ArevaEPRDCPEm Resource

From: Pederson Ronda M (AREVA NP INC) [Ronda.Pederson@areva.com]
Sent: Thursday, May 28, 2009 6:09 PM
To: Getachew Tesfaye
Cc: GUCWA Len T (EXT); BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 167, FSAR Ch. 15, Supplement 3
Attachments: RAI 167 Supplement 3 Response US EPR DC.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. Supplement 2 to AREVA NP's response to RAI No. 167 was sent April 30, 2009 to address 5 of the remaining questions.

The response file, "RAI 167 Supplement 3 Response US EPR DC.pdf" provides technically correct and complete responses to the 3 remaining questions, as committed.

The following table indicates the respective pages in the response document, "RAI 167 Supplement 3 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 167 – 15.06.05-29	2	19
RAI 167 – 15.06.05-34	20	24
RAI 167 – 15.06.05-37	25	28

This concludes the formal AREVA NP response to RAI 167, and there are no questions from this RAI for which AREVA NP has not provided responses.

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
Cell: 434-841-8788

From: Pederson Ronda M (AREVA NP INC)
Sent: Thursday, April 30, 2009 8:20 PM
To: Getachew Tesfaye (gxt2@nrc.gov)
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 2 of 2)

Getachew,

Response file, "RAI 167 Supplement 2 Response US EPR DC (part 2 of 2).pdf" attached.

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
Cell: 434-841-8788

From: Pederson Ronda M (AREVA NP INC)
Sent: Thursday, April 30, 2009 8:19 PM
To: Getachew Tesfaye (gxt2@nrc.gov)
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)

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
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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,

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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: 531

Mail Envelope Properties (5CEC4184E98FFE49A383961FAD402D31F11BFB)

Subject: Response to U.S. EPR Design Certification Application RAI No. 167, FSAR Ch. 15, Supplement 3
Sent Date: 5/28/2009 6:09:17 PM
Received Date: 5/28/2009 6:09:30 PM
From: Pederson Ronda M (AREVA NP INC)

Created By: Ronda.Pederson@areva.com

Recipients:
"GUCWA Len T (EXT)" <Len.Gucwa.ext@areva.com>
Tracking Status: None
"BENNETT Kathy A (OFR) (AREVA NP INC)" <Kathy.Bennett@areva.com>
Tracking Status: None
"DELANO Karen V (AREVA NP INC)" <Karen.Delano@areva.com>
Tracking Status: None
"Getachew Tesfaye" <Getachew.Tesfaye@nrc.gov>
Tracking Status: None

Post Office: AUSLYNCMX02.adom.ad.corp

Files	**Size**	**Date & Time**
MESSAGE	10622	5/28/2009 6:09:30 PM
RAI 167 Supplement 3 Response US EPR DC.pdf		3191345

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

Response to

Request for Additional Information No. 167, Supplement 3

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 15.06.05-29:

The report did not present results that describe possible accumulation of condensate in the steam generator (SG) exit chamber and the attached cold leg nozzle/piping nor did it consider the liquid conditions in the pump discharge pipe. Provide an assessment of the total amount of condensate generated in each loop.

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

Response to Question 15.06.05-29

Small break loss of coolant accidents (SBLOCA) that have the potential for boron dilution have three phases: natural circulation, boiler-condenser mode, and restart of natural circulation. The second and third phases are necessary for boron dilution and require five conditions to occur in sequence:

1. Stagnation of loop flow due to voiding of the steam generator (SG) tubes.
2. Primary coolant inventory reduction, so that the coolant level is below the tube sheet. When the level reaches the tube sheet, the steam inside the U-tubes is trapped by water and condenses almost completely. This results in intermittent circulation from the SG inlet to the SG outlet, which transports boron and disrupts the accumulation of condensate.
3. Steam generators at a lower pressure than the primary system (i.e., the SGs remove energy from the primary system).
4. Sufficient time spent condensing steam in the SGs to produce a large deborated slug.
5. Safety injection rate sufficient to refill the reactor coolant system (RCS), restart natural circulation, and move the slug to the reactor vessel.

The mass and boron concentration of the deborated slug depends on several factors, including the amount of time spent in the boiler-condenser mode, the boiling and condensation rates, the characteristics and the behavior of the refill, and the system geometry.

Four SBLOCAs (1.5 inch – 4 inch cold leg breaks) were analyzed to evaluate the key characteristics during the boron dilution event. The automatic depressurization and operator-initiated continued depressurization reduces SG pressure below the RCS pressure. The amount of time that it takes for the SGs to depressurize below the RCS pressure increases with increasing break size, because the RCS pressure drops as the break size becomes larger. At this point, and until the safety injection flow refills the RCS, the primary side is cooled and some of the steam condenses in the SG and collects in the crossover pipe. The relative elevations of the components downstream of the downside SG tubes limit the collection of condensate. Figure 15.6.5-29-1 shows the relative elevations of the SG, reactor vessel, cold leg, reactor coolant pump (RCP), and crossover leg. As shown, the SG outlet plenum is above the top of the cold leg, and can not fill with deborated water without draining into the cold leg. Figure 15.6.5-29-2 shows the internal configuration of the impeller discharge of the RCP as being close to the top of the cold leg (within approximately 3 inches). This geometry allows a maximum deborated fluid volume as the sum of the following (shown as the shaded area in Figure 15.6.5-29-1):

- The volume in the pump from the suction to discharge volute.
- The maximum volume of the loop seal that can fill with deborated fluid before spilling into the cold leg.

This volume represents the maximum deborated fluid volume that can build up before draining into the reactor vessel until the system refill begins to raise the level in the RCS. The volume of the shaded area in Figure 15.6.5-29-1 is 171 ft^3. To account for any small volumes of deborated fluid accumulation in the bottom of the pump casing or SG outlet plenum, the calculated deborated fluid volume is increased by 25 percent to be 216 ft^3. The PKL test had an equivalent volume of 388 ft^3, but in the PKL tests, due to pressure limitations of the facility, the slugs for the SBLOCA tests could not be formed under the same conditions as in the PWR transient. Instead, a large part of the slug generation had to be accomplished in a conditioning phase at a constant pressure. The PKL volume was conservatively maximized to fill the entire PKL loop seal, which is deeper than the U.S. EPR crossover pipe. In the three S-RELAP5 cases for which forward natural circulation ceased (2 inch – 4 inch), the crossover pipe was never completely filled prior to system refill.

Figure 15.6.5-29-3 through Figure 15.6.5-29-15 present, for each of the four sizes in the break spectrum, the quantities of water present in these locations downstream of the SG: the SG outlet plenum, the crossover pipe and the cold leg.

The 1.5 inch break is the lower end of the break spectrum and never completely looses the forward circulation of water from the upside to the downside of the SG U-tube. Loops 1 and 4, due to single failure (SF) and preventative maintenance (PM) assumptions, receive emergency feedwater (EFW) and medium head safety injection (MHSI). These loops have intermittent forward flow, which provides boron to the condensed steam collecting downstream of the SG tubes. Loops 1 and 4 are also the loops that return to a continuous forward natural circulation (at approximately 7000 seconds). The masses of water in the downstream locations as a function of time for the 1.5 inch SBLOCA are presented in Figures 15.6.5-29-3 through 15.6.5-29-5. While the 1.5 inch break contains the largest quantity of water in the analyzed spectrum in the downstream locations, this water contains more boron than the larger break sizes and therefore is less challenging with regard to boron dilution. In all three downstream locations of Loops 1 and 4, the initial mass only decreases slightly due to the break and loss of continuous circulation. The SG mass of water in the outlet plenum decreases to approximately 8,600 lbm then refills to approximately 11,000 lbm. The mass of water in the crossover pipe decreases to 6,800 lbm then refills to approximately 9,000 lbm. The cold leg mass decreases to approximately 6800 lbm then refills to approximately 9,000 lbm.

The masses of water for the 2 inch SBLOCA as a function of time are shown in Figures 15.6.5-29-6 through 15.6.5-29-8. During the boiler-condenser mode of operation, the SG outlet plenum contains very little water, less than 500 lbm, since it drains into the crossover pipe. Cold legs 1 and 4 each contain, on average, approximately 8,000 lbm and these loops pass the least quantity of steam. Cold legs 2 and 3 have, on average, 3,000 lbm of water. On the secondary side, Loops 2 and 3 have very little water in their SGs, which causes less condensation and more steam passes through the primary loops. This is because, with the SF and PM assumptions, cold legs 2 and 3 only receive safety injection (SI) from the low head safety injection (LHSI) cross-connects and no EFW, while cold legs 1 and 4 have MHSI, LHSI, and EFW on their secondary sides. The Loop 1 and 4 crossover pipes contain between 4,000 and 6,000 lbm of water (approximately one-half full), while the Loops 2 and 3 crossover pipes are initially lower, with less than 2,000 lbm of water. Figure 15.6.5-29-9 shows that prior to the restart of natural circulation the masses in the loops increase to approximately 6,000 lbm, largely due to the backflow through the RCS pumps in Loops 2 and 3. This backflow provides boron to the crossover pipes in these loops before experiencing erratic flow and then continuous forward natural circulation. This occurs when the RCS pressure drops below the LHSI shutoff head pressure and safety injection increases, refilling the system before the first restart of natural circulation in Loop 3.

The masses of water for the 3 inch SBLOCA as a function of time are shown in Figures 15.6.5-29-10 through 15.6.5-29-12. The boiler-condenser mode of cooling is longer for this break and is interrupted at approximately 3500 seconds by a drop in RCS pressure for approximately 1000 seconds. The decrease in RCS pressure is caused by the accumulator injecting cold water, which reduces the RCS temperature and pressure below the pressure of the secondary side. After the interruption at approximately 3,500 seconds, the SG outlet plenums contain very little water during the remainder of the boiler-condenser mode (approximately 250 lbm) until the refill period begins. The cold legs contain 1,000 to 2,500 lbm of water until refill begins, and vary depending on the loop because of the SF and PM assumptions and break location. The crossover pipes during the dynamic boiler-condenser mode contain approximately 1,000 to 5,500 lbm of water. During the refill period the backflow from the cold leg through the RCPs adds boron to the crossover pipe as the mass increases to 9,000 lbm before the first restart of natural circulation at approximately 10,000 seconds in Loop 2. The backflow continues, adding boron to the SG outlet plenum during the refill period.

