From: BRYAN Martin (EXT) [Martin.Bryan.ext@areva.com]
Sent: Tuesday, May 25, 2010 6:22 PM
To: Tesfaye, Getachew
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); HOLM Jerald S (EXT)
Subject: Response to U.S. EPR Design Certification Application RAI No. 241, FSAR Ch 15, Supplement 2
Attachments: RAI 241 Supplement 2 Response US EPR DC.pdf

Getachew,

AREVA NP Inc. (AREVA NP) previously provided a response to 5 of the 6 questions in RAI 241 in the file, "RAI 241 Supplement 1 Response US EPR DC.PDF". AREVA NP has discovered an error in the response to one of the questions, RAI 241- 15.06.05-51.

RAI 241 Supplement 2 contains a revision to the response originally provided in RAI 241 Supplement 1 for Question 15.06.05-51. In addition to added technical detail, the revision is concerned with two items:

1) The Wilson and Cunningham-Yeh void fraction correlation coefficients are corrected to agree with their original references (3, 4) rather than using those reported in References 1 and 2.

2) The analytical solution is revised to limit vapor generation to the active core. Vapor generation is set to zero above the top of active fuel (TAF).

Both of these items change the details presented in the RAI 241 Supplement 1 response, but, do not change the overall conclusions regarding the core being covered by a two-phase mixture. The text of the response is also revised to acknowledge the influence of hot leg injection on the results of this evaluation and to reflect discussions with the NRC regarding the original response to this question.

The attached file, "RAI 241 Supplement 1 Response US EPR DC.PDF" provides a technically correct response to Question RAI 241 – 15.06.05-51.

The following table indicates the respective pages in the response document, "RAI 241 Supplement 2 Response US EPR DC.PDF," that contain AREVA NP's response to the subject question.

Question #	Start Page	End Page
RAI 241 — 15.06.05-51	2	14

This concludes the formal AREVA NP response to RAI 241, and there are no questions from this RAI for which AREVA NP has not provided responses.

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
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Martin.Bryan.ext@areva.com

From: WELLS Russell D (AREVA NP INC)
Sent: Wednesday, November 25, 2009 10:27 AM
To: 'Getachew Tesfaye'
Cc: Pederson Ronda M (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 241, FSAR Ch 15, Supplement 1

Getachew,

AREVA NP Inc. (AREVA NP) provided a response to 1 of the 6 questions of RAI No. 241 on August 5, 2009. The attached file, "RAI 241 Supplement 1 Response US EPR DC.PDF" provides technically correct responses to the remaining 5 questions, as committed.

The following table indicates the respective pages in the response document, "RAI 241 Supplement 1 Response US EPR DC.PDF," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 241 — 15.06.05-51	2	11
RAI 241 — 15.06.05-52	12	14
RAI 241 — 15.06.05-53	15	16
RAI 241 — 15.06.05-54	17	17
RAI 241 — 15.06.05-55	18	26

This concludes the formal AREVA NP response to RAI 241, and there are no questions from this RAI for which AREVA NP has not provided responses.

Sincerely,

(Russ Wells on behalf of)
Ronda Pederson

ronda.pederson@areva.com
Licensing Manager, U.S. EPR Design Certification
New Plants Deployment
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From: Pederson Ronda M (AREVA NP INC)
Sent: Wednesday, August 05, 2009 2:48 PM
To: Tesfaye, Getachew
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. 241 (2769, 2804),FSAR Ch. 15

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 241 Response US EPR DC.pdf" provides a technically correct and complete response to 1 of the 6 questions.

