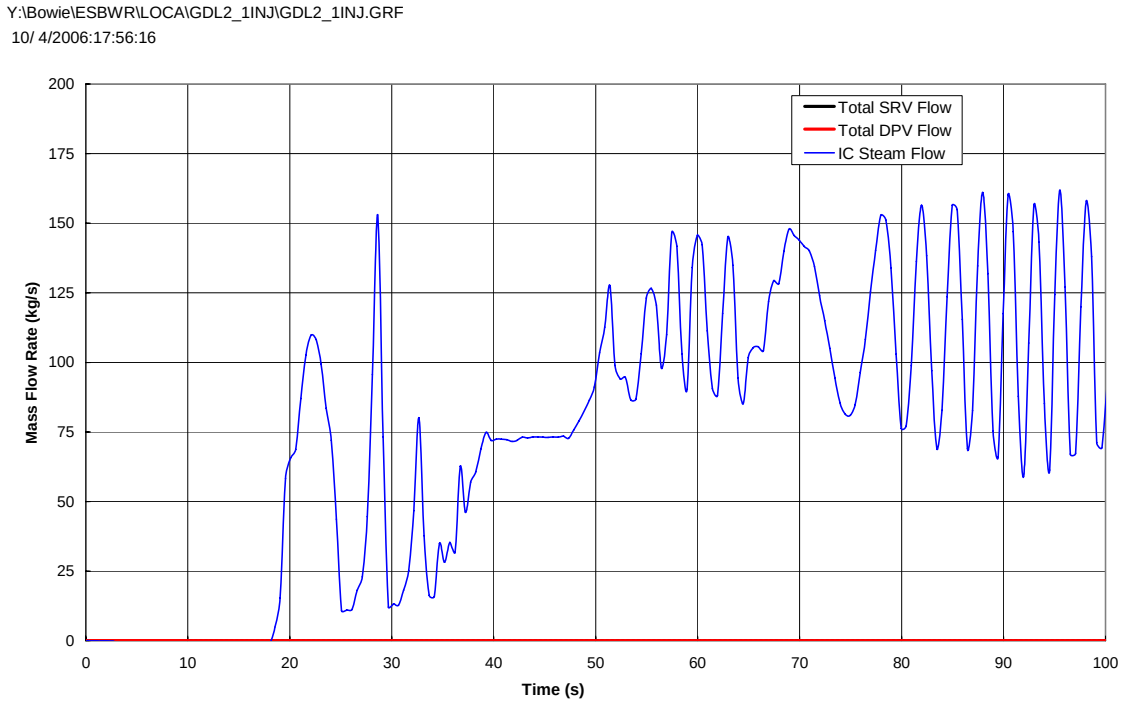

Figure 6.3-36b. ADS Flow, GDCS Injection Line Break, 1 GDCS Valve Failure

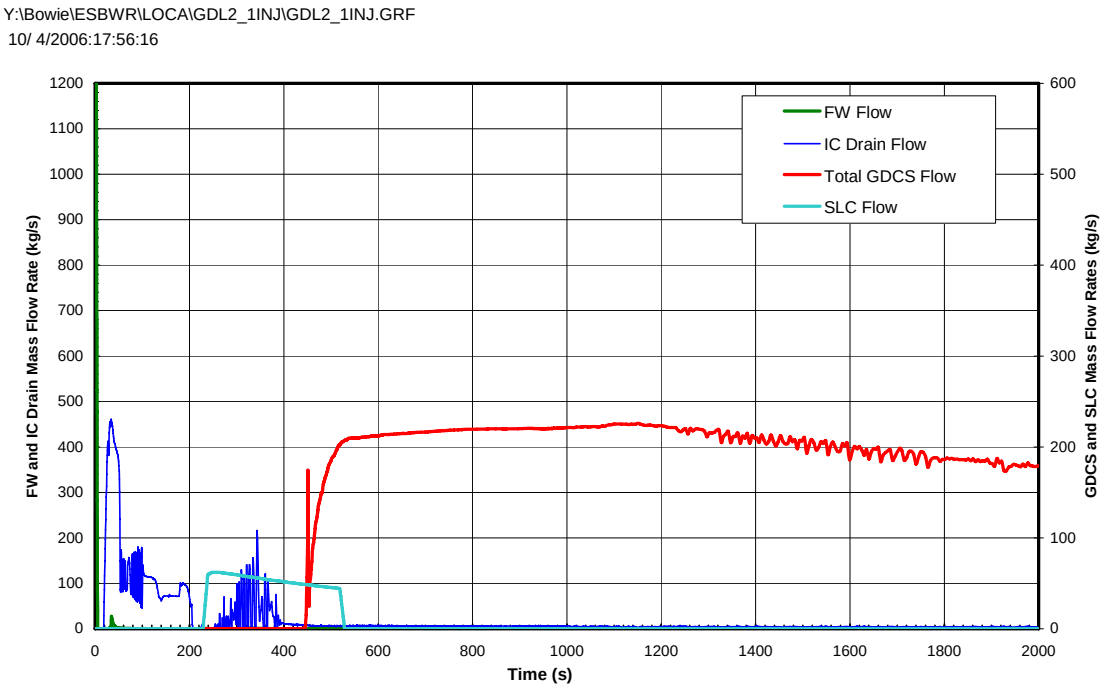