The masses of water for the 4 inch SBLOCA as a function of time are shown in Figures 15.6.5-29-13 through 15.6.5-29-15. No water collects in the SG outlet plenum until the safety injection systems begin to overwhelm the break flow and refill the RCS. The cold legs contain between 1,000 and 3,000 lbm of water before the system refill begins. The crossover pipes for Loops 2, 3, and 4 collect very little water (approximately 200 lbm each) before condensation begins and the Loop 1 crossover pipe clears to approximately the same mass of water when primary condensation becomes feasible. At this point, the water in the downstream locations contains a high concentration of boron. With the SG operator-initiated cooldown at 90°F/h, the secondary side pressure becomes lower than the RCS pressure at approximately 7000 seconds, beginning the boiler-condenser mode of operation. The crossover pipes fill to approximately 5,000 lbm of water during this dynamic period before the system refill begins. During the refill period the backflow from the cold leg through the RCPs adds boron to the crossover pipe as the mass of water increases to approximately 9,000 lbm before the first restart of natural circulation in Loop 3 at approximately 13,000 seconds. The backflow continues, adding boron to the SG outlet plenum during the refill period during which the mass increases from approximately 100 lbm to 11,000 lbm.

An SBLOCA evolves through early natural circulation, to boiler-condenser mode, and finally the restart of natural circulation. The only accidents of importance to boron dilution are those that spend sufficient time in the boiler-condenser mode to accumulate a large buildup of deborated water. Regardless of the length of time spent in this mode, the amount of deborated fluid is limited by the geometry of the U.S. EPR RCS. The accumulation of water in the downstream locations is provided for a spectrum of breaks. The spectrum ranged from a 1.5 inch break that did not completely lose forward circulation, to the 4 inch break that continued for approximately 7000 seconds before the SG was sufficiently depressurized and the system reached the boiler-condenser mode of cooling. In all cases, the slug of water collected during the boiler-condenser mode of cooling was less than the crossover pipe volume. Then during the refill stage, the crossover pipe and SG outlet plenum refilled prior to the restart of natural circulation, thereby adding boron to the original slug.

FSAR Impact:

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

Figure 15.6.5-29-1—Elevation View of the U.S. EPR Crossover Pipe

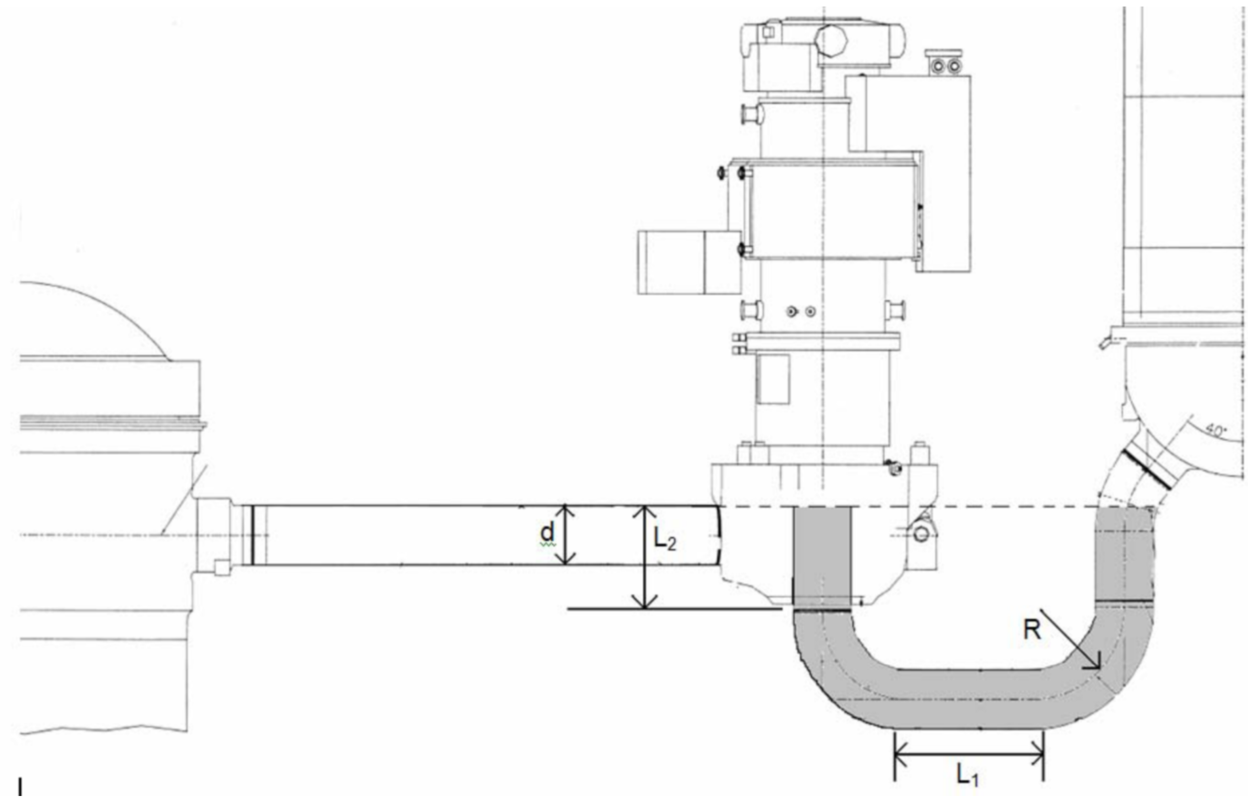


Figure 15.6.5-29-2:—Reactor Coolant Pump Cold Leg Spill Height

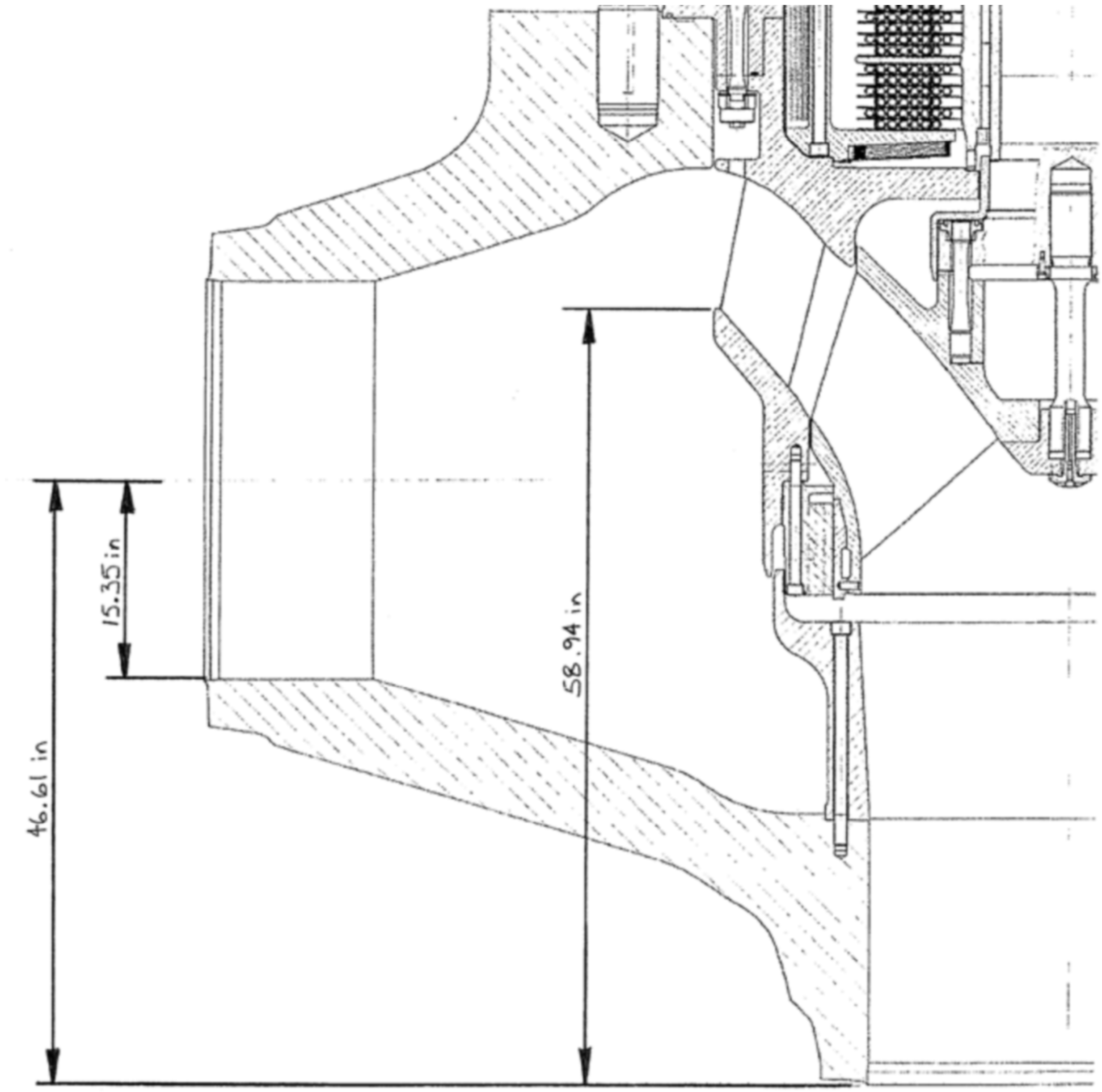


Figure 15.6.5-29-3—Mass of Water in the Steam Generator Outlet Plenum for the 1.5 inch Cold Leg LOCA