The following table indicates the respective pages in the response document, "RAI 241 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 241 — 15.02.01-15.02.05-9	2	3
RAI 241 — 15.06.05-51	4	4
RAI 241 — 15.06.05-52	5	5
RAI 241 — 15.06.05-53	6	6
RAI 241 — 15.06.05-54	7	7
RAI 241 — 15.06.05-55	8	8

A complete answer is not provided for 5 of the 6 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 241 — 15.06.05-51	December 3, 2009
RAI 241 — 15.06.05-52	December 3, 2009
RAI 241 — 15.06.05-53	December 3, 2009
RAI 241 — 15.06.05-54	December 3, 2009
RAI 241 — 15.06.05-55	December 3, 2009

Sincerely,

Ronda Pederson

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From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Tuesday, July 07, 2009 7:57 AM
To: ZZ-DL-A-USEPR-DL
Cc: Liang, Chu-Yu; Forsaty, Fred; Lu, Shanlai; Donoghue, Joseph; Carneal, Jason; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 241 (2769, 2804),FSAR Ch. 15

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on June 5, 2009, and discussed with your staff on July 2, 2009. Draft RAI Question 15.06.05-50 was deleted 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: 1459

Mail Envelope Properties (BC417D9255991046A37DD56CF597DB7106445348)

Subject: Response to U.S. EPR Design Certification Application RAI No. 241, FSAR Ch 15, Supplement 2
Sent Date: 5/25/2010 6:22:06 PM
Received Date: 5/25/2010 6:42:16 PM
From: BRYAN Martin (EXT)

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Files	**Size**	**Date & Time**
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RAI 241 Supplement 2 Response US EPR DC.pdf		1038714

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

Response to

Request for Additional Information No. 241, Supplement 2

7/07/2009

U.S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 15.02.01-15.02.05 - Loss of External Load; Turbine Trip; Loss of Condenser Vacuum; Closure of Main Steam Isolation Valve (BWR); and Steam Pressure Regulator Failure (Closed)
SRP Section: 15.06.05 - Loss of Coolant Accidents Resulting From Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary
Application FSAR Ch 15

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

Question 15.06.05-51:

If the two-phase mixture level drops below the TAF anytime during the U.S. EPR long term cooling phase of a LOCA, cladding heatup and oxidation can result.

Please provide the results of a thermal-hydraulic analysis quantifying the two-phase mixture level within the reactor core barrel during the long term cooling of the U.S. EPR core under the most limiting break size, break location and ECCS performance conditions. Discuss the conservatism of the obtained results. For important modeling parameters that are expected to vary within a certain range, substantiate the conservatism in selecting the value for each parameter or provide sensitivity assessments over the expected range of variation.

This question is as a follow-up to the reactor systems audit held on April 21-24, 2009.

Revised Response to Question 15.06.05-51:

The following is a revision to the response originally provided as Reference 5. In addition to added technical detail, the revision is concerned with two items:

1) The Wilson and Cunningham-Yeh void fraction correlation coefficients are corrected to agree with their original references (3, 4) rather than using those reported in References 1 and 2.

2) The analytical solution is revised to limit vapor generation to the active core. Vapor generation is set to zero above the top of active fuel (TAF).

Both of these items change the details presented in the RAI 241 Supplement 1 response (Reference 5), but, do not change the overall conclusions regarding the core being covered by a two-phase mixture. The text of the response is also revised to acknowledge the influence of hot leg injection on the results of this evaluation and to reflect discussions with the NRC regarding the original response to this question.

Hot leg injection is initiated by the operator 60 minutes after the occurrence of a loss of coolant accident (LOCA) to suppress steaming to the containment, prevent boron precipitation, and provide long-term cooling of the core. The functionality of hot leg injection is described in ANP-10299P, Revision 2, Applicability of AREVA NP Containment Response Evaluation Methodology to the U.S. EPR™ for Large Break LOCA Analysis.