Figure 6.3-37a. Flows Into Vessel, GDCS Injection Line Break, 1 GDCS Valve Failure

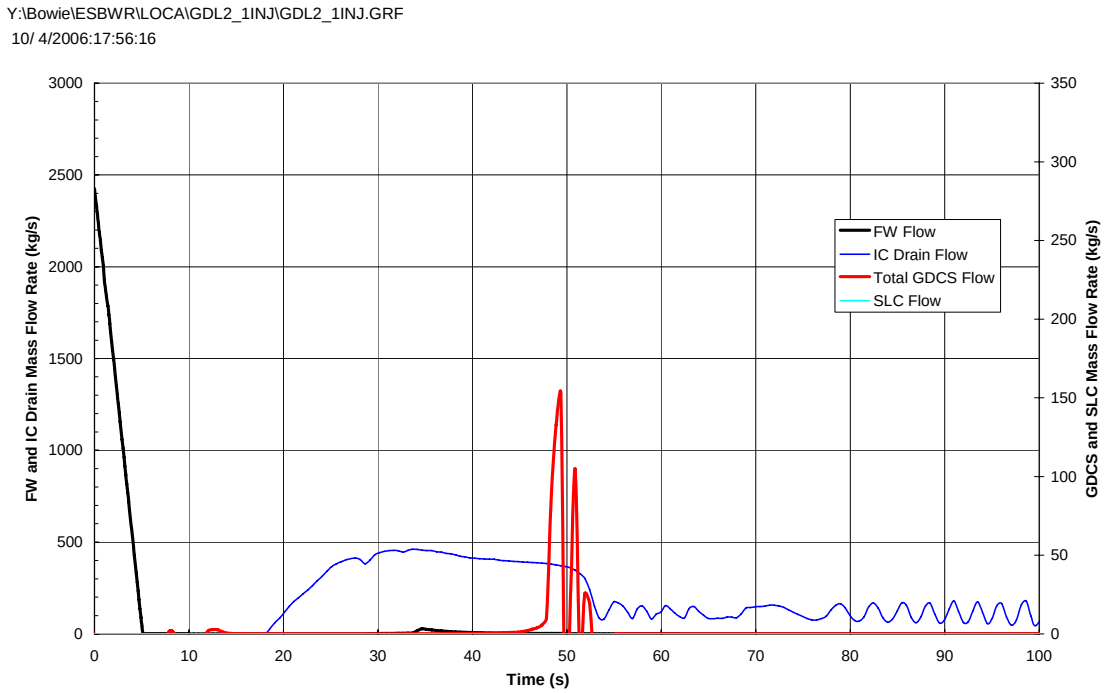

Figure 6.3-37b. Flows Into Vessel, GDCS Injection Line Break, 1 GDCS Valve Failure