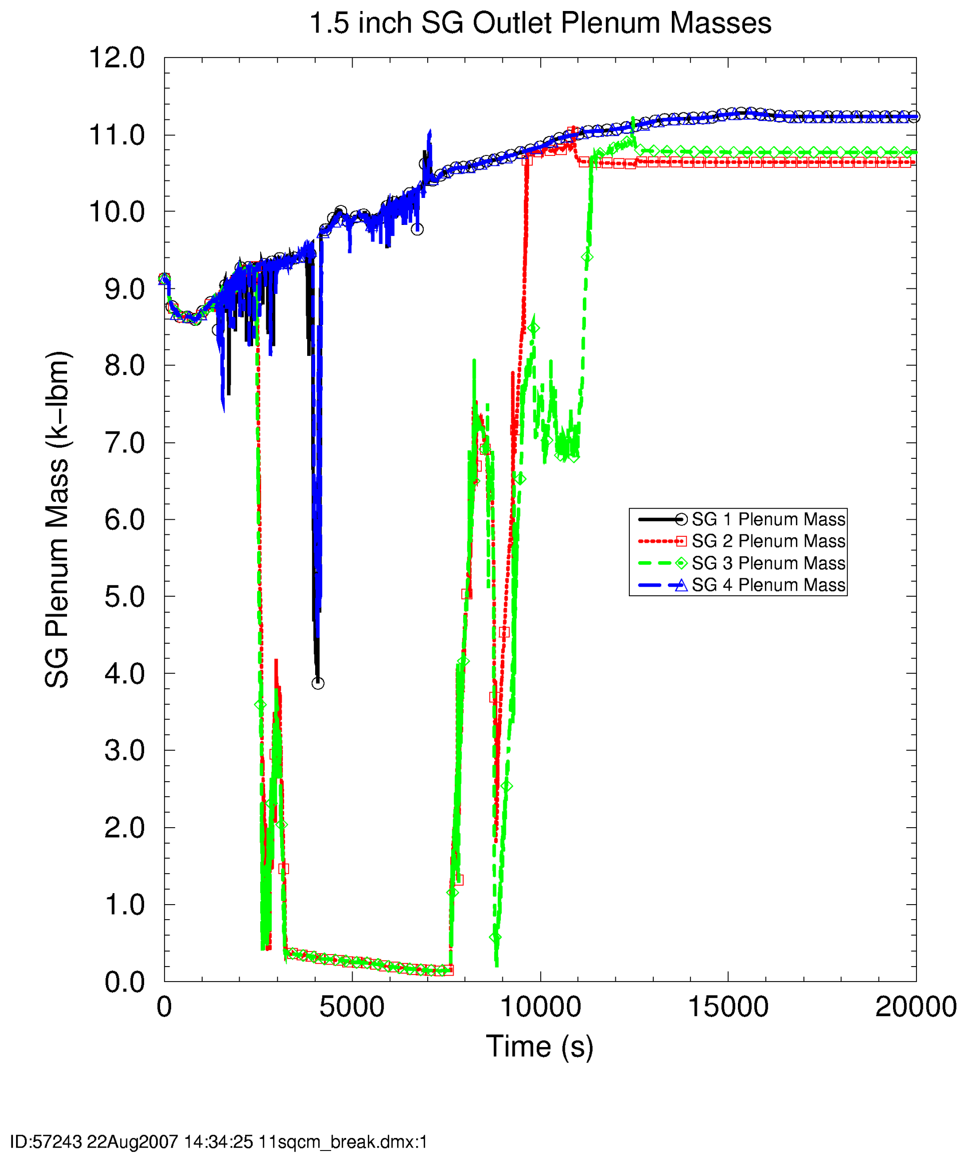
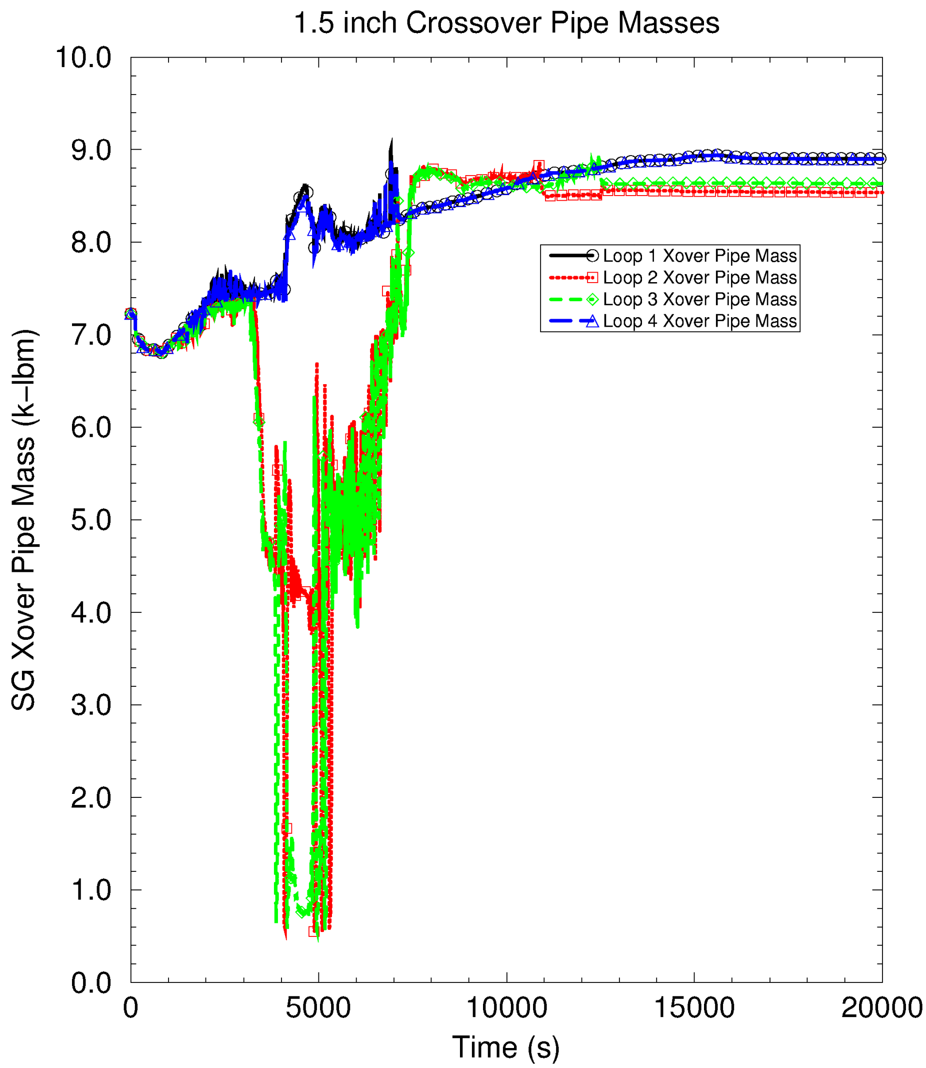


Figure 15.6.5-29-4—Mass of Water in the Crossover Pipe for the 1.5 inch Cold Leg LOCA



ID:57243 22Aug2007 14:34:25 11sqcm_break.dmx:1

Figure 15.6.5-29-5—Mass of Water in the Cold Leg Pipe for the 1.5 inch Cold Leg LOCA

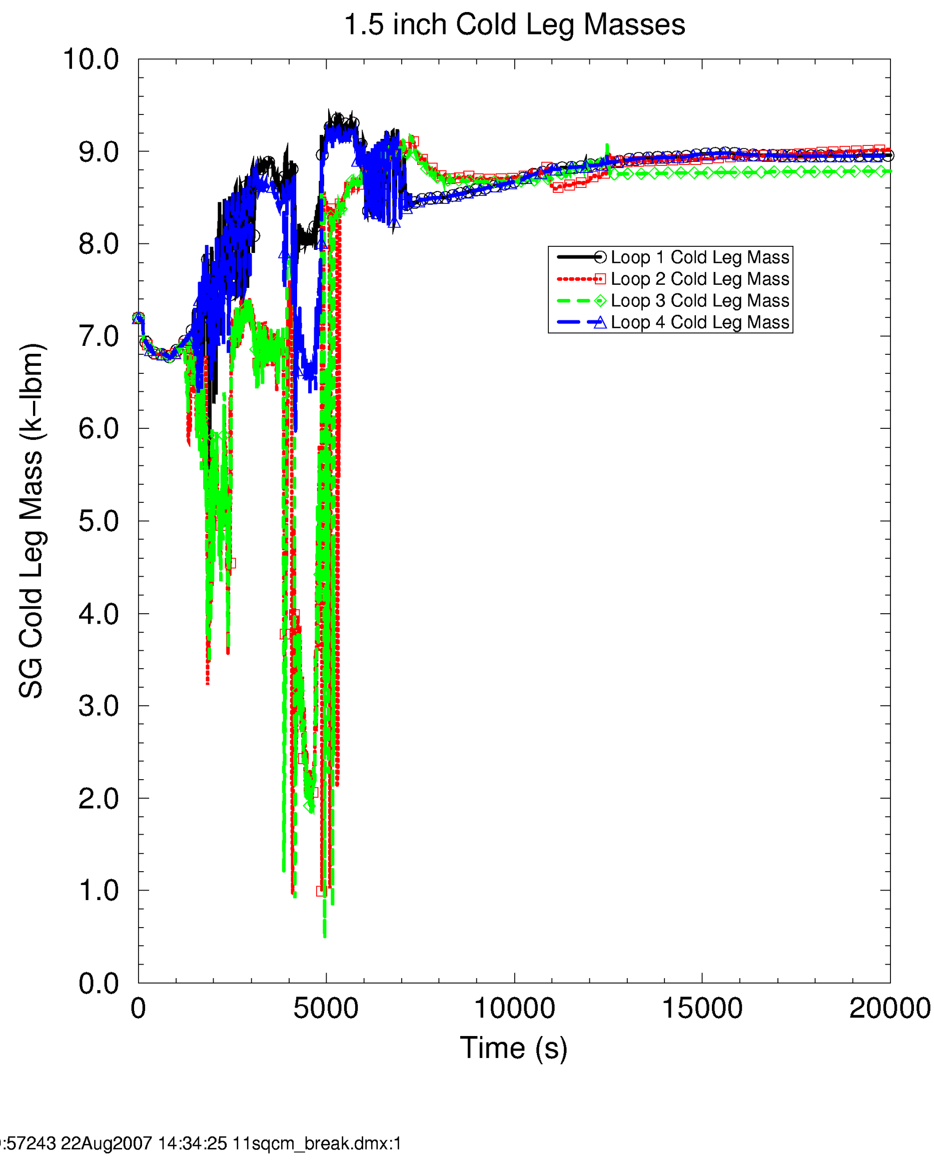


Figure 15.6.5-29-6—Mass of Water in the Steam Generator Outlet Plenum for the 2 inch Cold Leg LOCA