Low head safety injection (LHSI) water is drawn from the in-containment refueling water storage tank (IRWST) and cooled via a heat exchanger before being injected into the reactor coolant system. At 60 minutes, the operator realigns the LHSI system to deliver about 75 percent of the water (120 kg/s per train) to their respective hot legs. The colder LHSI water drains into the upper plenum and down onto the top of the core. Test data shows that condensation rates in the upper plenum are high if a mixture level exists between the hot leg nozzle and the top of the core (Section 6.1.4 of ANP-10299, Revision 2). The spilling LHSI water from the hot leg impinges on the guide tubes in the upper plenum. The colder injected water then flows downward through the cooler peripheral assemblies, crosses to hotter assemblies, and reinforces natural circulation within the reactor vessel and core. Within a few hours, there is sufficient hot leg LHSI to terminate net steaming from the core.

For large breaks, continued operation of hot leg injection fills the reactor vessel to the level of the cold legs where the excess water spills to containment. In that case, the hot leg injected water flows down through the core, up through the downcomer, and to the break. That flow of water removes concentrated borated water from the core and lower plenum. For small breaks, hot leg injection fills the primary system and leads to natural circulation. That also removes concentrated borated water from the lower plenum and core.

While hot leg injection has important benefits to long term cooling and boron control, the analysis only takes credit for it indirectly by neglecting the possible density increase from the concentration of boron in the lower plenum and core. The static balance analysis only considers cold leg injection.

EGG-TFM-7993 (Reference 1) presents a long term core cooling assessment in the post-reflood period by using a quasi-steady static-balance approach and RELAP5. Reference 1 concluded that the simplified analysis was conservative relative to a full system analysis using RELAP5.

A quasi-steady static-balance analysis approach, similar to that presented in Reference 1, is used to calculate the two-phase mixture level in the core as a function of decay power during the post-reflood period. The ANS 1971/1973 Standard is used to define decay power and time after full power reactor shutdown. LHSI remains operable and maintains the postulated water elevation.

Figure 15.06.05-51-1 shows the concept and essential features of the quasi-steady static-balance model. The assumptions and description are as follows:

1) The system is assumed to have reached a quiescent state without significant fluid dynamic effects.

2) Elevations are relative to the bottom of the active fuel. The TAF is at elevation Z_{CORE}. The top of the cross-over pipe U-bend (loop seal) is at elevation Z_{LS}. The water level in the loop seal piping, Z_3, is shown below the elevation Z_{LS} to acknowledge possible depression of the water level during steam venting via the loop seal; however, details of the depression are not modeled. The water level Z_3 increases above Z_{LS} at low decay power when steam is not vented through the loop seal.

   Elevations:

Z_{LS}	Top of cross-over pipe U-bend (loop seal)
Z_{CL}	Cold leg
Z_{CORE}	Top of core (active fuel)
Z_0	Start of bulk boiling
Z_1	Core collapsed liquid level
Z_2	Core two-phase mixture level
Z_3	Water elevation in loop seal piping

3) LHSI is operational and injects sufficient water to offset the loss through the largest break and maintains postulated (conservative) water levels as shown in Figure 15.06.05-51-1. LHSI capacity for a single pump at 14.5 psia is 334 lb/second, which provides makeup water to the core where the steaming rate is less than 10 lb/second in the post-reflood period of interest. With adequate IRWST inventory, LHSI injection continuously delivers water to the primary system.

4) When the LHSI system is switched to hot leg injection after 60 minutes, it will deliver about 75 percent of its subcooled water to the hot leg where it condenses steam and delivers a large quantity of water directly to the top of the core; however, hot leg injection is not credited in this analysis other than to clear concentrated borated water from the lower plenum and core. Hot leg injection keeps the core covered with water starting at about one hour into the post-reflood period.

5) A cold leg break between the reactor coolant pump and reactor vessel is the most limiting location because of restricted steam venting though the loop seal as shown in Figure 15.06.05-51-1. Other break locations do not impose significant limitations to the venting of steam and do not cause a depression of the collapsed liquid level in the core. The analysis is independent of break size and geometry because of the conservative assumption that LHSI maintains postulated water levels. A top break versus a bottom break has only a small impact on the core collapsed liquid level. The water elevation in the cold leg affects both the elevation head in the downcomer and the timing (decay power) at the minimum core collapsed level; These are compensating effects.