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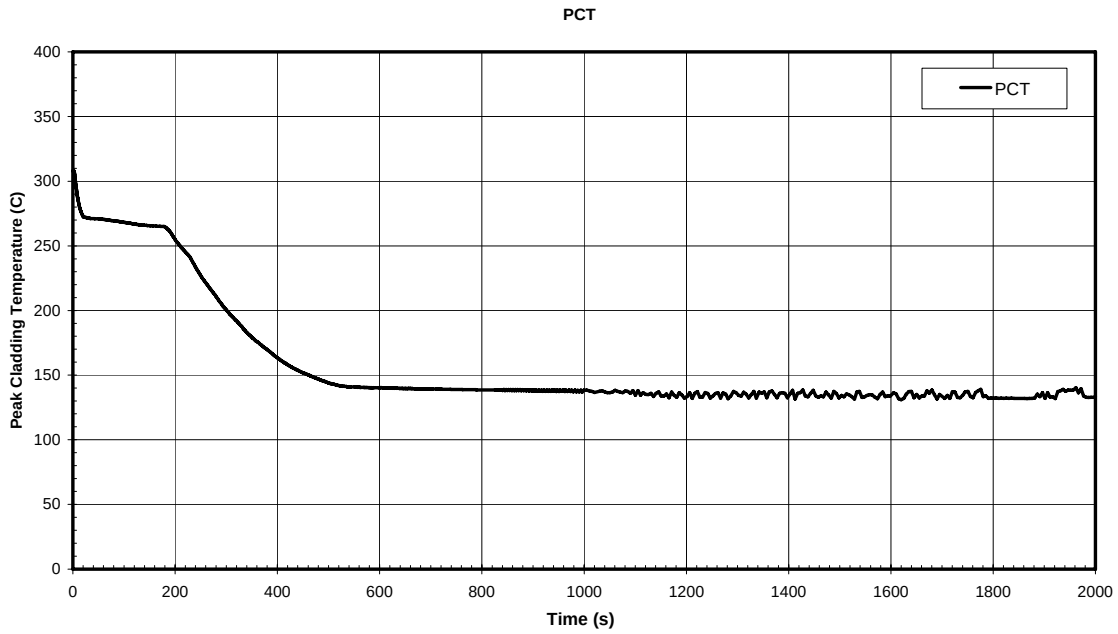

Figure 6.3-38a. PCT, GDCS Injection Line Break, 1 GDCS Valve Failure

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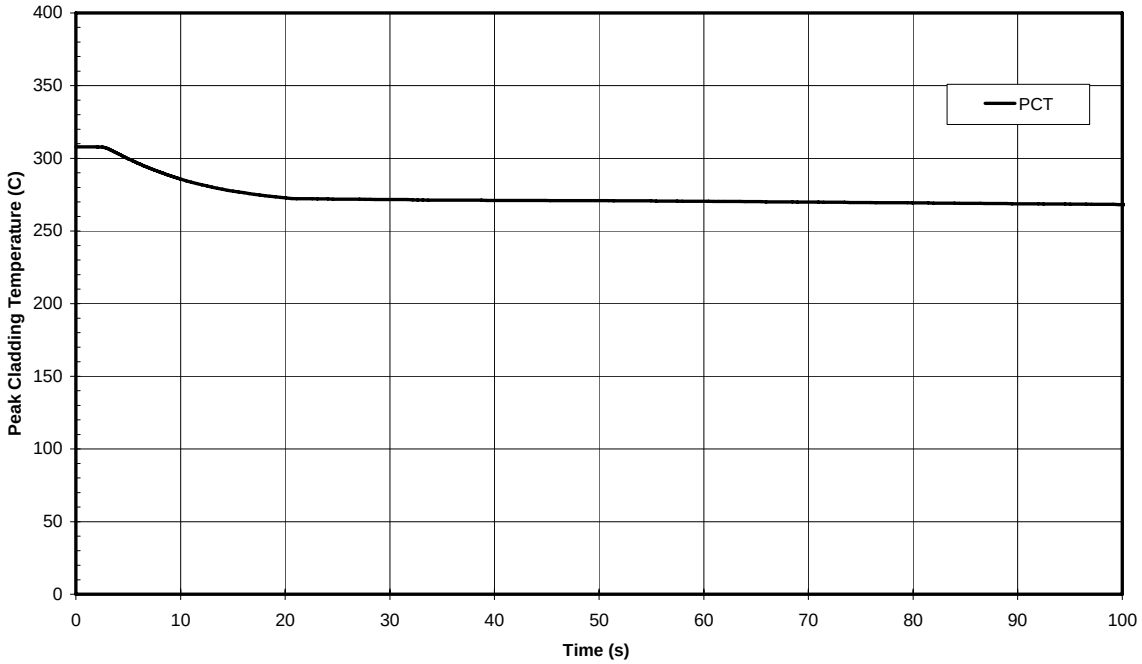