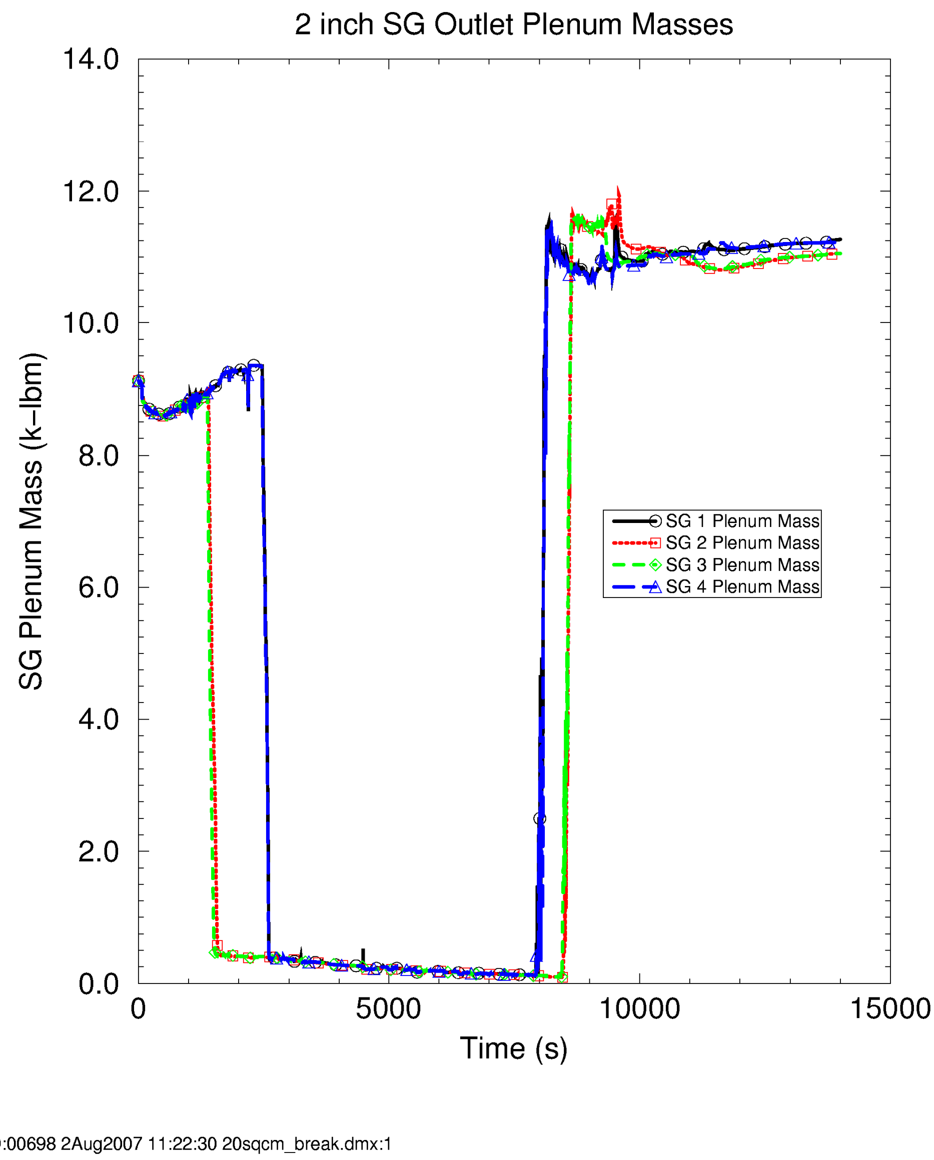


Figure 15.6.5-29-7—Mass of Water in the Crossover Pipe for the 2 inch Cold Leg LOCA

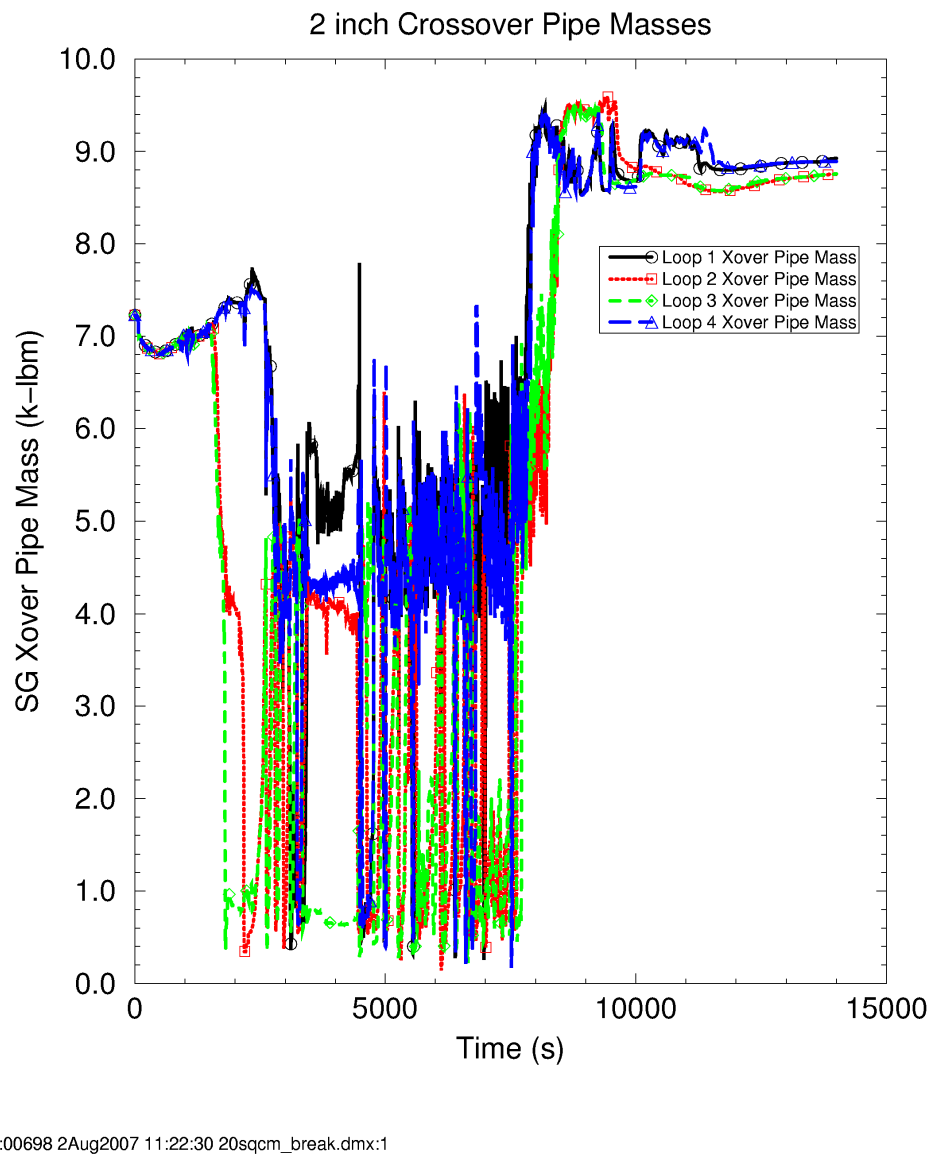
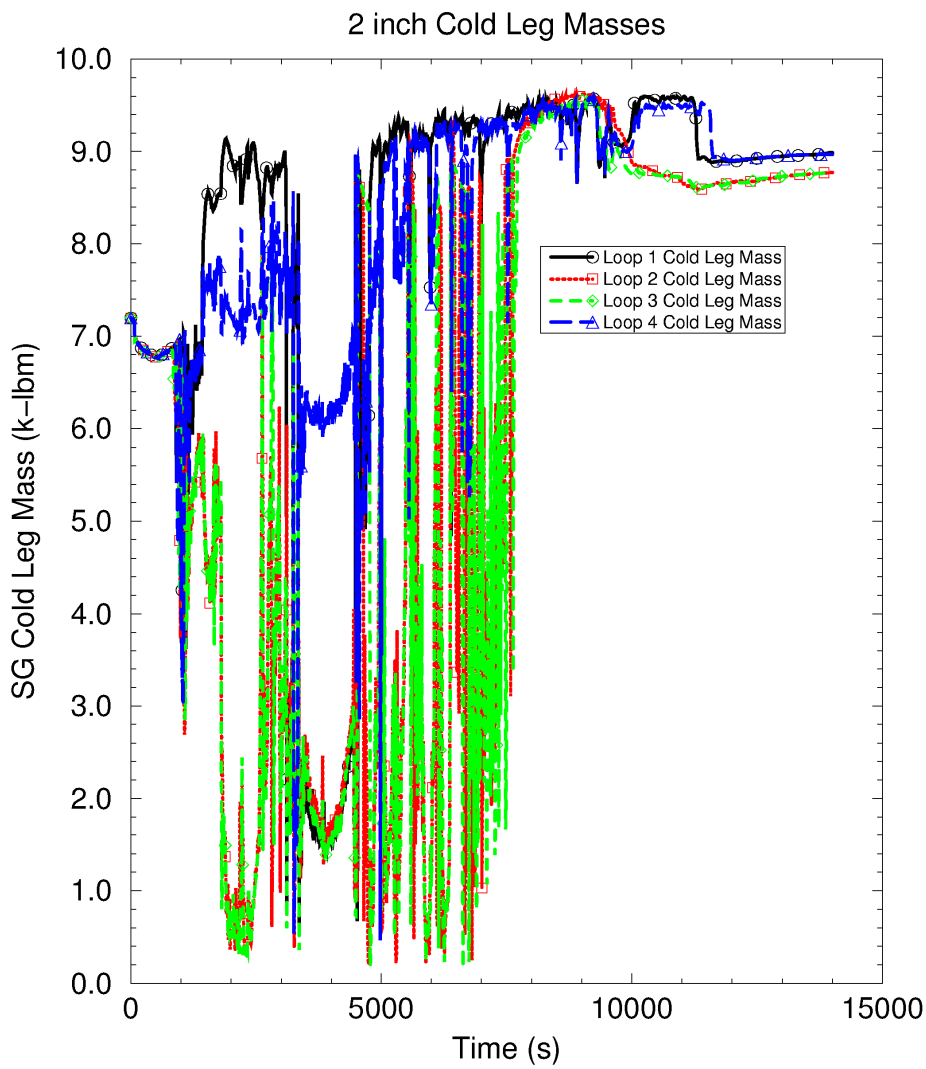


Figure 15.6.5-29-8—Mass of Water in the Cold Leg Pipe for the 2 inch Cold Leg LOCA



ID:00698 2Aug2007 11:22:30 20sqcm_break.dmx:1

Figure 15.6.5-29-9—Loop 2 and 3 Crossover Pipe Mass for the 2 inch Cold Leg LOCA: 6000-12000 seconds

