ArevaEPRDCPEm Resource

From:	Pederson Ronda M (AREVA NP INC) [Ronda.Pederson@areva.com]
Sent:	Thursday, April 30, 2009 8:19 PM
To:	Getachew Tesfaye
Cc:	BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); HOLM Jerald S (EXT); GUCWA Len T (EXT)
Subject:	Response to U.S. EPR Design Certification Application RAI No. 167, FSAR Ch. 15, Supplement 2 (Part 1 of 2)
Attachments:	RAI 167 Supplement 2 Response US EPR DC (part 1 of 2).pdf

Getachew,

AREVA NP Inc. (AREVA NP) provided responses to 4 of the 17 questions of RAI No. 167 on February 19, 2009. Supplement 1 to AREVA NP's response to RAI No. 167 was sent March 31, 2009 to address 5 of the remaining questions.

The response files, "RAI 167 Supplement 2 Response US EPR DC (part 1 of 2).pdf" and "RAI 167 Supplement 2 Response US EPR DC (part 2 of 2).pdf" provide technically correct and complete responses to 5 of the remaining 8 questions, as committed. Due to transmittal size limitations, the response file has been separated to e-mail the response in two parts.

Appended are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 167 Question 15.06.05-33.

The following table indicates the respective pages in the response document, "RAI 167 Supplement 2 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 167 – 15.06.05-30	2	6
RAI 167 – 15.06.05-31	7	20
RAI 167 – 15.06.05-32	21	22
RAI 167 – 15.06.05-33	23	24
RAI 167 – 15.06.05-36	25	28

The schedule for a technically correct and complete response to the remaining three questions in RAI No. 167 remains unchanged and is provided below:

Question #	Response Date
RAI 167 – 15.06.05-29	May 29, 2009
RAI 167 – 15.06.05-34	May 29, 2009
RAI 167 – 15.06.05-37	May 29, 2009

Sincerely,

Ronda Pederson
ronda.pederson@areva.com
Licensing Manager, U.S. EPR Design Certification
AREVA NP Inc.
An AREVA and Siemens company
3315 Old Forest Road

Lynchburg, VA 24506-0935
Phone: 434-832-3694
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From: Pederson Ronda M (AREVA NP INC)
Sent: Tuesday, March 31, 2009 7:56 PM
To: 'Getachew Tesfaye'
Cc: BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); GUCWA Len T (EXT)
Subject: Response to U.S. EPR Design Certification Application RAI No. 167, Supplement 1

Getachew,

On February 19, 2009, AREVA NP Inc. (AREVA NP) provided technically correct and complete responses to 4 of the 17 questions in RAI No. 167. The proprietary and non-proprietary versions of the response to RAI No. 167, Supplement 1 are submitted via AREVA NP Inc. letter, "Response to U.S. EPR Design Certification Application RAI No. 167" – NRC 09:030, dated March 31, 2009. The enclosure to that letter provides technically correct and complete responses to 5 of the remaining 13 questions in RAI No. 167. An affidavit to support withholding of information from public disclosure, per 10CFR2.390(b), is provided as an enclosure to the letter.

The following table indicates the RAI No. 167 questions that are answered in the subject AREVA NP Inc. letter.

Question #	Start Page	End Page
RAI 167—15.06.05-28	2	4
RAI 167—15.06.05-38	5	34
RAI 167—15.06.05-39	35	35
RAI 167—15.06.05-41	36	36
RAI 167—15.06.05-42	37	46

The schedule for a technically correct and complete response to the remaining eight questions remains unchanged and is provided below:

Question #	Response Date
RAI 167—15.06.05-29	May 29, 2009
RAI 167—15.06.05-30	May 1, 2009
RAI 167—15.06.05-31	May 1, 2009
RAI 167—15.06.05-32	May 1, 2009
RAI 167—15.06.05-33	May 1, 2009
RAI 167—15.06.05-34	May 29, 2009
RAI 167—15.06.05-36	May 1, 2009
RAI 167—15.06.05-37	May 29, 2009

Sincerely,

Ronda Pederson

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From: Pederson Ronda M (AREVA NP INC)
Sent: Thursday, February 19, 2009 7:19 PM
To: 'Getachew Tesfaye'
Cc: DELANO Karen V (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); GUCWA Len T (EXT)
Subject: Response to U.S. EPR Design Certification Application RAI No. 167, FSAR Ch. 15

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 167 Response US EPR DC.pdf" provides technically correct and complete responses to 4 of the 17 questions.

RAI 167, Question 15.06.05-40 requested that AREVA NP provide S-RELAP5 code input files. Since the requested files contain information that AREVA NP considers proprietary, the information is provided on a proprietary compact disk (CD) as an enclosure to AREVA NP Inc. letter, "Response to U.S. EPR Design Certification Application RAI No. 167, Question 15.06.05-40– SRELAP5 Code Input Files," dated February 19, 2009. An affidavit to support withholding of information from public disclosure, per 10CFR2.390(b), is provided as an enclosure to that letter.

The following table indicates the respective pages in the response document, "RAI 167 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 167—15.03.03-15.03.04-9	2	3
RAI 167—15.06.05-27	4	5
RAI 167—15.06.05-28	6	6
RAI 167—15.06.05-29	7	7
RAI 167—15.06.05-30	8	8
RAI 167—15.06.05-31	9	9
RAI 167—15.06.05-32	10	10
RAI 167—15.06.05-33	11	11
RAI 167—15.06.05-34	12	12
RAI 167—15.06.05-35	13	15
RAI 167—15.06.05-36	16	16
RAI 167—15.06.05-37	17	17
RAI 167—15.06.05-38	18	18
RAI 167—15.06.05-39	19	19
RAI 167—15.06.05-40	20	22

RAI 167—15.06.05-41	23	23
RAI 167—15.06.05-42	24	24

A complete answer is not provided for 13 of the 17 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 167—15.06.05-28	April 1, 2009
RAI 167—15.06.05-29	May 29, 2009
RAI 167—15.06.05-30	May 1, 2009
RAI 167—15.06.05-31	May 1, 2009
RAI 167—15.06.05-32	May 1, 2009
RAI 167—15.06.05-33	May 1, 2009
RAI 167—15.06.05-34	May 29, 2009
RAI 167—15.06.05-36	May 1, 2009
RAI 167—15.06.05-37	May 29, 2009
RAI 167—15.06.05-38	April 1, 2009
RAI 167—15.06.05-39	April 1, 2009
RAI 167—15.06.05-41	April 1, 2009
RAI 167—15.06.05-42	April 1, 2009

Sincerely,

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From: Getachew Tesfaye [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Friday, January 23, 2009 10:22 AM
To: ZZ-DL-A-USEPR-DL
Cc: Fred Forsaty; Jaclyn Dorn; John Budzynski; Shanlai Lu; Joseph Donoghue; Jason Carneal; Prosanta Chowdhury; Joseph Colaccino; Meena Khanna; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 167 (1711, 1838,1832), FSAR Ch. 15

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on January 6, 2009, and discussed with your staff on January 16, 2009. Draft RAI Question 15.03.01-15.03.02-1 was deleted and Draft RAI Questions 15.06.05-39 and 15.06.05-42 were modified as a result of that discussion. The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs. For any RAIs that cannot be answered within 30 days, it is expected that a date for receipt of this information will be provided to the staff within the 30 day period so that the staff can assess how this information will impact the published schedule.

Thanks,

Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
(301) 415-3361

Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 445

Mail Envelope Properties (5CEC4184E98FFE49A383961FAD402D31DFFBCE)

Subject: Response to U.S. EPR Design Certification Application RAI No. 167, FSAR Ch. 15, Supplement 2 (Part 1 of 2)
Sent Date: 4/30/2009 8:19:03 PM
Received Date: 4/30/2009 8:19:13 PM
From: Pederson Ronda M (AREVA NP INC)

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Post Office: AUSLYNCMX02.adom.ad.corp

Files	**Size**	**Date & Time**
MESSAGE	8148	4/30/2009 8:19:13 PM
RAI 167 Supplement 2 Response US EPR DC (part 1 of 2).pdf		3439358

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

Response to

Request for Additional Information No. 167, Supplement 2

1/23/2009

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 15.03.01-15.03.02 - Loss of Forced Reactor Coolant Flow Including Trip of Pump Motor and Flow Controller Malfunctions
SRP Section: 15.03.03-15.03.04 - Reactor Coolant Pump Rotor Seizure and Reactor Coolant Pump Shaft Break
SRP Section: 15.06.05 - Loss of Coolant Accidents Resulting From Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary

Application Section: FSAR Ch 15

QUESTIONS for Reactor System, Nuclear Performance and Code Review (SRSB)

Question 15.06.05-30:

Explain the availability, quantity and distribution of emergency core cooling system (ECCS) flow for each individual loop consistent with the analysis assumptions made. Address the possibility for conditions that deprive a loop from any ECCS injection. If such a possibility exists, address associated effects on the restart of the natural circulation and mixing in the corresponding cold loop.

Reference: SBLOCA Analysis Report 32-9057270-000 in Support of Boron Dilution and Boron Precipitation Effects, dated December 14, 2006.

Response to Question 15.06.05-30:

Table 15.06.05-30-1 lists the available quantities of water and the boron concentrations in the in-containment refueling water storage tank (IRWST), extra borating system (EBS) tanks, and accumulators. The IRWST is the safety-related source of water for emergency core cooling in the event of a LOCA. During a LOCA, the IRWST collects the discharge from the reactor coolant system (RCS) , allowing it to be re-circulated by the safety injection system (SIS). The medium head safety injection (MHSI) and low head safety injection (LHSI) systems inject continuously upon initiation when the pressure drops below their respective deadhead pressures. The accumulators inject water in a passive manner as the RCS pressure allows. Because of the lower pressures, the larger breaks would use all of the accumulator water.

The U.S. EPR emergency core cooling system (ECCS) is arranged as four independent safety injection trains with the ability to cross-connect the LHSI trains when one LHSI train is inoperable. The EBS has two independent trains, each supplying two cold legs; Figure 15.06.05-30-1 shows the functional arrangement. The design basis for the ECCS includes provision for the single failure of one train and another train out of service for maintenance.

The most severe single failure is one that affects both the MHSI and the LHSI feeding one loop. With any train out for maintenance, both cross-connects are open. The presence and location of a single failure and maintenance creates multiple combinations of ECCS injection capability. The possible injection scenarios are shown in Table 15.06.05-30-2. If a system delivers all its flow to one loop, that loop receives a “1.” If the cross-connects are open, the LHSI system will deliver approximately half its flow to each of the two loops, therefore in the table each loop receives a “0.5.” Because some of the safety injection (SI) flow will be lost out the break (in loop 4), the “Effective SI” is the quantity of SI that participates in refilling the RCS. The result is that there are, within the design basis, scenarios for which one or two loops will not receive SI flow. These loops will receive backfill from the reactor vessel with water at the downcomer boron concentration as the plant refills. There is also the possibility, within the plant capabilities, that the emergency operating procedures will direct manual initiation of the EBS system for all the loops, including those that are not receiving SI. The accumulators inject into all four cold legs passively as the RCS pressure permits.