Figure 6.3-38b. PCT, GDCS Injection Line Break, 1 GDCS Valve Failure

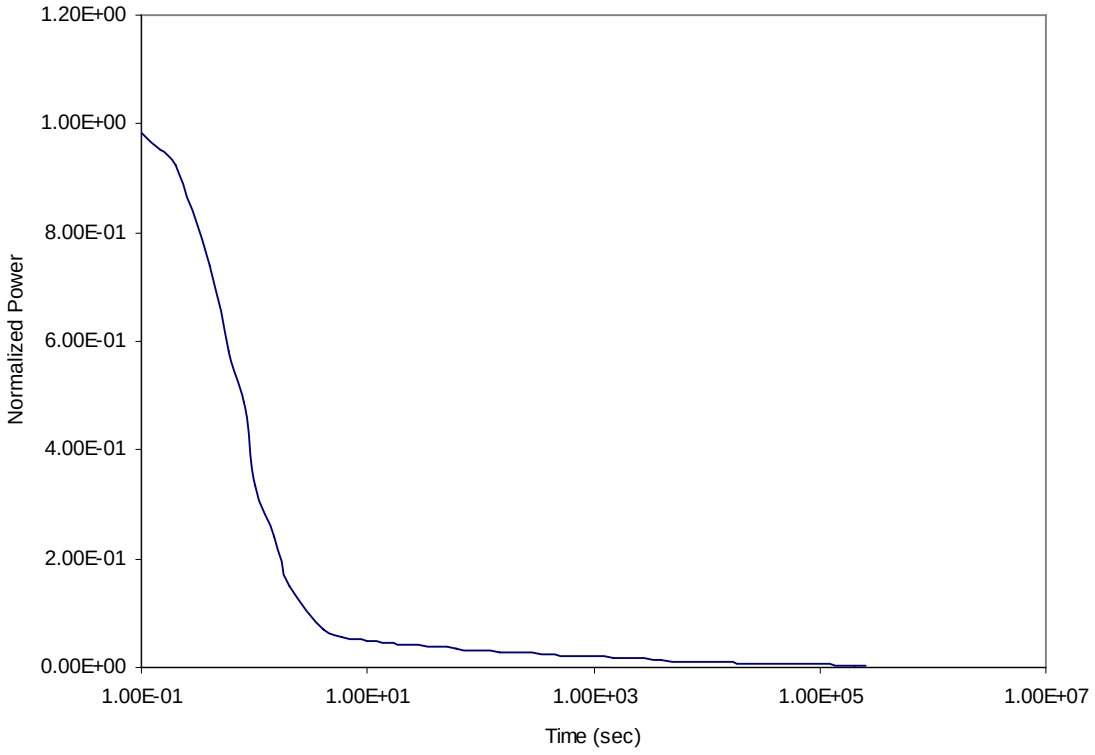

Figure 6.3-39. Normalized Shutdown Power