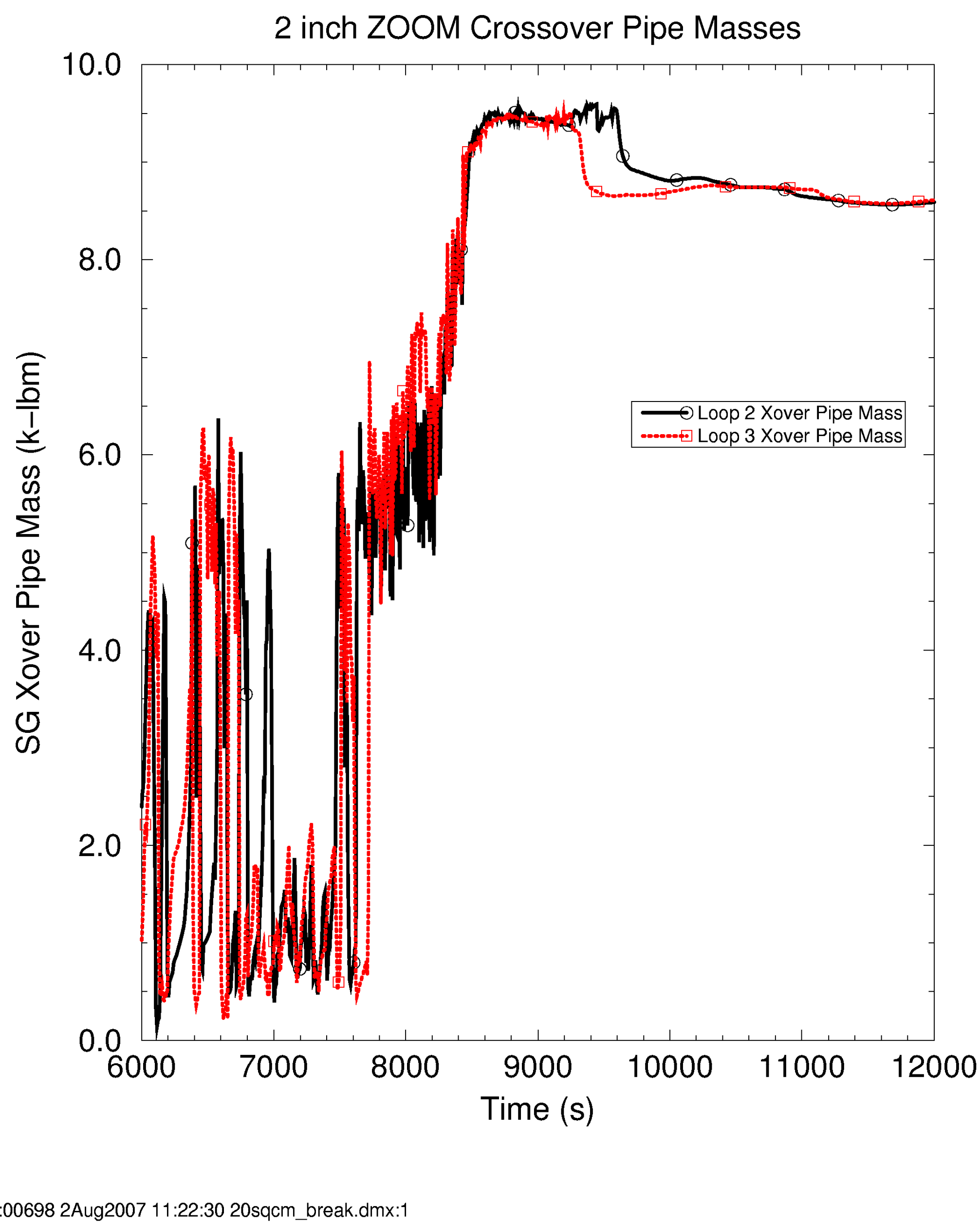


Figure 15.6.5-29-10—Mass of Water in the Steam Generator Outlet Plenum for the 3 inch Cold Leg LOCA

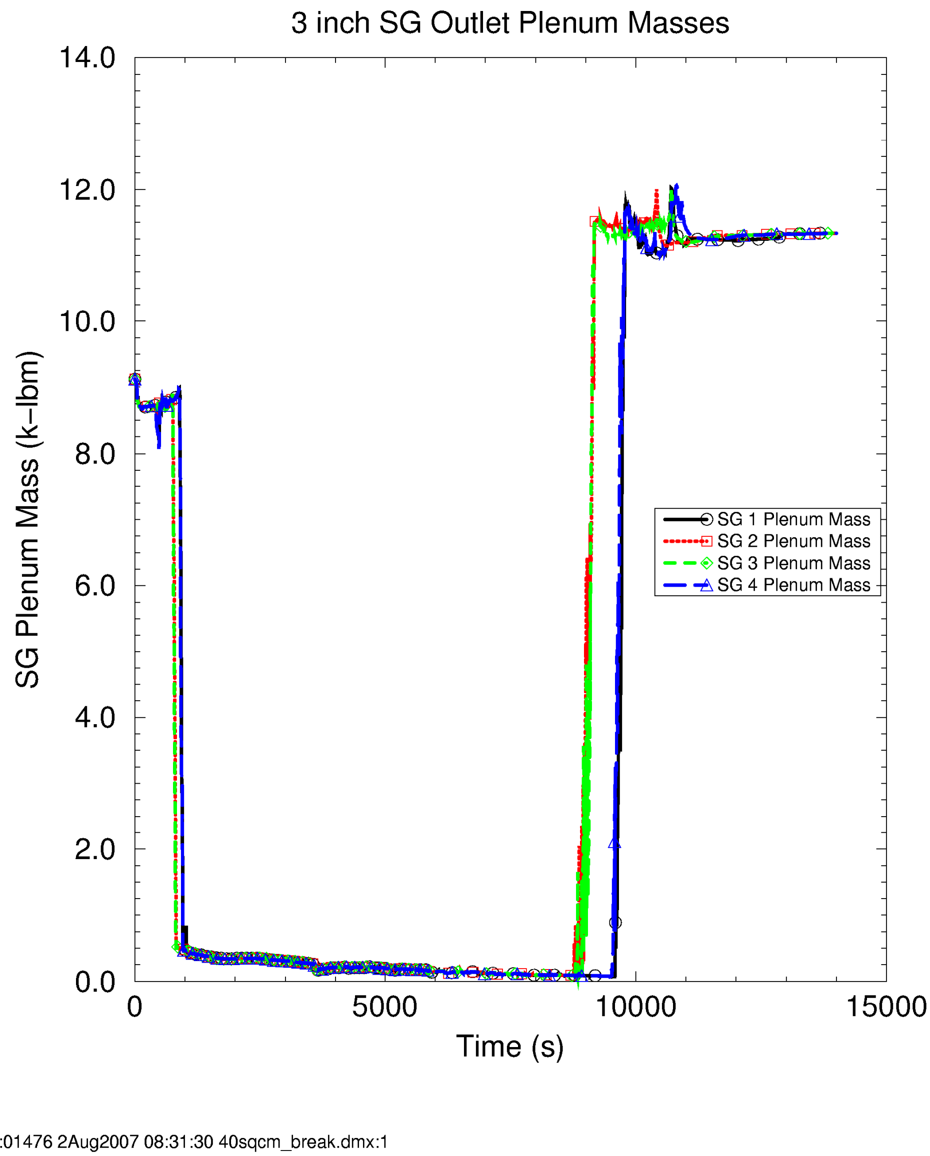


Figure 15.6.5-29-11—Mass of Water in the Crossover Pipe for the 3 inch Cold Leg LOCA

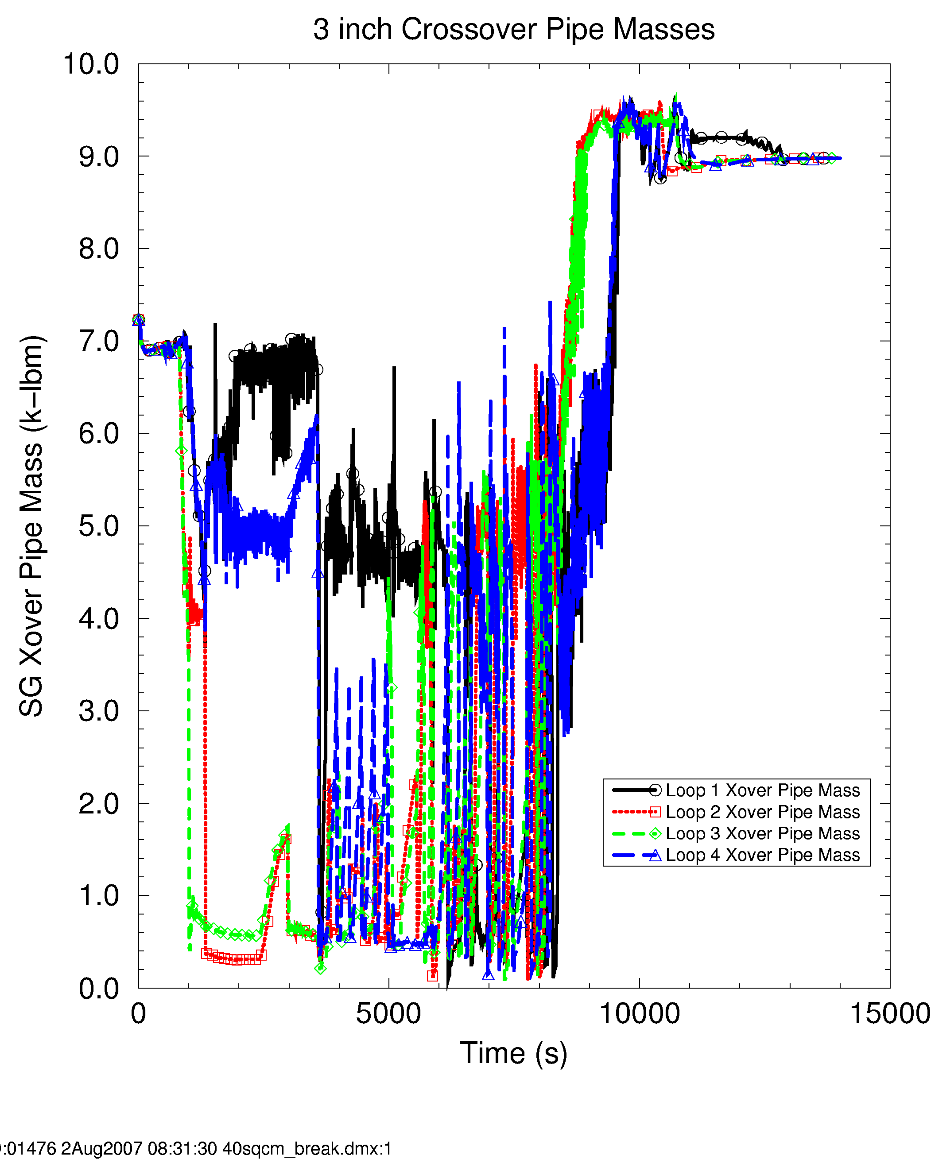


Figure 15.6.5-29-12—Mass of Water in the Cold Leg Pipe for the 3 inch Cold Leg LOCA