The U.S. EPR FSAR, Tier 2, Section 15.6.5 SBLOCA analyses are synonymous with Scenario 7 of Table 15.06.05-30-2. The analyses also assume the failure and maintenance outage of the steam generator emergency feedwater system (EFW) in loops 2 and 3. As seen with Scenario 7, loops 1 and 4 have active MHSI and LHSI pumps. Because one train of SI is out for maintenance, the cross connects are open, providing LHSI to loops 2 and 3 once the system depressurizes either via break flow or steam generator cooldown.

In the SBLOCA analyses, the cross-connects allow all four loops to be supplied with LHSI flow after sufficient system depressurization. For a differing set of failure assumptions in Scenario 6, two loops have no SI if the EBS is not manually activated. However, this condition is essentially the same as that explicitly analyzed. Because the flow out the break is limited by the break size, the quantity of water going into the RCS is independent of the combinations and will refill the RCS with essentially the same timing and sequence. During refill of the RCS crossover pipe, there is backflow of borated water for a loop with SI from the cold leg and by backflow from the reactor vessel for a loop without SI. These backflows and the dynamics of the refill will re-borate those crossover pipes before two-phase natural circulation begins. Thus, the analysis provides a reasonable representation of the system behavior for all injection scenarios.

The EBS system is not modeled in the S-RELAP5 analysis of these events because the code does not track the boron concentration and compared to the SI flow rates, the EBS flow rates are small. Specifically, two EBS trains each injecting into two of the four RCS loops (all four cold legs receive EBS) with a nominal flow rate in each train of 52 gpm, (minimum/maximum = 49 gpm (6.73 lbm/s)/55.4 gpm (7.61 lbm/s)). The presence or absence of the EBS is therefore negligible with regard to the time of the restart of natural circulation. However, the activation of the EBS does impact the RCS boron concentrations. The EBS tanks have a maximum injection time of ~12,000 seconds and a minimum injection time of ~8,000 seconds. If the system is activated during refill and remains on at the restart of natural circulation, the boron concentrations entering the core are maximized. If the EBS is not activated or the tanks empty prior to the restart of natural circulation, the boron concentration entering the core is reduced. Where this latter case is possible, the concentrations are evaluated with and without EBS injection.

FSAR Impact:

The FSAR will not be changed as a result of this question.

Table 15.06.05-30-1—Quantity and Distribution of ECCS and EBS

System	Liquid Volume, Maximum/Minimum (ft^3)	Boron Concentration, Maximum/Minimum (ppm)
IRWST	70,010 / 66,886	1900 / 1700
EBS (per tank, one tank per EBS train, two trains per EBS)	1295 / 997	7300 / 7000
Accumulator (one per loop)	1413 / 1236	1900 / 1700

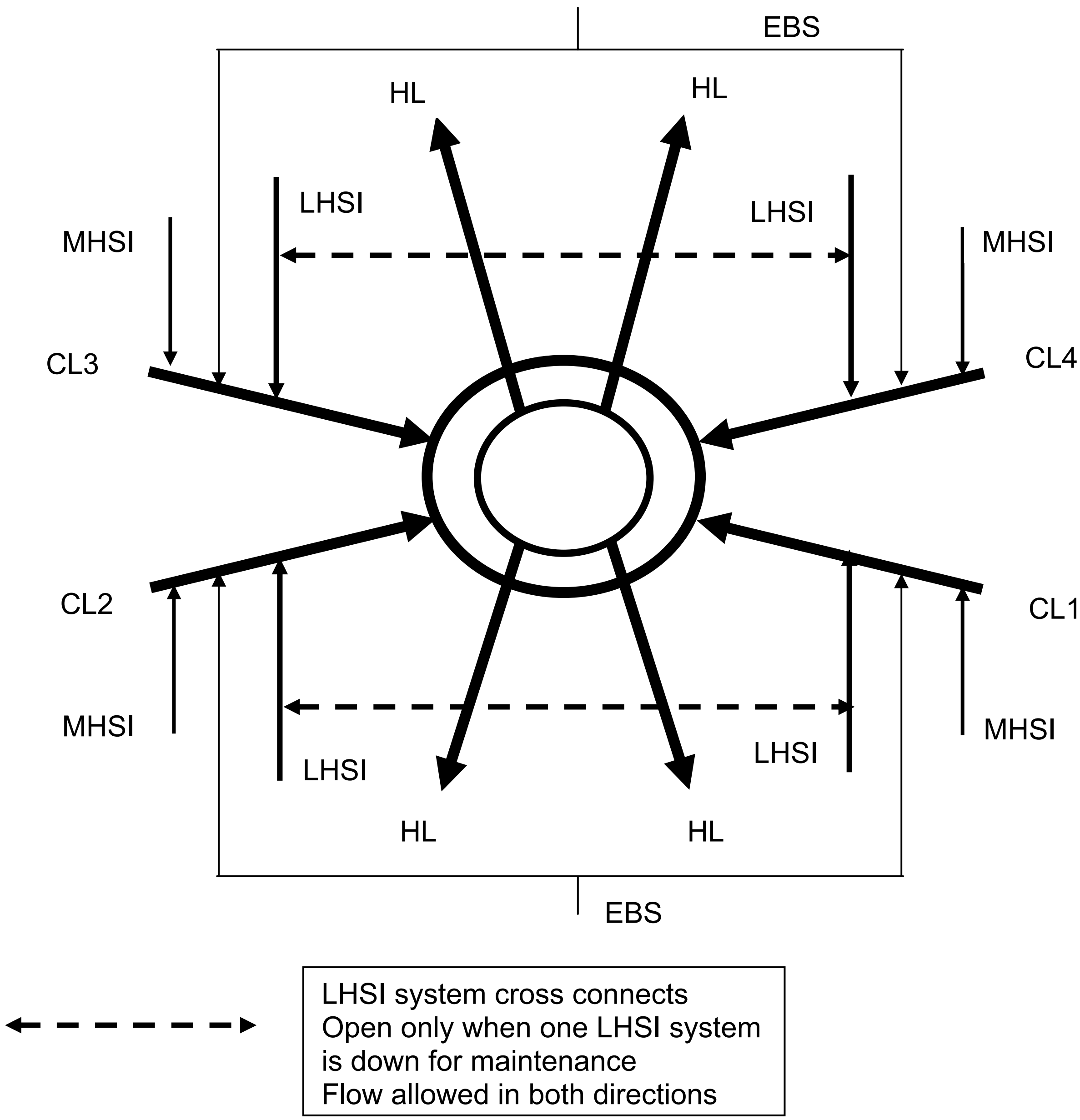
Table 15.06.05-30-2—Spectrum of Injection Scenarios

Injection Scenario	Single Failure Loop(1)	Loop Out for Maintenance	System	Loop 1	Loop 2	Loop 3	Loop 4(2)	Effective SI
1	0	0	MHSI	1	1	1	1	3 + Portion of SI not lost out break
			LHSI	1	1	1	1	3 + Portion of SI not lost out break
2	4	0	MHSI	1	1	1	0	3
			LHSI	1	1	1	0	3
3	2	0	MHSI	1	0	1	1	2 + Portion of SI not lost out break
			LHSI	1	0	1	1	2 + Portion of SI not lost out break
4	4	2(3)	MHSI	1	0	1	0	2
			LHSI	0.5	0.5	0.5	0.5	1.5 + Portion of SI not lost out break
5	4	3	MHSI	1	1	0	0	2
			LHSI	1	1	0	0	2
6	1	2	MHSI	0	0	1	1	1 + Portion of SI not lost out break
			LHSI	0	0	1	1	1 + Portion of SI not lost out break
7	2(3)	3	MHSI	1	0	0	1	1 + Portion of SI not lost out break
			LHSI	0.5	0.5	0.5	0.5	1.5 + Portion of SI not lost out break

Notes:

1. There is no difference between the single failure train and the train out for maintenance as both preclude the operation of one MHSI and one LHSI. Thus the condition of a single failure in loop 2 and a maintenance outage in loop 3 is synonymous with the condition of a single failure in loop 3 and a maintenance outage in loop 2.
2. Loop 4 is the loop with the break. Depending on the break size, some to all of the SI flows out the break.
3. Because Loop 1 and Loop 2 are cross-connected, this scenario is identical to that in which Loop 1 is the affected loop.

Figure 15.06.05-30-1—ECCS and EBS Functional Arrangement with RCS Loops



Question 15.06.05-31:

Describe the SG secondary response in terms of pressure, temperature and liquid inventory conditions for each individual SG consistent with the analysis assumptions made, including EFW availability and depressurization considerations.

Reference: SBLOCA Analysis Report 32-9057270-000 in Support of Boron Dilution and Boron Precipitation Effects, dated December 14, 2006.

Response to Question 15.06.05-31:

For the four boron dilution cases analyzed (1.5 inch – 4 inch breaks), the SG pressures are provided in Figures 15.06.05-31-1 through 15.06.05-31-4. The analysis of the 6 inch break was run to demonstrate the prevention of boron precipitation. For this 6 inch break, the continued cooldown of the SGs does not depressurize them below the reactor coolant system (RCS) pressure until approximately 12,000 seconds into the event. Thus, the SG pressures for this accident are not included.

The secondary side is near saturated conditions. Given the pressure, the boiling temperature is known for the secondary side of the SGs. The automatic partial cooldown that brings the SG pressure to 870 psia occurs over the first 1200 seconds. At 1800 seconds the plant operator initiates the continued SG cooldown at 90°F/hr. In the 4 inch SBLOCA case the SG pressure curve is not flat from 1200 seconds to 1800 seconds because the primary depressurization is more rapid than the secondary, and the primary side coolant passing through the SGs is cooling the secondary side. In the 2 inch break, there is a temporary pressure reduction in SG 2 between 9000 and 10,000 seconds due to backflow of cold safety injection water into the SG tube region prior to the start of circulation.

The water levels in SGs 1 and 4 are controlled by the emergency feedwater (EFW) system. Plots of the SG mass inventory are provided in Figures 15.06.05-31-5 through 15.06.05-31-8. Due to the maintenance of one train and the single failure assumption, EFW is not provided to SG 2 and SG 3, thereby allowing the levels and inventory in those SGs to fall into the tube regions (for the 1.5 inch and 2 inch case these generators dry out; for the 3 inch and 4 inch case some water remains). The plots of the EFW flows are provided in Figures 15.06.05-31-9 through 5.06.05-31-12. The quantity of EFW used by each SG is provided in Table 15.06.05-31-1 for each of the cases analyzed. For each break size the cases were run at least until the end of the operator-initiated 90ºF/hr cooldown. The EFW is not exhausted in either of the two EFW trains that operate for any of the break size cases. Furthermore, the U.S. EPR design allows any train pump to take suction from any storage tank and feed any SG. As such, all of the EFW is available for the operators to use as-needed. However, due to the energy lost out the break, the quantity of EFW actually used is adequate and decreases as the break size increases.

FSAR Impact:

The FSAR will not be changed as a result of this question.

Table 15.06.05-31-1—Emergency Feed Water Available and Used

Available or Used (approximate)	Train 1 (gallons)	Train 2 (gallons)	Train 3 (gallons)	Train 4 (gallons)	Total (gallons)
Available	111,000	100,000	100,000	111,000	422,000
1.5 inch Case	44,500	0	0	44,500	89,000
2 inch Case	31,000	0	0	29,000	60,000
3 inch Case	21,000	0	0	20,500	41,500
4 inch Case	16,000	0	0	17,000	33,000

Figure 15.06.05-31-1—Steam Generator Secondary Pressure for 1.5 inch Break

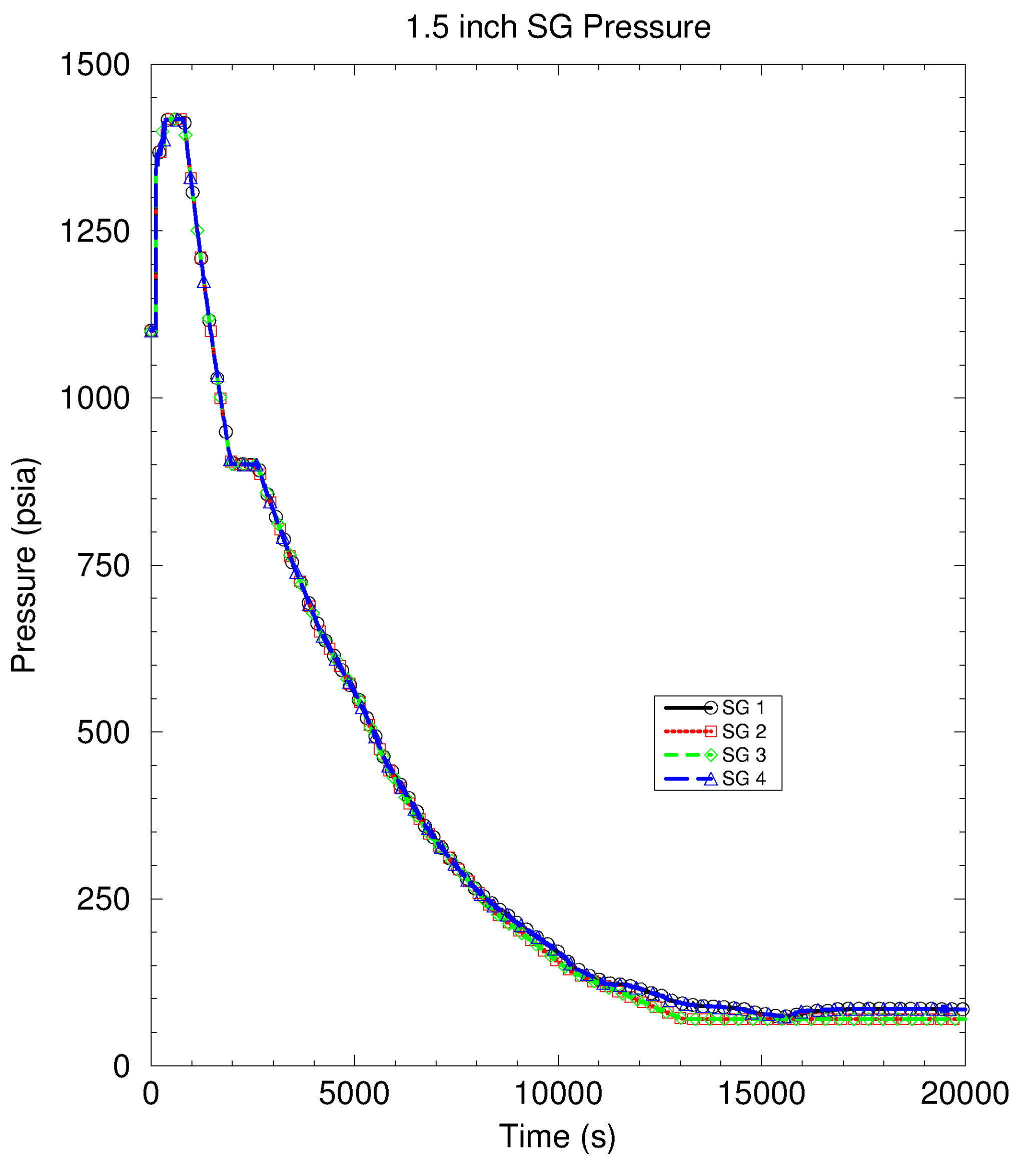


Figure 15.06.05-31-2—Steam Generator Secondary Pressure for 2 inch Break

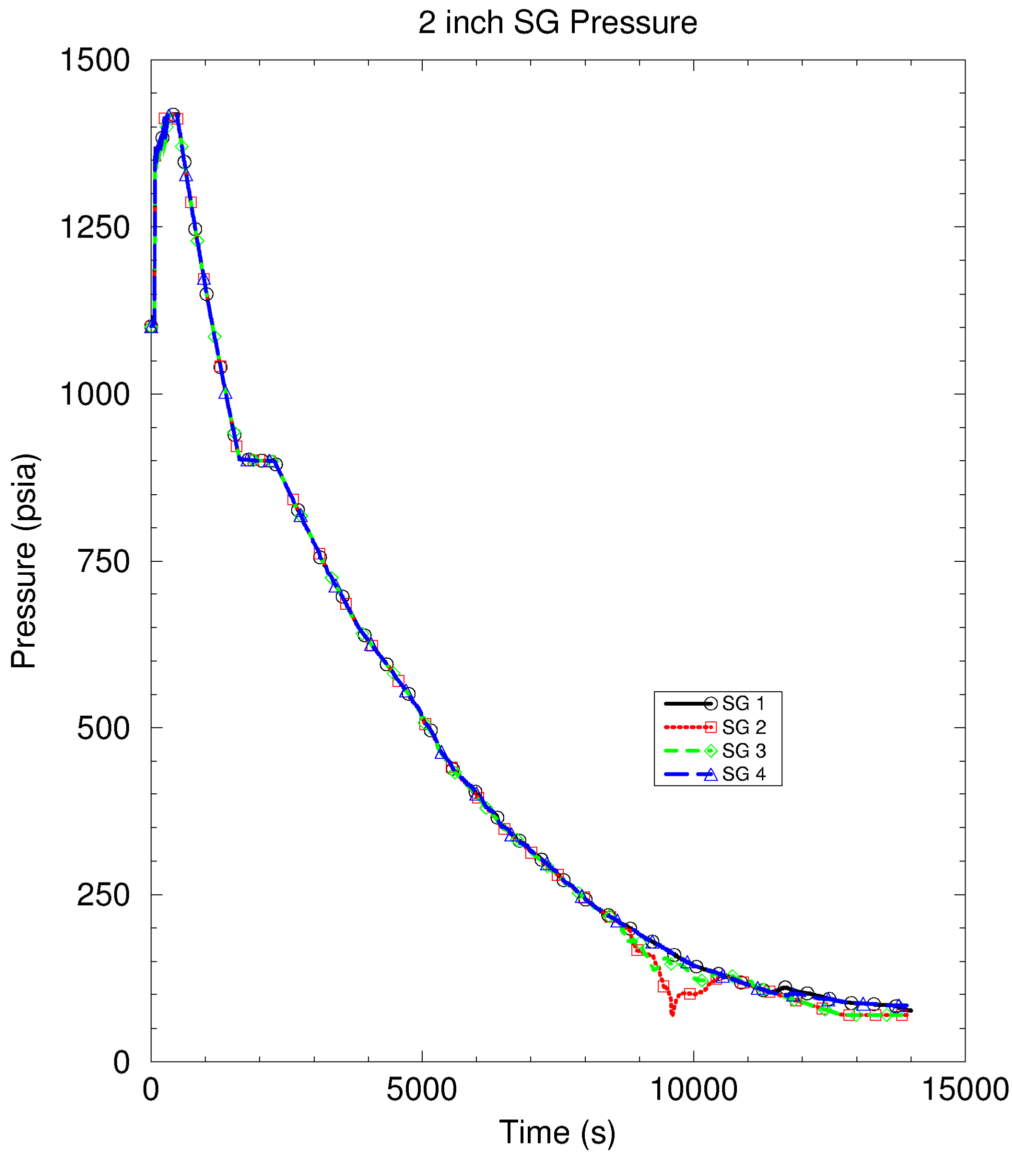


Figure 15.06.05-31-3—Steam Generator Secondary Pressure for 3 inch Break

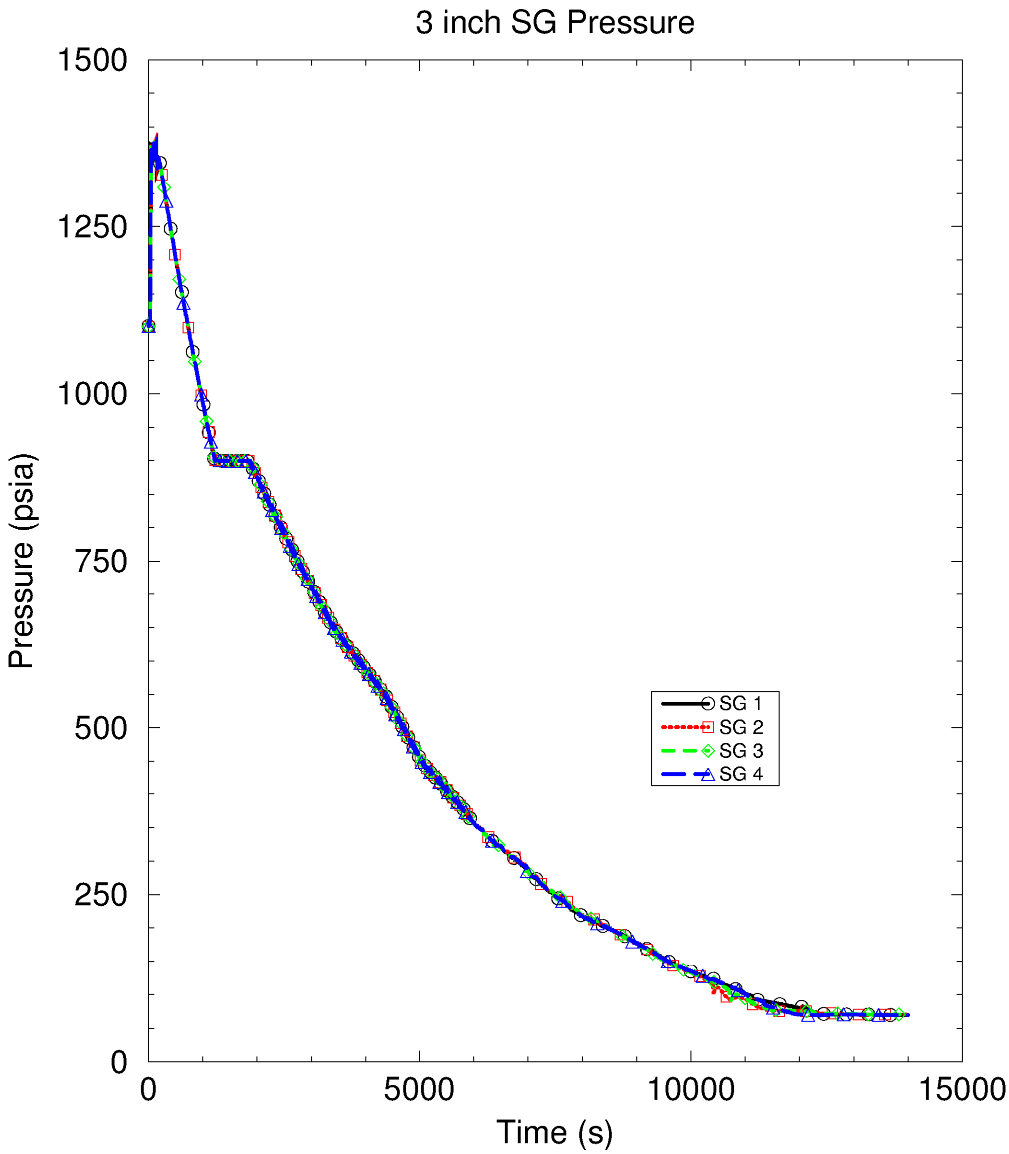


Figure 15.06.05-31-4—Steam Generator Secondary Pressure for 4 inch Break

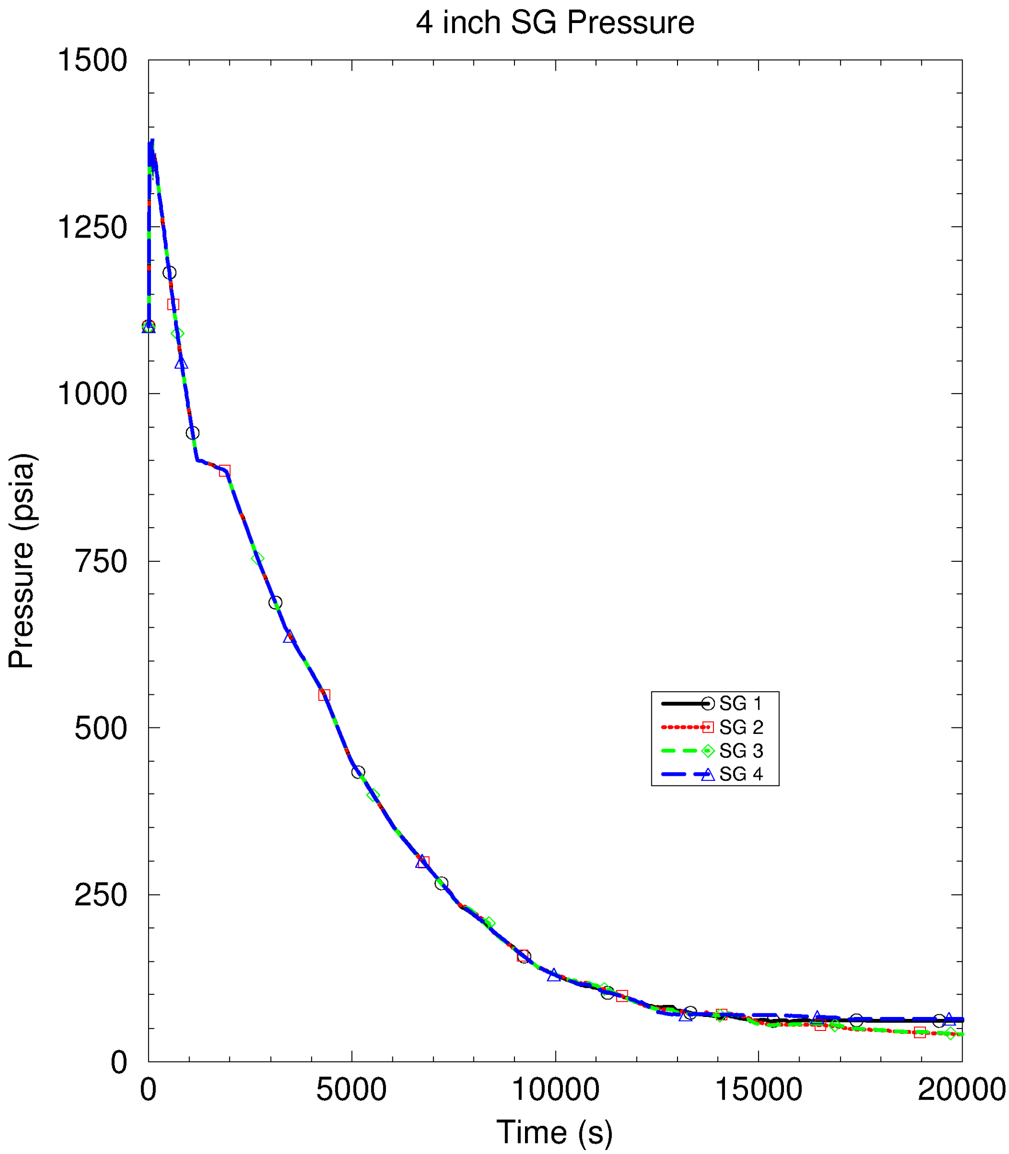