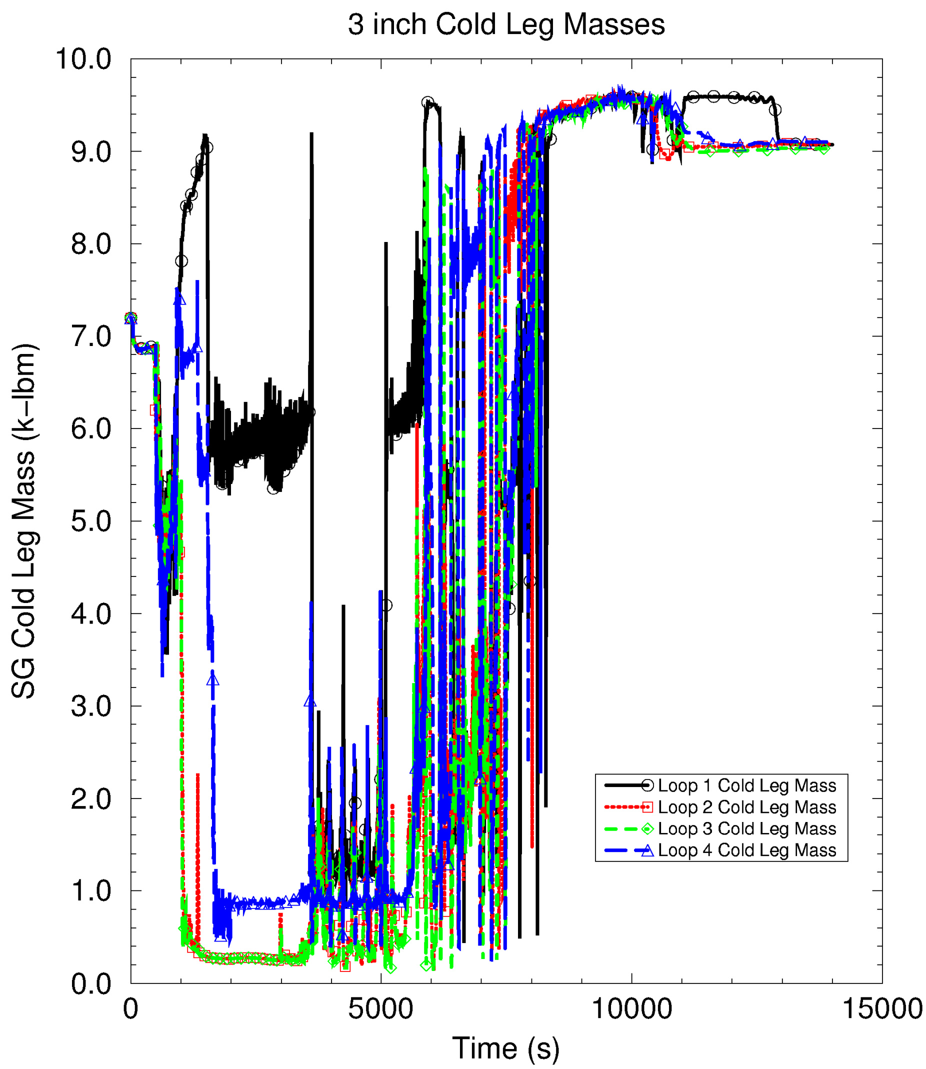


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Figure 15.6.5-29-13—Mass of Water in the Steam Generator Outlet Plenum for the 4 inch Cold Leg LOCA

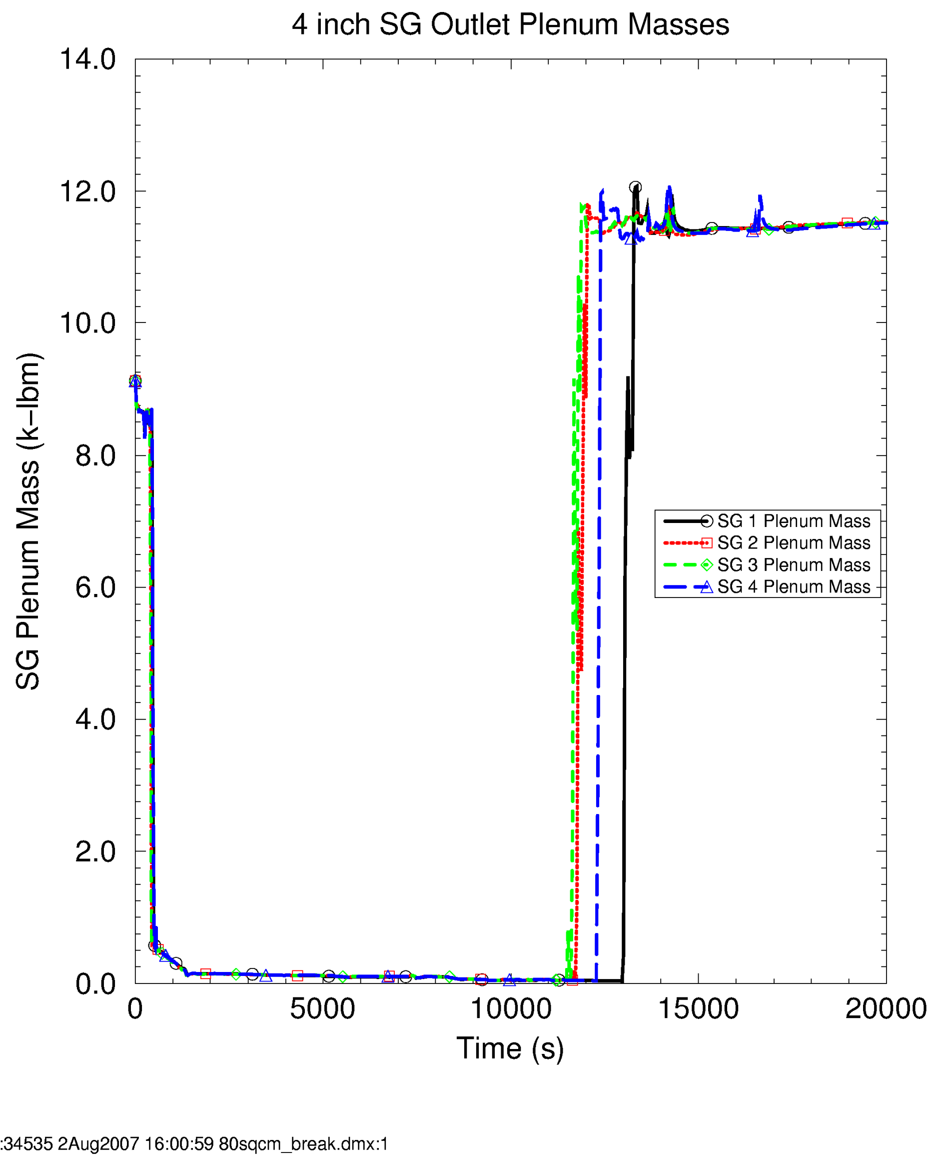


Figure 15.6.5-29-14—Mass of Water in the Crossover Pipe for the 4 inch Cold Leg LOCA

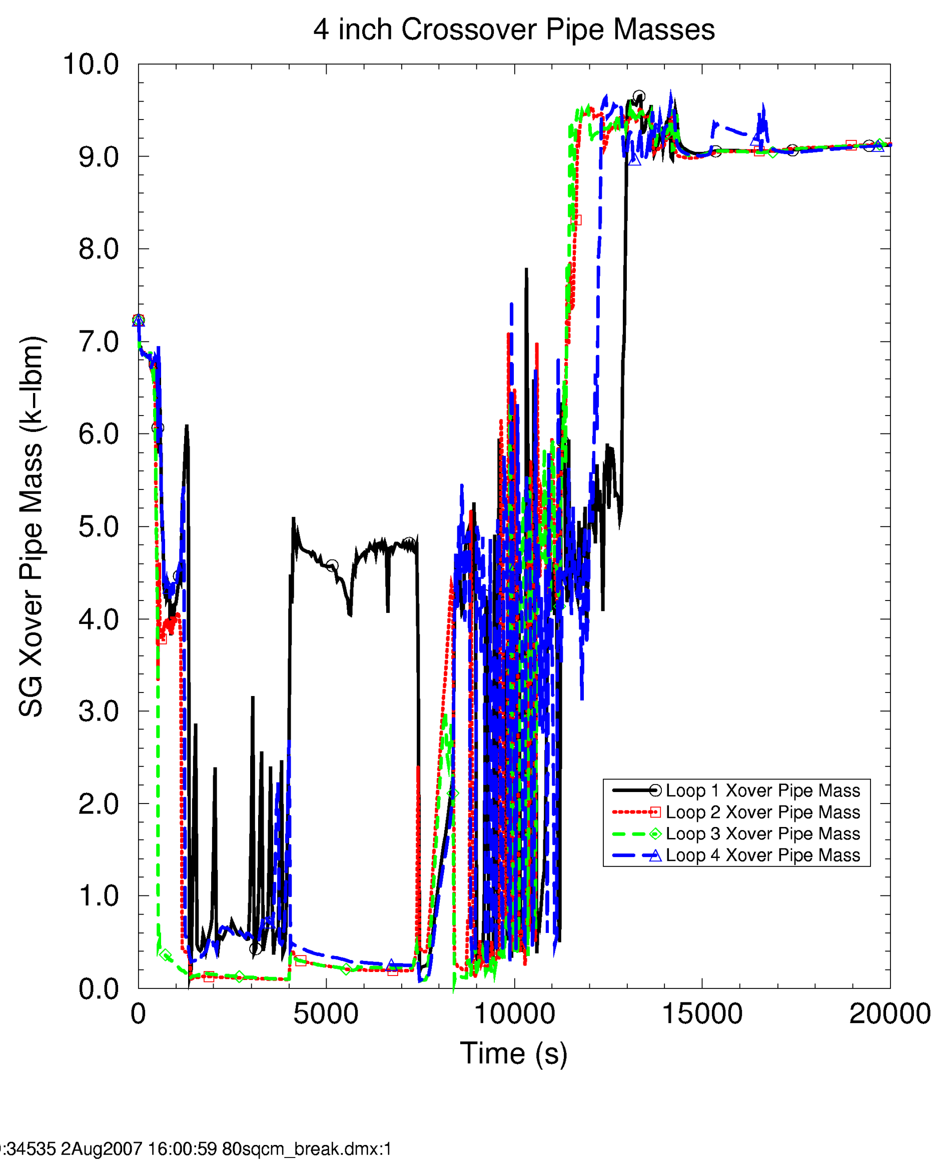
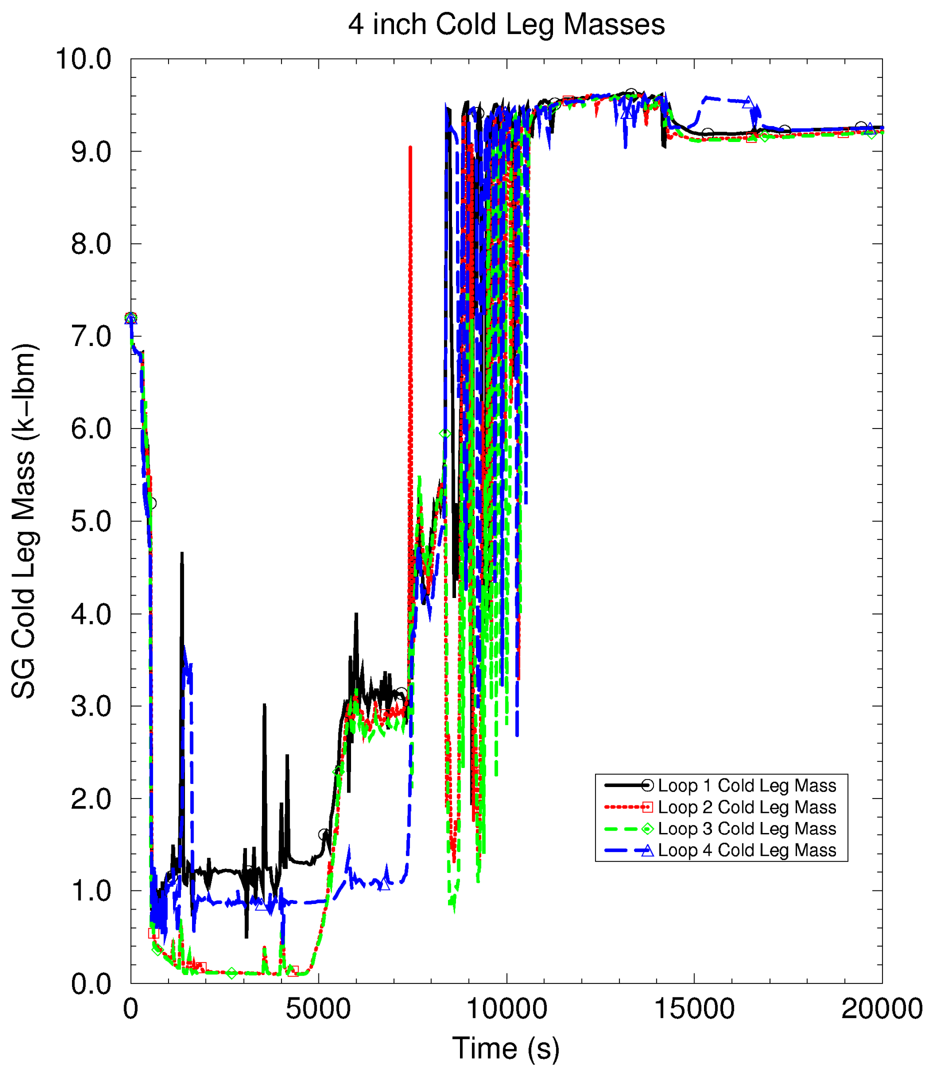