Figure 15.06.05-31-5—Steam Generator Secondary Inventory for 1.5 inch Break

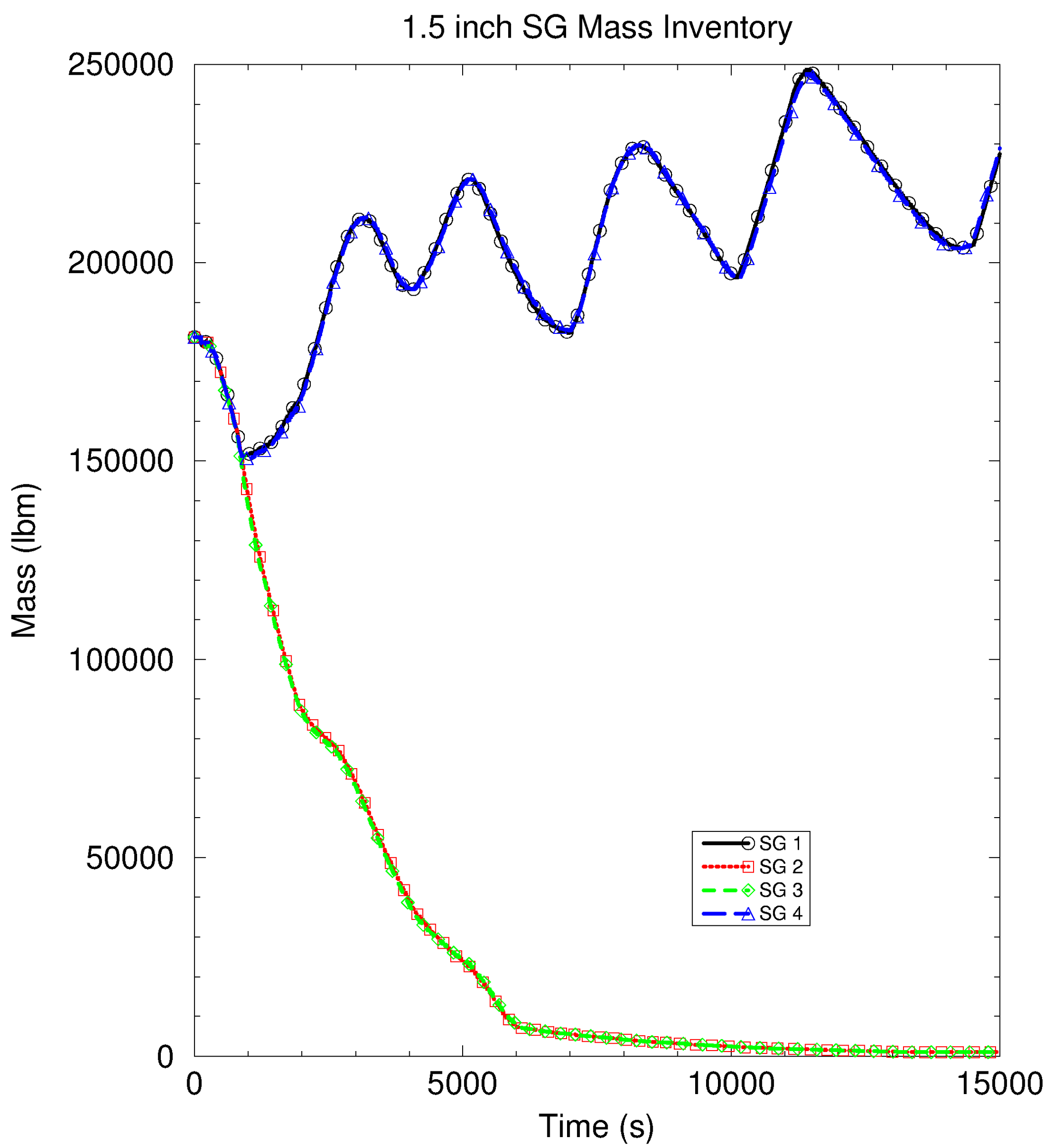


Figure 15.06.05-31-6—Steam Generator Secondary Inventory for 2 inch Break

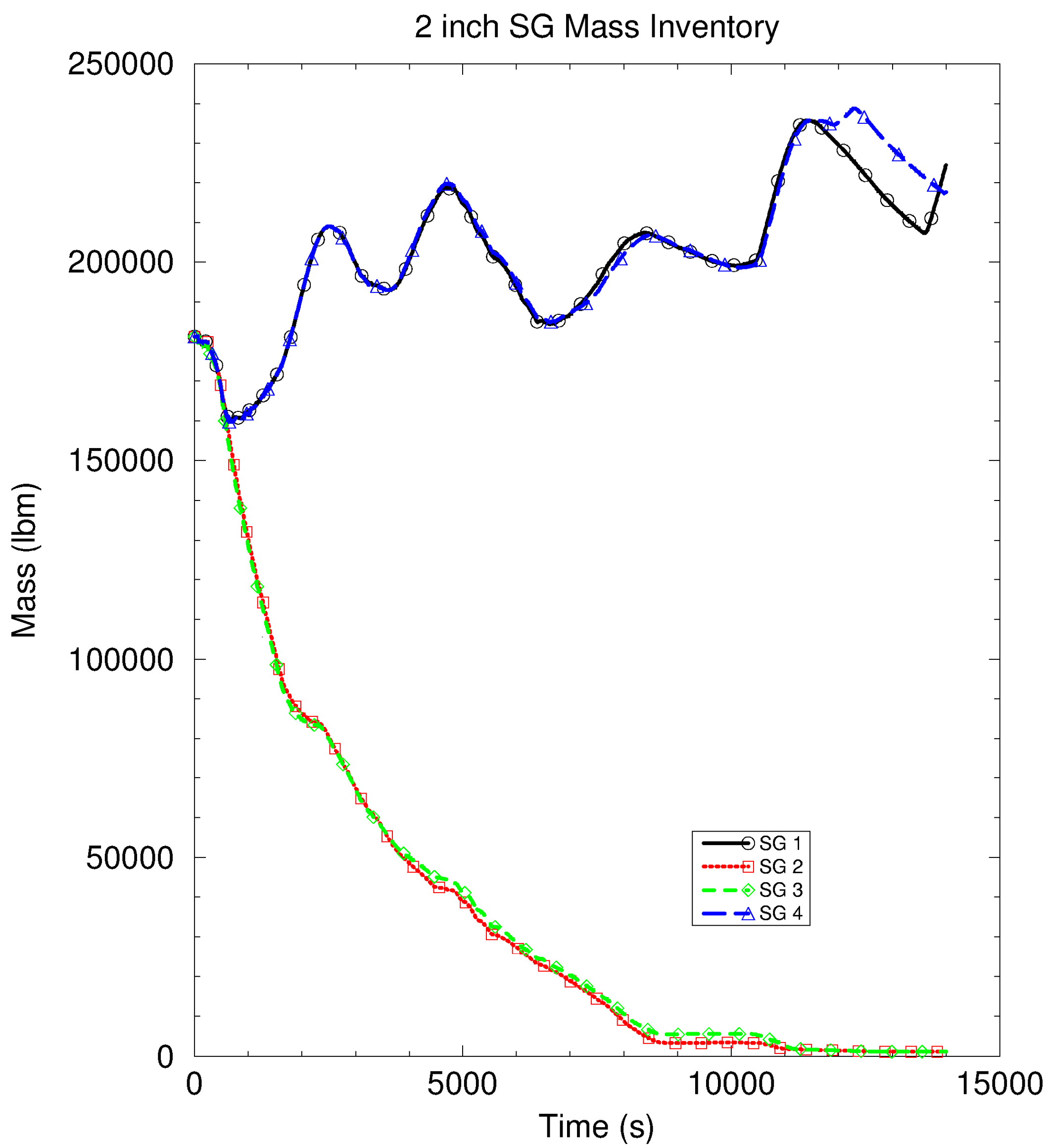


Figure 15.06.05-31-7—Steam Generator Secondary Inventory for 3 inch Break

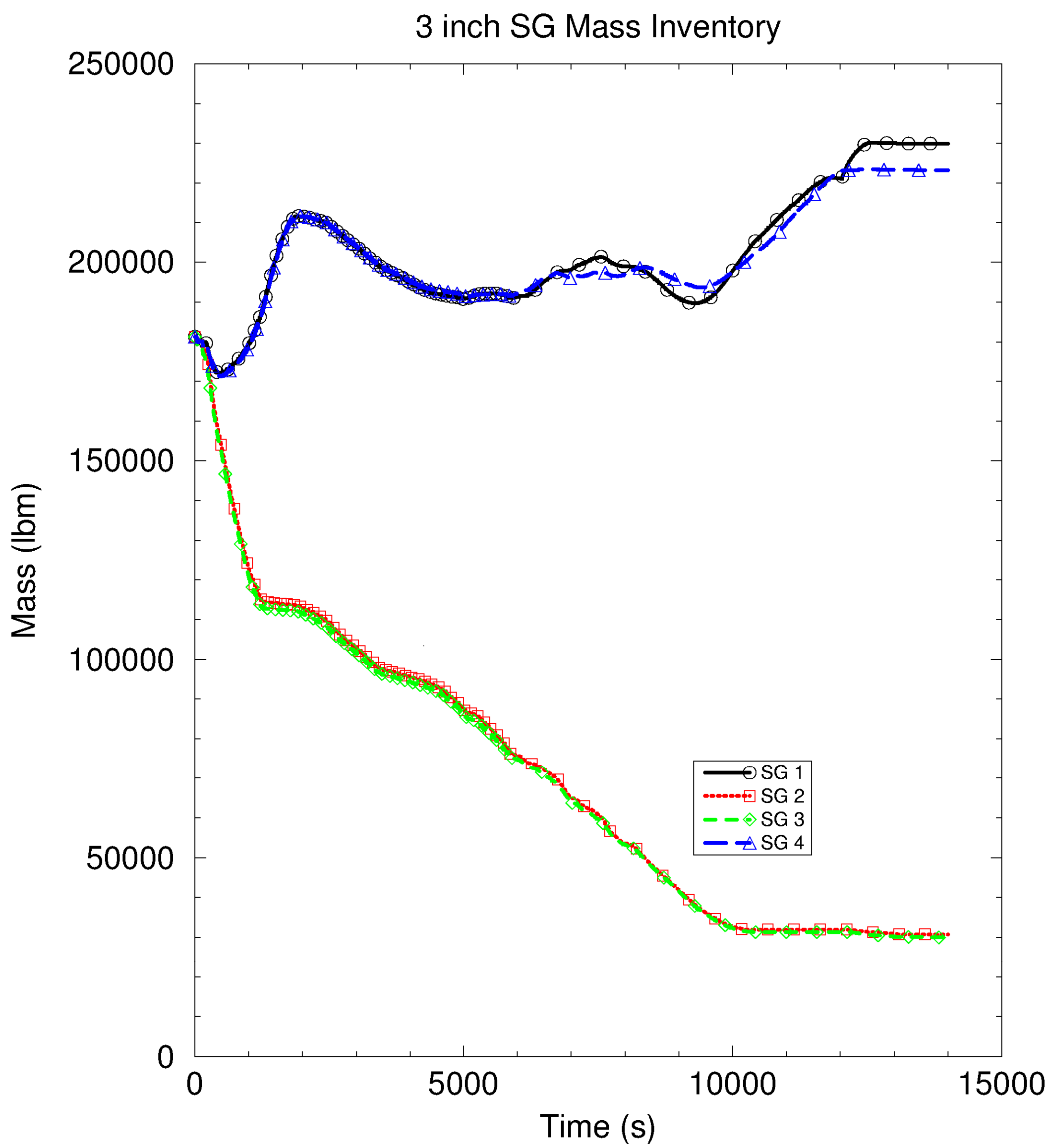


Figure 15.06.05-31-8—Steam Generator Secondary Inventory for 4 inch Break

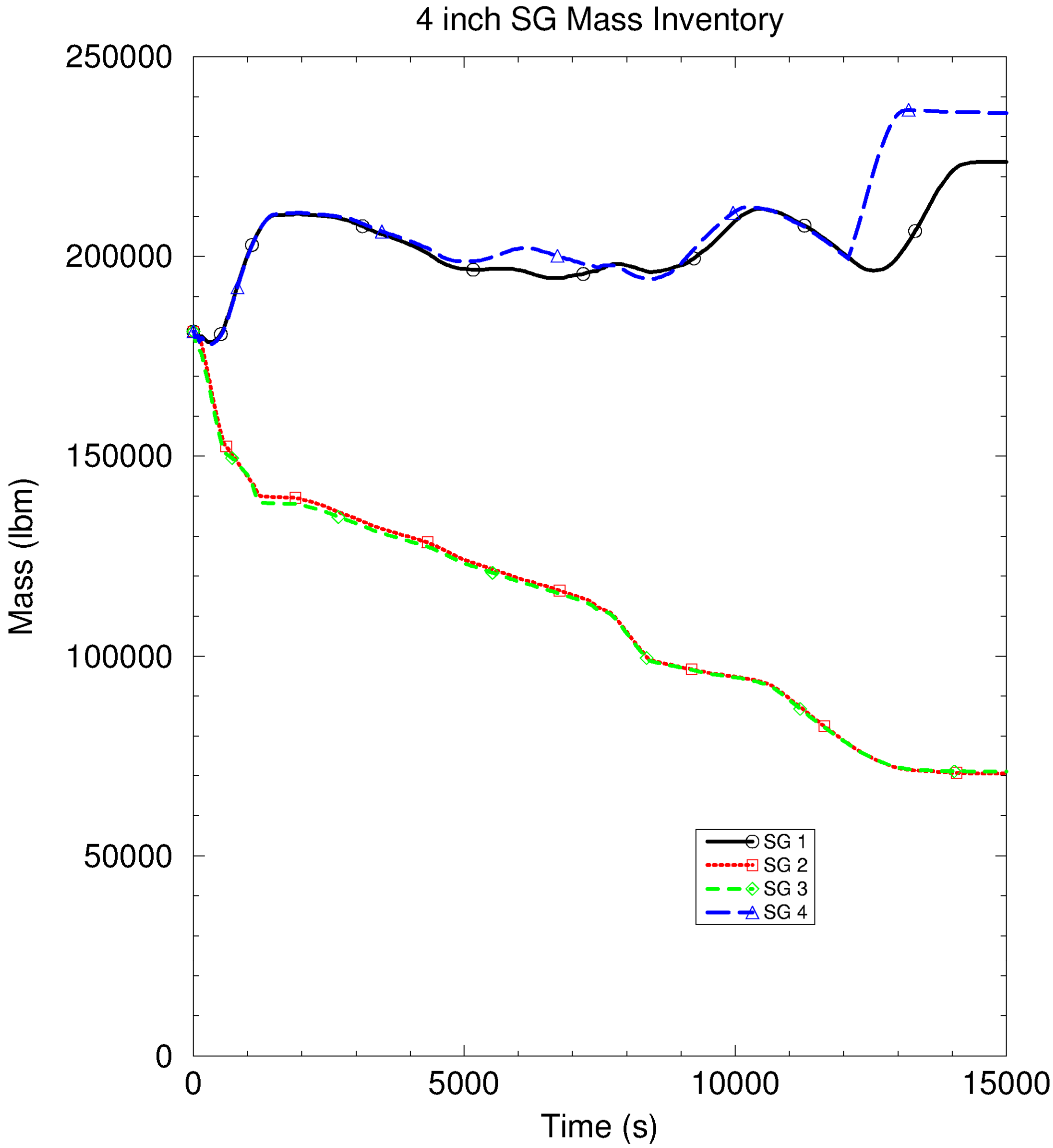


Figure 15.06.05-31-9—Steam Generator Emergency Feedwater Flow for 1.5 inch Break

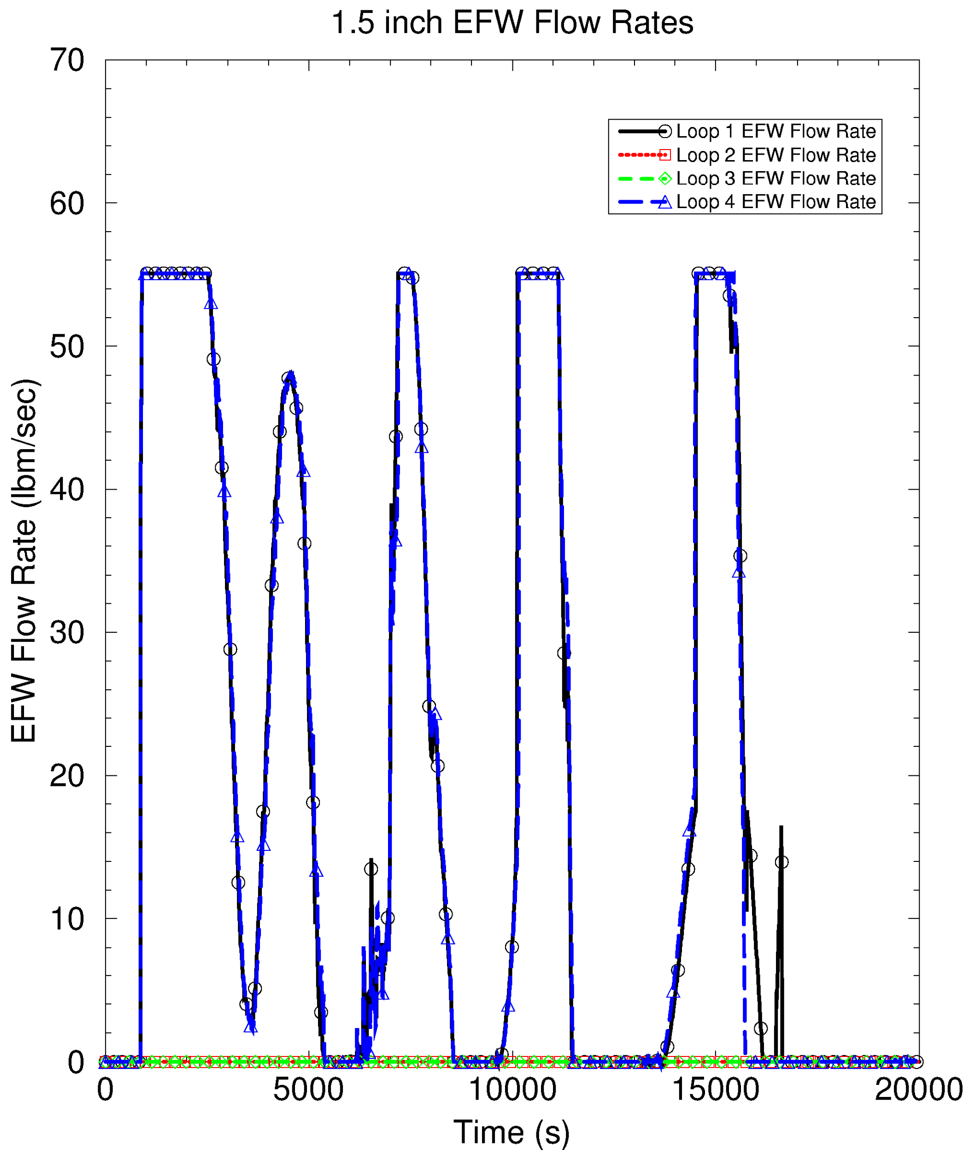


Figure 15.06.05-31-10—Steam Generator Emergency Feedwater Flow for 2 inch Break

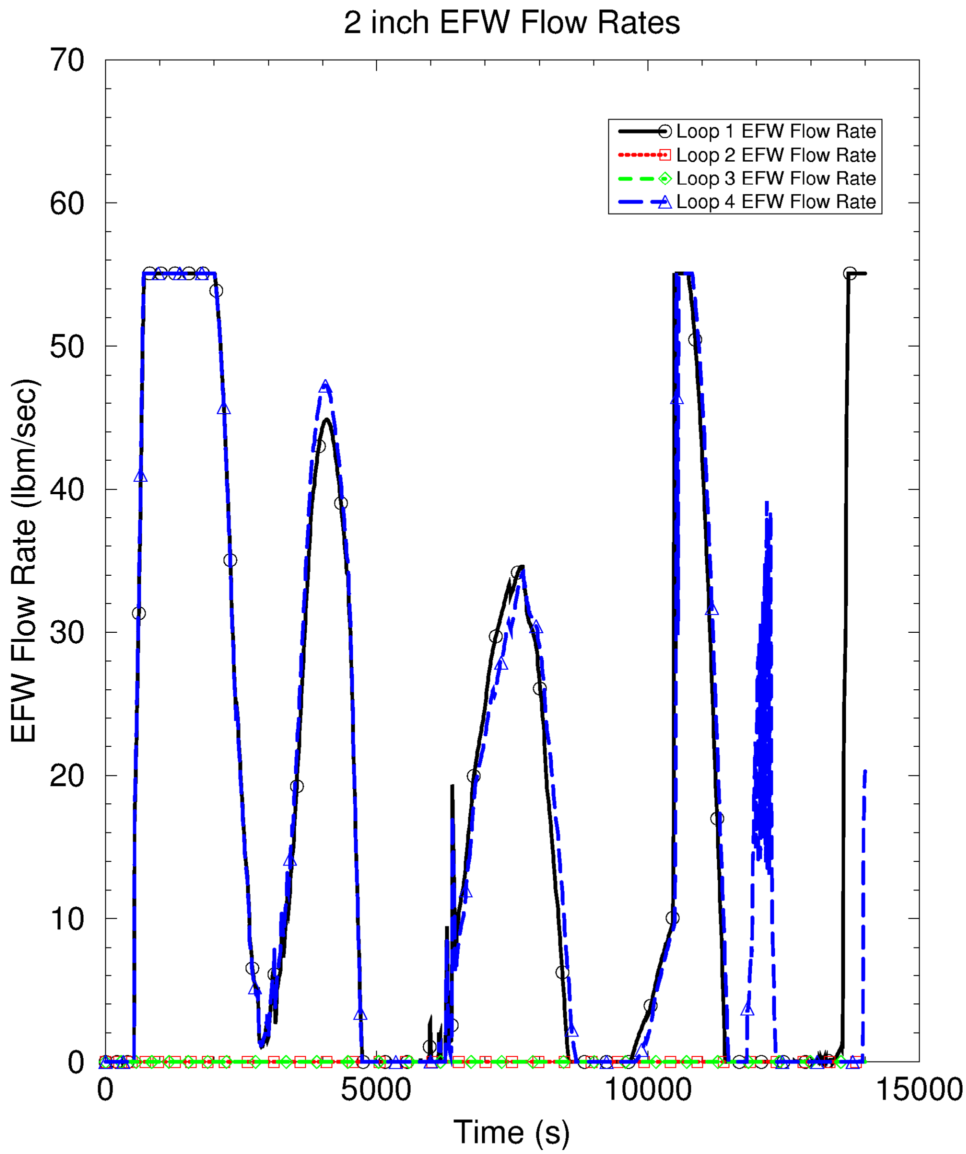


Figure 15.06.05-31-11—Steam Generator Emergency Feedwater Flow for 3 inch Break

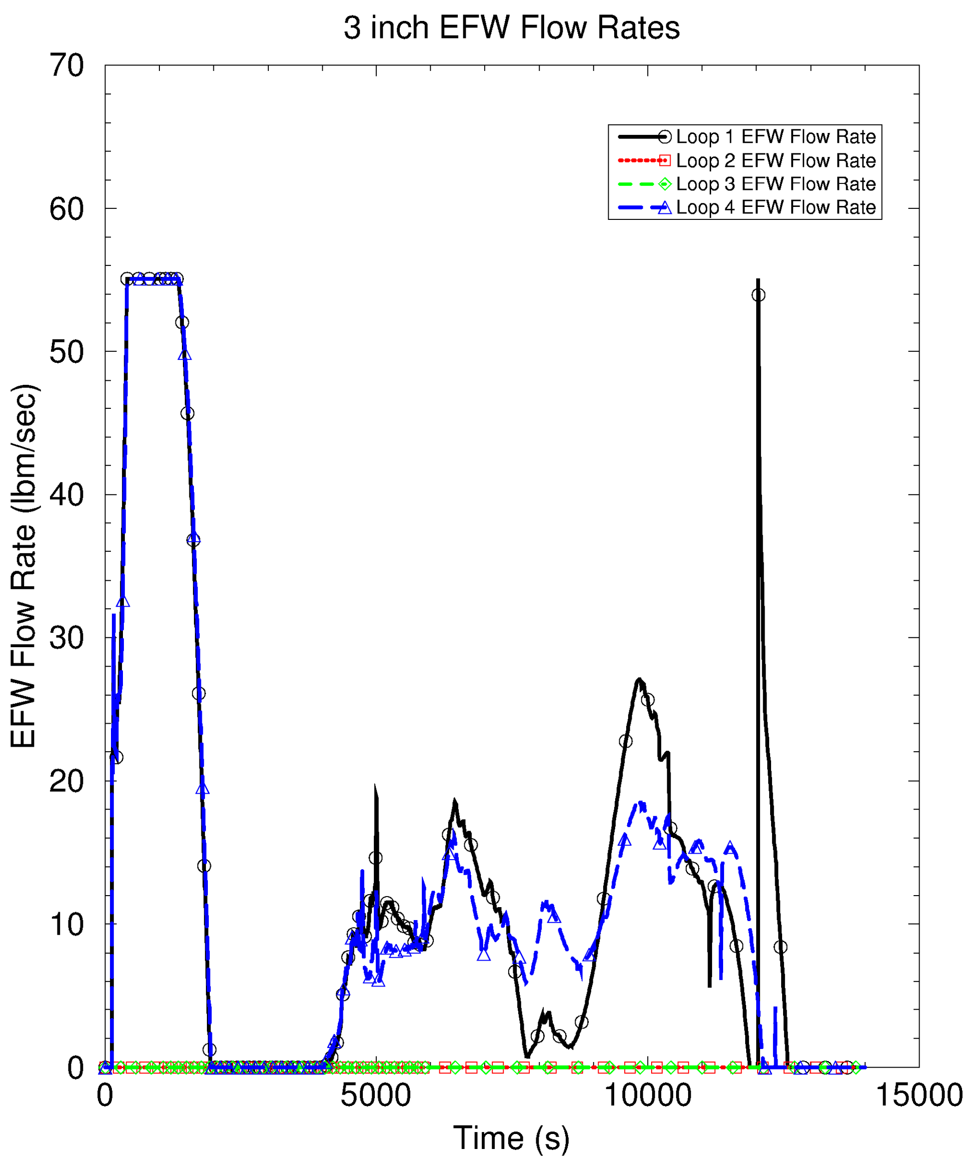
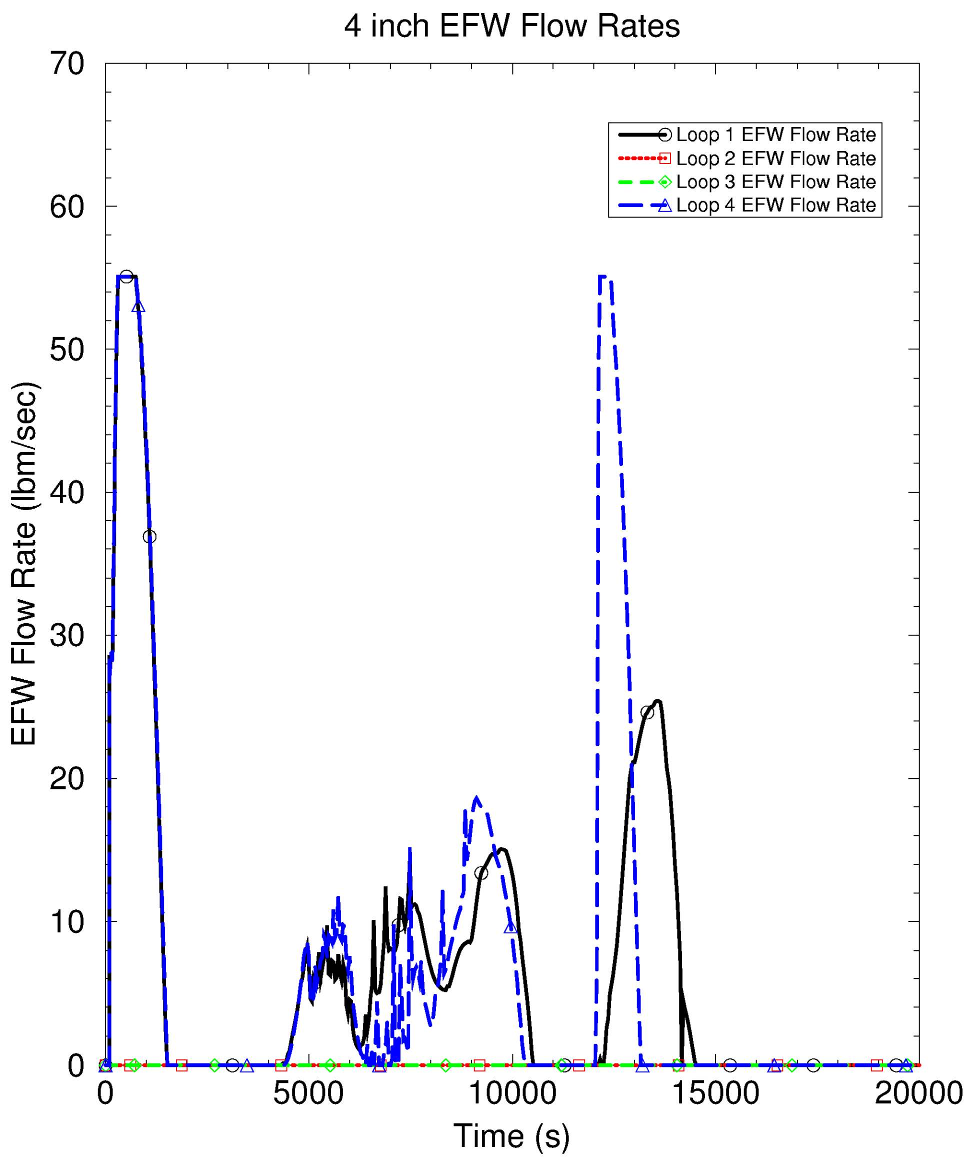