Figure 15.6.5-29-15—Mass of Water in the Cold Leg Pipe for the 4 inch Cold Leg LOCA



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Question 15.06.05-34:

Explain the criticality consequences if a coherent slug of un-borated water of the quantity corresponding to the volume of a single crossover pipe were to be transported to the reactor vessel inlet by resumption of natural circulation.

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

Response to Question 15.06.05-34:

AREVA NP Technical Report ANP-10288P (Reference 1) evaluated the re-boration of a slug of water as it traveled from the reactor vessel downcomer to the core inlet based on the PKL tests and the STAR-CD computational fluid dynamics (CFD) code. The PKL test and the STAR-CD analysis are discussed in the response to request for additional information (RAI) Questions 15.06.05-36 and 15.06.05-37, respectively. ANP-10288P demonstrates that the safety injection fluid re-borates the slug above the minimum boron concentration limit for a full core before it reaches the core inlet when natural circulation restarts. Thus, recriticality is precluded.

To evaluate the effect of a slug of deborated water in the reactor core, additional neutronics analyses have been performed. These analyses determined the minimum boron concentration required to maintain a one percent core shutdown margin (SDM) for a slug of varying volumes and core locations. The following reactor conditions were used in these analyses:

- All rods inserted, minus the most reactive rod (ARI-MRR)
- Reactor coolant temperature, 350°F
- Reactor coolant pressure, 435 psia
- Xenon free
- Zero percent reactor power
- One percent SDM

The size of the slug was varied from 25 percent to 100 percent of the maximum deborated fluid volume (100 percent volume = 216 ft^3, see RAI 15.06.05-29), and included a deborated slug that would occupy the full core (877.1 ft^3). The slug was flattened, keeping the volume constant, so that it has the full flow area of the core (as shown in Figure 15.6.5-34-1). The location of the slug volume was also varied vertically within the core. The remainder of the core was assumed to be at a conservative concentration of 3000 ppm natural boron (the in-containment refueling water storage tank (IRWST) minimum boron concentration is 3235 ppm). The 18 month equilibrium cycle at the beginning of cycle with the slug located near the top of the core was found to be the most limiting condition. The resulting required concentration, as a function of slug vertical length, is given in Figure 15.6.5-34-2 and Table 15.6.5-34-1, and covers a slug vertical length that varies from a full core length down to 10.2 inches. Each boron concentration value in Figure 15.6.5-34-2 and Table 15.6.5-34-1 is the minimum natural boron concentration required when the slug is in the core, and includes an additional 100 ppm for conservatism. These analyses demonstrate that a 216 ft^3 slug of water will require a minimum concentration of 1396 ppm as natural boron to maintain a one percent SDM.

Four break sizes ranging from 1.5 to 4 inches were analyzed with the S-RELAP5 code to evaluate the re-boration of a slug of pure water as the system refills and returns to natural circulation. The thermal-hydraulic characteristics and masses at key locations were used to determine conservative analytical approximations of the boron concentration in the slug as it transits through the reactor coolant pump (RCP) into the reactor vessel downcomer region. For the 1.5 inch break, liquid flowing over the steam generator U-tubes did not stop, thus preventing a deborated slug from forming with a concentration that would allow the core to go critical. For larger break sizes, the slug was re-borated by the safety injection systems and extra borating system (EBS) due to backflow through the RCP during the refill stage prior to the restart of natural circulation.

Mixing between the slug and the safety injection fluid was assumed in the cold leg, but as demonstrated in the STAR-CD CFD analysis, this has a very small impact on the concentration at the core inlet (see the response to RAI Question 15.06.05-37). If the restart of natural circulation occurred after the minimum EBS expiration time, the concentration was evaluated both with and without EBS injection. The minimum boron concentration entering the reactor vessel downcomer region from the natural circulation loop was 1722 ppm for the 3 inch break (limiting case) after the EBS tanks were depleted. This is higher than 1519 ppm, which is the minimum concentration required to maintain the reactor subcritical for a full core without credit for equilibrium xenon. This analysis conservatively takes no credit for the mixing that occurs (as evidenced in the PKL tests and the STAR-CD CFD analysis) in the downcomer and lower head regions due to the safety injection from the other loops. The results of the boron concentration evaluation based on the S-RELAP5 analyses are above the minimum required boron concentration for a one percent SDM with a xenon free core and agree with the conclusions from the PKL tests and the STAR-CD CFD analyses that show there are no criticality consequences.

References:

1. AREVA NP Technical Report ANP-10288P, Revision 0, “U.S. EPR Post-LOCA Boron Precipitation and Boron Dilution Technical Report,” AREVA NP Inc., November 2007.

FSAR Impact:

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

Table 15.6.5-34-1—Boron Concentration for 1% Shutdown Margin as a Function of Slug Size

% of Maximum Deborate Volume	Vertical Length of Slug in the Core (inches)	Volume of Slug (ft^3)	Xe Concentration	Boron Concentration for 1% SDM, (ppm natural boron)
100%	40.7	216	Equilibrium	1000
100%	40.7	216	None	1396
75%	30.5	162	None	1347
50%	20.4	108	None	1101
25%	10.2	54	None	738
N/A, Full Core	165.4	877.1	None	1519

Figure 15.6.5-34-1—Crossover Pipe Slug in Core as Flat Slab

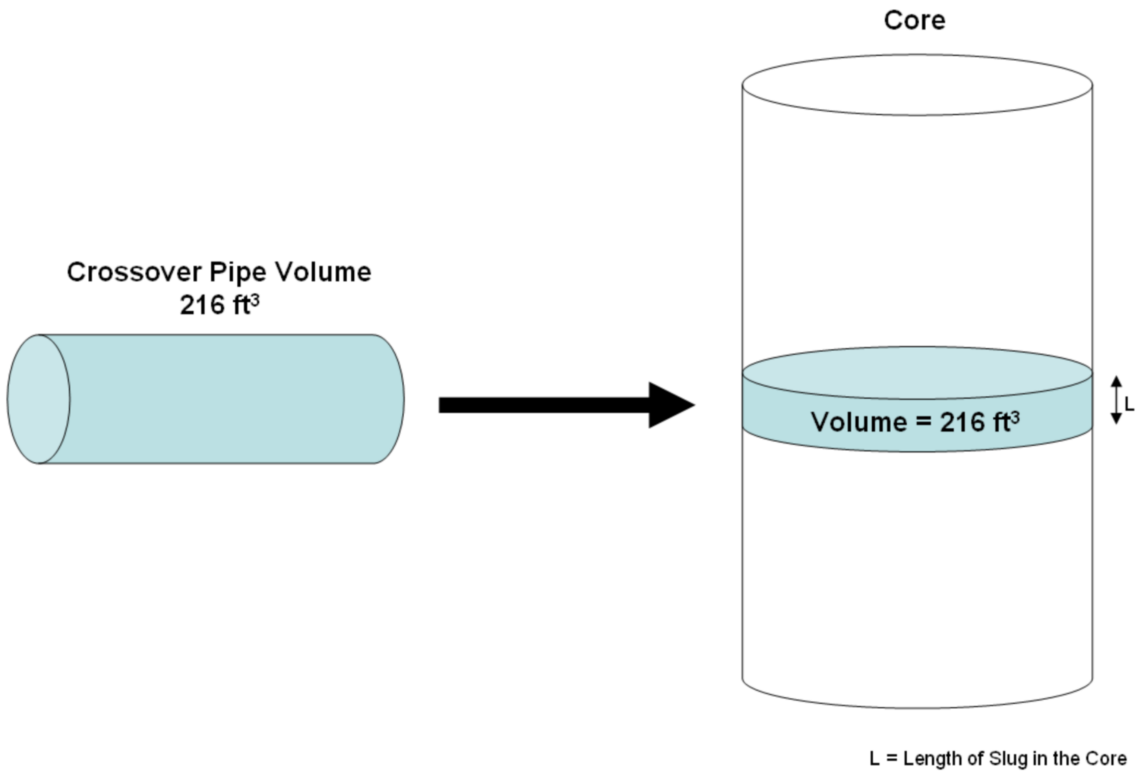
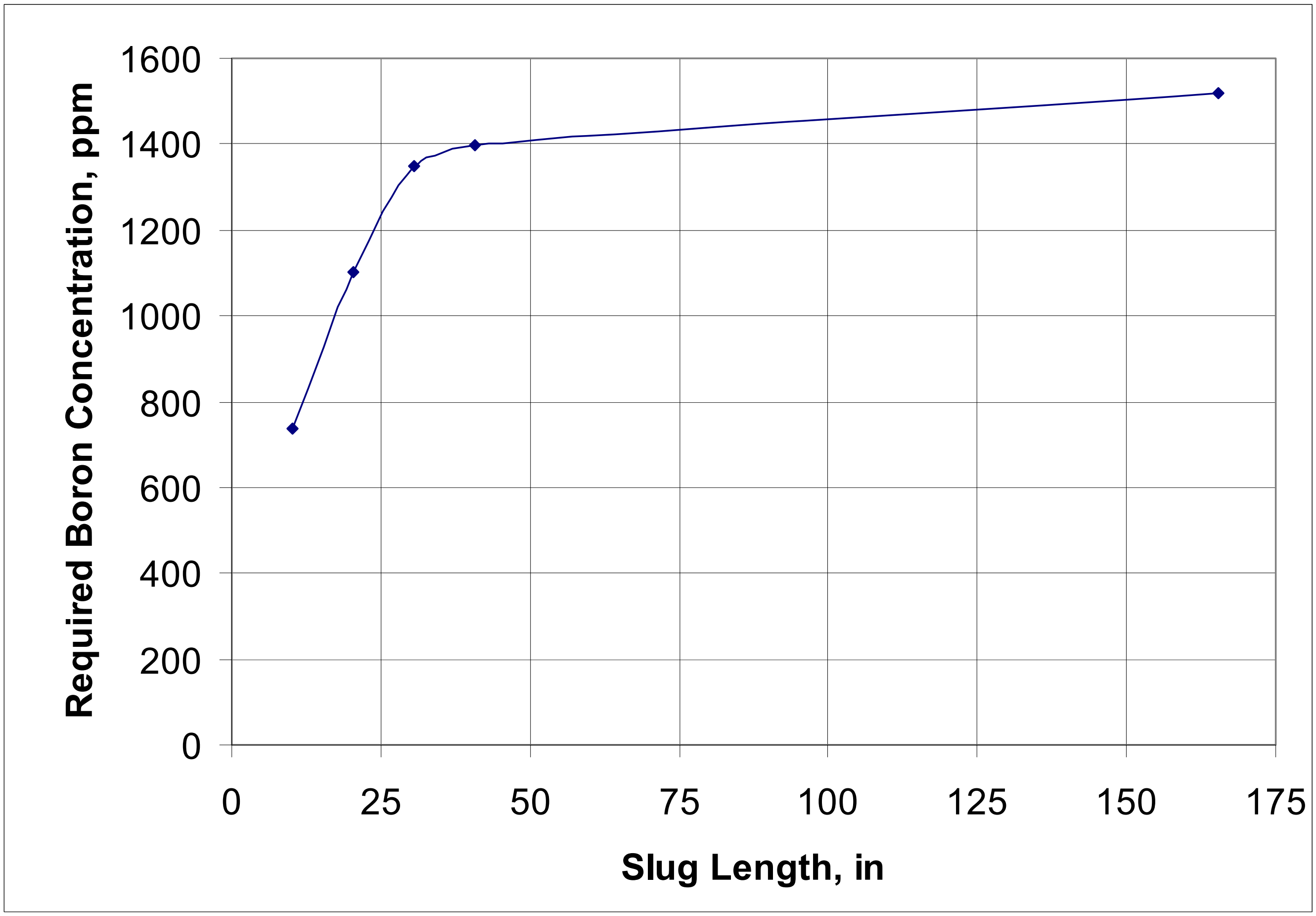


Figure 15.6.5-34-2—Boron Concentration for 1% Shutdown Margin for 18 Month Equilibrium Cycle, Xenon Free



Question 15.06.05-37:

Explain the extent of mixing of the un-borated slug and the ECCS injection in the cold leg. Explain the relevancy of the CFD calculations which were performed for Olkiluoto-3 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 15.06.05-37:

Several “local” computational fluid dynamics (CFD) analyses were performed for the Olkiluoto 3 (OL3) nuclear power plant (the first EPR under construction) using the STAR-CD CFD code to assess the mixing between the deborated water of the moving slug, the highly borated water of the safety injection (SI) system and extra borating system (EBS), and the borated water in the cold leg, downcomer, and lower plenum. The analyses are termed "local" because the reactor coolant system (RCS) modeling was limited to the four cold legs, the reactor vessel downcomer, and the lower plenum (i.e., up to core inlet). The minimum boron concentrations at the core inlet predicted by the CFD analysis were then used to draw conclusions for OL3 regarding the return to criticality if a slug of water with a highly reduced boron concentration was sent to the core at the restart of natural circulation. The boundary conditions for the CFD analysis were based on the PKL test and by a system analysis. The system analysis was performed for OL3 from the beginning of a loss of coolant accident (LOCA) until the restart of natural circulation to determine the times of restart and RCS conditions, such as temperature and pressure. The PKL test results (see the response to RAI Question 15.06.05-36) were used to define the volume of the slug, the slug flow rate profile at the restart of natural circulation, and the initial boron concentrations in the slug.

Two cases (Case 3 and Case 4) from the STAR-CD analyses were selected as representative of the mixing that occurs. These cases are based on the natural circulation peak flow from the PKL tests and closely match the restart flow rates seen in the U.S. EPR S-RELAP5 analyses performed in support of the boron dilution evaluation.

The loop flow assumptions used in Case 3 and Case 4 are:

- Cold Leg 1 – EBS injection
- Cold Leg 2 – Both medium head safety injection (MHSI) and EBS injection
- Cold Leg 3 – Broken loop; neither in-flow nor out-flow
- Cold Leg 4 – Restart of natural circulation; both MHSI and EBS injection

Case 3 assumes complete mixing of the MHSI and EBS fluid with the slug at the entrance to the downcomer. In contrast, Case 4 assumes stratified flow in the cold leg by using separated inlets to the downcomer for the slug and for the MHSI and EBS flow. For each case, three sets of slug volumes and boron concentrations were analyzed, as shown in Table 15.6.5-37-1. Set-1 is the analysis based on the volume and concentration of the slug generated in the PKL test. Two additional, more conservative sets of volume/boron concentration combinations, Set-2 and Set-3, were also evaluated. In both these sets two slugs were sent to the core. The first slug was from the downward area of the steam generator (SG) tubes simulating condensate in the SG downside tubes, SG outlet plenum, and crossover pipe for a slug volume of 639 ft^3. In Set

2, this first slug had a concentration of 50 ppm, while in Set 3 it had a concentration of 400 ppm. The second slug was from the upward area simulating condensate in the SG upside tubes and SG inlet plenum, for a volume of 480 ft^3. In both Set 2 and Set 3 the boron concentration of the second slug was 685 ppm in both sets. The STAR-CD analysis results for OL3 are provided in Table 15.6.5-37-2. Although Case 3 and Case 4 had opposing assumptions regarding the mixing of the slug with the SI and EBS flow in the cold leg, the difference in the boron concentrations at the core inlet for Case 3 and Case 4 is small.

There are no differences in the OL3 and U.S. EPR RCS geometry used in the STAR-CD simulation. Because the geometry of the OL3 RCS is the same as the U.S. EPR RCS, the results from these CFD analyses can (with an evaluation of the differences in the safety injection boron concentrations) be applied directly. A key difference between the U.S. EPR and the OL3 design in the CFD analyses is the boron concentrations in the in-containment refueling water storage tank (IRWST), the accumulators, and the EBS tanks. The equivalent boron concentration as natural boron in the U.S. EPR reactor is higher than that used in the STAR-CD CFD analyses (see Table 15.6.5-37-3). Additionally, the volume/concentrations sets had slug sizes significantly larger than the volume of the crossover pipe, which was shown in the S-RELAP5 analyses not to be completely full prior to the refill stage. As shown in Table 15.6.5-37-2, even with large slug volumes and system boron concentrations lower than those used in the U.S. EPR, the STAR-CD CFD results show there is mixing in the reactor vessel sufficient to raise the minimum boron concentration at the core inlet above that which is required for maintaining a 1 percent core shutdown margin when completely filled at the critical concentration. Thus, the STAR-CD CFD analyses confirm that the U.S. EPR natural circulation restart will not make the core critical.

FSAR Impact:

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

Table 15.6.5-37-1—STAR-CD CFD Case Description

		Set 1, 1 Slug Simulating PKL	**Set 2, 2 Slugs Sent to the Core**	**Set 3, 2 Slugs Sent to the Core**
	Mixing Assumption at Downcomer Inlet	**Slug Volume and Concentration**	**Slug Volume and Concentration**	**Slug Volume and Concentration**
Case 3	Fully Mixed	388 ft^3 @ 50 ppm	639 ft^3 @ 50 ppm 480 ft^3 @ 685 ppm	639 ft^3 @ 400 ppm 480 ft^3 @ 685 ppm
Case 4	Stratified	388 ft^3 @ 50 ppm	639 ft^3 @ 50 ppm 480 ft^3 @ 685 ppm	639 ft^3 @ 400 ppm 480 ft^3 @ 685 ppm

Table 15.6.5-37-2—STAR-CD Evaluation of the Minimum Boron Concentration at the Core Inlet

Slugs Volume and Concentration	Minimum Boron Concentration at Core Inlet, Cold Leg Mixed Case 3, ppm	Minimum Boron Concentration at Core Inlet, Separated Inlets Case 4, ppm	Required Boron Concentration for U.S. EPR Full Core, 1% Shutdown Margin, ppm
Set 1 388ft^3 @ 50 ppm	2043	2454	1519
Set 2 639/480 ft^3 @ 50/685 ppm	2001	1987	1519
Set 3 639/480 ft^3 @ 400/685 ppm	2075	2102	1519

Table 15.6.5-37-3—OL3 and U.S. EPR Comparison

	Slug Size (ft^3)	IRWST Boron Concentration (ppm)	EBS Tank Concentration (ppm)
OL3 STAR-CD CFD	Set 1: 388 Set 2*: 639 and 480 Set 3*: 639 and 480	2700	11,750
U.S. EPR Design	Maximum Deborate Volume: 216	3235	13,335

* Set 2 and Set 3 simulate sending two slugs to the core