Figure 15.06.05-31-12—Steam Generator Emergency Feedwater Flow for 4 inch Break



Question 15.06.05-32:

Discuss the sufficiency of the cases analyzed in terms of number of break sizes considered within the break area range and spectrum.

Reference: SBLOCA Analysis Report 32-9057270-000 in Support of Boron Dilution and Boron Precipitation Effects, dated December 14, 2006.

Response to Question 15.06.05-32:

The boron dilution analyses evaluated a spectrum breaks ranging from 1.5 inches up to 4 inches in diameter. This covers the range from where the break will be overwhelmed by just the medium head safety injection (MHSI), to the cases where the system depressurizes and is refilled by a combination of the MHSI and low head safety injection (LHSI) flow. The 1.5 inch break is the low end of the spectrum of breaks considered because it has a relatively long first natural circulation stage and relatively short boiler-condenser and system refill stages. In the 1.5 inch case, the liquid carryover at the top of the steam generator (SG) U-tubes does not go to zero and is sufficient to keep the condensate borated. Thus, the 1.5 inch break is small enough to bound the low end of the break spectrum.

Due to break flow, the 4 inch break depressurizes the primary side faster than the secondary side (see Figure 15.06.05-32-1). With the continued SG cooldown, the secondary pressure drops below the primary system pressure at around 7000 seconds, thus allowing the SGs to begin to cool and potentially condense primary side steam. Between this point and the restart to natural circulation, the MHSI and LHSI are injecting approximately 350 to 700 lbm/s of IRWST water. Assuming all of the decay heat based on the Appendix K model is evaporating saturated water, the evaporation rate would be about 60 lbm/s. Under these conditions the system refill will be initiated. Larger breaks have an even longer period of time before the condensation on the secondary side becomes effective in removing energy from the primary side. At later times, the decay heat will be less and the safety injection will be higher. Thus, the 4 inch case is bounding and larger breaks do not need to be considered for boron dilution.

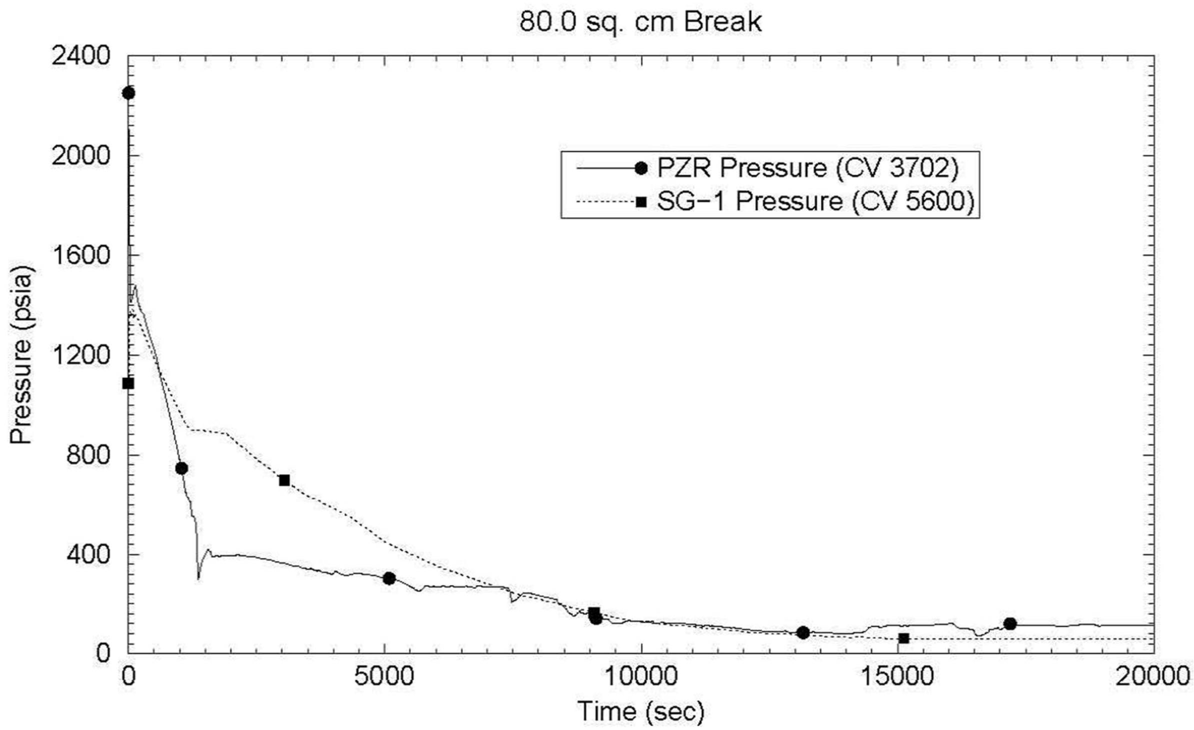
Two intermediate break sizes, a 2 inch and a 3 inch, were also analyzed. In both cases the reduced boron concentration slug is re-borated by backflow through the reactor coolant system pumps prior to the first loop returning to natural circulation.

One break size case above the 1.5 inch to 4 inch break spectrum is analyzed for boron precipitation to demonstrate that the small break results, as described in the U.S. EPR FSAR, are bounded by the large break loss of coolant accident (LOCA) boron precipitation results. The water content in the core region is greater than that of the large break LOCA and is sufficient to prevent the boron concentration from reaching the precipitation limit before the plant operator would switch to hot side injection.

FSAR Impact:

The FSAR will not be changed as a result of this question.

Figure 15.06.05-32-1—Pressurizer Pressure and SG 1 Pressure



Question 15.06.05-33:

Discuss the adequacy of the S-RELAP model that is used to analyze the boron dilution and boron precipitation effects in the EPR SBLOCA analysis report referenced below.

Reference: SBLOCA Analysis Report 32-9057270-000 in Support of Boron Dilution and Boron Precipitation Effects, dated December 14, 2006.

Response to Question 15.06.05-33:

A spectrum of small breaks (from 1.5 – 4 inches in diameter) was analyzed for the boron dilution events associated with the small break loss of coolant accident (SBLOCA). The intent of the analysis was to establish the event characteristics and thermal-hydraulic behavior associated with the secondary side steam generator (SG) depressurization and cooldown initiated by the operators after 30 minutes. These analyses provide the volumes of liquid that accumulate in the reactor coolant system (RCS) downstream of the SG U-tube bend, as well as the fluid dynamics associated with the refill and start of natural circulation.

The S-RELAP5 model was assessed against the tests in the PKL Test Facility, which was designed to replicate system refill and the restart of natural circulation. The model was found to be adequate to simulate these effects, as discussed in the response to Question 15.06.05-36. While the precise timing is different, the S-RELAP5 analyses follow the same evolution of the event as the PKL tests. The flow dynamics are very similar to those observed in the PKL tests after the boiler condenser stage, including the backflow behavior during refill which increases the boron concentration in the crossover pipe prior to the restart of natural circulation. The S-RELAP5 code is not used to track the concentrations of boron. Instead, the liquid volumes and relevant flow rates are used in a follow-on calculation of the boron concentrations. This latter calculation establishes the boron concentration in the liquid sent to the reactor vessel, and subsequently to the core, when natural circulation restarts.

The same model used to evaluate the smaller breaks for boron dilution was used to analyze a 6 inch break for the evaluation of boron precipitation. The 6 inch break assumes the restart of SG cooldown at a rate of 90^{o}F/hr and a switch to hot leg injection (a majority of the low head safety injection (LHSI) flow is redirected to the hot leg) at 30 minutes. The typical SBLOCA model has a core with three regions: a hot assembly, an inner core region of 71 assemblies, and an outer core region of 169 assemblies. To more accurately model the effect of hot leg injection, the SBLOCA model was updated with a four-region core model: a hot assembly, a central core region of 6 assemblies, an average core region containing 186 assemblies, and a peripheral core region of 48 assemblies. The typical SBLOCA model has a single volume upper plenum. The new model has a three region upper plenum (the hot assembly and inner core region are combined). Because the 6.5 inch break was the most limiting peak cladding temperature (PCT) case, this break size was analyzed with the four-region core. Additionally, the original analysis assumed a 50/50 LHSI flow split between the hot side and cold side injection. The revised analysis uses pressure vs. flow input developed specifically for hot leg injection, directing approximately 75% of the LHSI flow to the hot leg.

The revised model changes how the system responds to the switch to hot side injection. It shows that the hot side injection flow patterns return flow from the loops receiving hot side injection to the upper plenum. The behavior of the flow in the upper plenum and core is similar to that seen in test facilities with hot side injection. This behavior is described in the revised

U.S. EPR FSAR, Tier 2, Section 15.6.5.4 will be revised to describe this behavior. As seen in the revised U.S. EPR FSAR, Tier 2, Figure 15.6-84, the redirected flow reverses the flow in loops one and four into the upper plenum, making additional coolant available to the core region. These are the loops with the operating safety injection trains and are the same loops receiving emergency feedwater (EFW) injection.

Revised U.S. EPR FSAR, Tier 2, Figure 15.6-85 shows that the hot leg injected water flows from the upper plenum, further reversing the fuel assembly flow in the peripheral region of the core. Some of the downflow continues out through the lower plenum to the lower head region (see revised U.S. EPR FSAR, Tier 2, Figure 15.6-86). At 7000 seconds into the event, the continued cooldown of the steam generators has not caused the secondary side pressure to reach the point where the steam generators will remove decay heat, as illustrated by the RCS pressure and the steam generator 1 pressure (see revised U.S. EPR FSAR, Tier 2, Figure 15.6-87). The increase in the percentage of LHSI being directed to the hot leg (75% vs. 50% previously assumed) increases the return of LHSI to the upper plenum from loops 1 and 4. The difference in the RCS behavior indicates that the original conclusions are conservative and resolves any concern about the adequacy of the model used in the boron precipitation analysis.

FSAR Updates:

U.S. EPR FSAR, Tier 2, Figure 15.6-84, Figure 15.6-85, Figure 15.6-86, Figure 15.6-87, and Figure 15.6-92 will be added as described in the response and indicated on the enclosed markup. U.S. EPR FSAR, Tier 2, Section 15.6.5.4 will be revised as described in the response and indicated on the enclosed markup.

Question 15.06.05-36:

Explain why the qualitative behavior observed in the PKL tests is applicable to the US EPR.

Reference: SBLOCA Analysis Report 32-9057270-000 in Support of Boron Dilution and Boron Precipitation Effects, dated December 14, 2006.

Response to Question 15.06.05-36:

Tests were performed at AREVA's PKL Test Facility in Erlangen, Germany to evaluate the small break loss of coolant accident (SBLOCA) inherent boron dilution event as it evolves in a modern pressurized water reactor (PWR). The reference plant is the Phillipsburg 2 nuclear power plant. The test facility simulates all four loops, a power of 1300 MWe, and is full scale in height and 1:145 scale in volume and power. The flow area scaling is also 1:145, however pressure drops are adjusted in selected locations to match the reference reactor. The qualitative behaviors demonstrated by the PKL tests that are used as part of the justification for the analytical methodology for evaluating the U.S. EPR inherent boron dilution event are:

1. The backfill of the steam generator (SG) outlet plenum and downside tubes via the cold legs prior to the establishing erratic or sustained natural circulation.
2. The inability of the plant to initiate natural circulation in more than one loop at a time.
3. The occurrence of an extended period of erratic circulation prior to achieving sustained liquid natural circulation during plant refill.

Additionally, the boron concentrations delivered to the core in the PKL test show that the calculational approach applied to the U.S. EPR is conservative.

The important scaling considerations for the key qualitative behaviors are height and flow area. Height scaling at 100% means the driving heads that develop during the simulation correspond appropriately to the conditions developed in the rest of the system. The attention to the pressure drops around the system help to achieve appropriate flows once circulation initiates. The PKL scaling in the hot legs and the SG inlet plenums was modified to preserve entrainment and de-entrainment effects between the reactor vessel and the steam generators. The U.S. EPR safety injection systems provide higher flow rates than the PKL test simulates because they are stronger functions of reactor coolant system (RCS) pressure. Therefore, the specific timing in the PKL test should not be applied directly. However, the evidence of flow regimes or conditions, such as erratic two-phase flow before initiation of natural circulation, is credible as backup to full scale plant simulations.

The main PKL F1.1 test assumptions, compared to the U.S. EPR, were:

- Two high-pressure injection systems are available that inject independently into all four cold legs. (In the U.S. EPR, the extra borating system (EBS) has two trains injecting to the four cold legs and four trains of medium head safety injection (MHSI) and low head safety injection (LHSI) flow. Each MHSI injects into a single cold leg. Each LHSI injects into a single cold leg unless the cross-connects are open.)
    - Only one high pressure injection system is used. (In the U.S. EPR S-RELAP5 SBLOCA analysis there are two trains, but one MHSI train is delivered to the broken loop.)

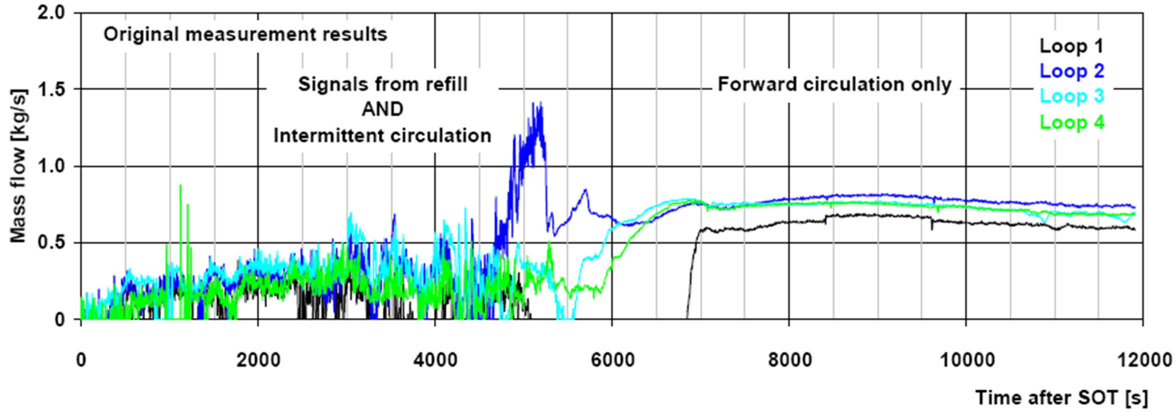
  - No accumulators or low pressure injection used. (In the U.S. EPR S-RELAP5 SBLOCA analysis the accumulators and two trains of LHSI are used with the cross-connects open delivering water to all four cold legs.)
- SG cooldown at ~100ºF/hr for all four SGs. (The U.S. EPR cooldown rate is 90ºF/hr.)
- 2.15 inch break. (The U.S. EPR break spectrum is 1.5 – 4 inch breaks that include a 2 inch break.)
- Initial boron concentration:
  - <50 ppm in the crossover pipe. (The U.S. EPR slug concentration analysis assumes 0 ppm in the condensate.)
  - >4000 ppm in the core region. (The U.S. EPR slug concentration analysis assumes 3035 ppm.)
  - Safety injection boron concentration: 2500 ppm (U.S. EPR safety injection minimum boron concentration: 3235 ppm and U.S. EPR EBS injection minimum boron concentration: 13,335 ppm all as natural boron).

The S-RELAP5 analyses for the evaluation of boron dilution show flow dynamics similar to those observed in the PKL tests after the boiler condenser stage (see Figure 15.06.05-36-1) and thus the boron concentrations should behave in a similar manner. The S-RELAP5 analyses also follow a very similar path for the spectrum of events analyzed; however, the timing for the U.S. EPR is shorter due largely to the higher safety injection rates (48 lbm/s (0.33 lbm/s x 145) for the PKL test vs. 200 lbm/s or higher for the U.S. EPR. The major difference between the PKL F1.1 test and the U.S. EPR is that the U.S. EPR analyses includes the EBS injection flows and the single failure criteria, where safety injection goes into individual loops and emergency feedwater is supplied to the corresponding steam generators. In the PKL test, at about 1835 seconds into the transient the boron concentration in the pump suction increased to about 406 ppm and the SG outlet concentration had not increased. As the backflow continued, the pump suction increased to 900 ppm at 3120 seconds and the SG outlet was beginning to increase as the backflow pushed water into the SG outlet plenum (see Figure 15.06.05-36-2). This backflow behavior in the refill stage is the same as observed in the S-RELAP5 analyses. In addition, the PKL test started with the lower equivalent safety injection boron concentrations and still demonstrated that the concentrations in the bottom of the downcomer will be greater than that required to prevent recriticality.

FSAR Impact:

The FSAR will not be changed as a result of this question.

Figure 15.06.05-36-1—Flow Dynamics Comparison of PKL III F1.1 Test (top) and U.S. EPR 20.0 cm^2 Break S-RELAP5 Analysis (bottom)



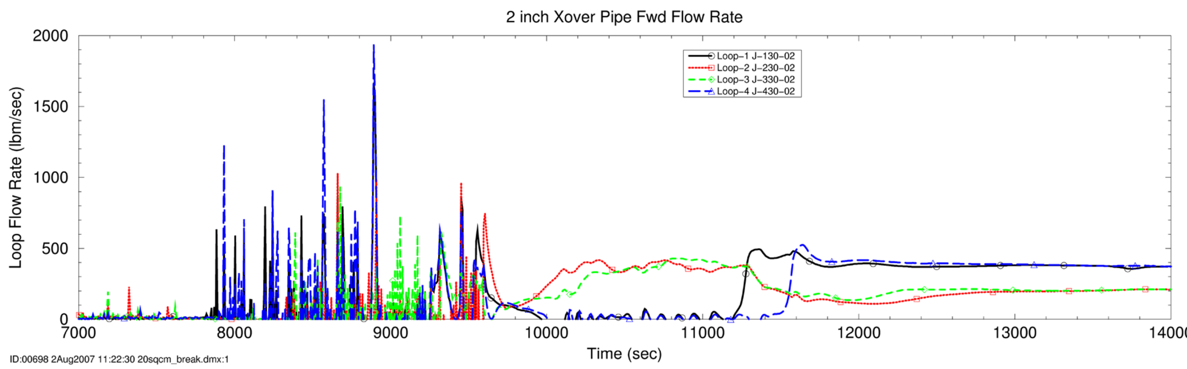


Figure 15.06.05-36-2—Boron Concentrations in the PKL III F1.1 Test