6) Water densities in the cold leg, loop seal, downcomer, and core are not well defined and require assumptions. While variation of those densities can change the details of the results, the density variations do not significantly affect the overall conclusion that the core is adequately covered by a two-phase mixture.

7) Steam generators are cooled down and are neither a heat source, nor a heat sink for primary side steam. Reflux condensation of steam in the steam generators is excluded from this analysis. Reflux condensation can return water to the upper plenum to assist with long term core cooling.

8) There are two escape flow paths for steam generated by decay heat in the core. Steam flows through the design leakage paths from the downcomer to the hot-leg and from the downcomer to the upper-head. These parallel leakage paths are combined to form Path 1. Path 1 vents steam through the leakage paths to the downcomer, to the cold leg and then to the break. Venting is in the reverse direction (as compared to water leakage for normal operation).

   Path 2 vents steam through the hot-leg, steam generator, loop seal, reactor coolant pump, and then to the break.

9) The elevation at the top of the cold leg cross-over pipe U-bend (loop seal) is important to the static balance analysis and the determination of the core collapsed liquid level. The elevation at the top of the U-bend is 0.1 ft below the elevation at the TAF.

10) Pressure drops are defined by elevation head differences in the loops and reactor vessel. Fluid frictional resistance is very small for Paths 2 and 3 and hydrostatic head

dominates for the post-reflood period. Pressure drop in the bypass (Path 1) is defined by flow resistance modeling with a loss coefficient (K/A^2) derived from a separate analysis of the U.S. EPR reactor vessel.

11) The water and steam are saturated at the selected primary system pressure except for the water in the downcomer and core inlet. The subcooled water temperature at the core inlet is at the LHSI temperature. Subcooled water at the core inlet produces a lower two-phase mixture level than if saturated water is assumed.

12) The core is assumed to have a uniform axial and radial power distribution as indicated in Reference 1 and in "The Prediction of Two-Phase Mixture Level and Hydrodynamically-Controlled Dryout under Low Flow Conditions" (Reference 2). This assumption is sufficient for this long term cooling assessment and allows a closed form analytical solution for the two-phase mixture level, Z_2, in terms of the core power and collapsed liquid level, Z_1, and the start of boiling at elevation Z_0.

13) The loops are assumed to be symmetric regarding loop seal filling and venting.

Static-balance modeling is used to define the collapsed liquid level in the core and the associated water levels. There are three periods of interest:

1) High decay power in the post-reflood period causes the steam generated within the active core to vent through Path 1 and Path 2 as shown in Figure 15.06.05-51-1. The depression of Z_3 below Z_{LS} is not accurately known; however, Z_3 approaches Z_{LS} as the steaming rate approaches the transition (see Item 2). The impact of the depression of Z_3 on Z_1 is also offset by a reduction in elevation head of the two-phase mixture in the vertical leg on the pump side of the loop seal that increases Z_1. The Zuber-Finlay correlation (Co=1.25, V_{gj} constant = 1.41), as presented in Reference 2, is used to compute the void fraction in that vertical leg, which is not a critical choice. This is also a period when the high steaming rate causes significant level swell. Thus, the assumption of $Z_3 = Z_{LS}$ is an acceptable approximation for this period.

2) As the power decreases, the steam generation rate decreases. A power transition is reached where all steam is vented through Path 1 (bypass) and no steam is vented through Path 2 (loop seal). At this transition, the loop seal water level, $Z_{3,}$ is at the loop seal elevation, Z_{LS}. The minimum core collapsed liquid level, Z_{1min}, is equal to the loop seal elevation, so, $Z_{1min} = Z_3 = Z_{LS}$. The void fraction in the vertical leg of the loop seal is also zero.

   Using the static balance modeling, the steam flow resistance pressure drop through Path 1 equals the elevation head of water in the vertical leg of the loop seal. The resulting steaming rate at this transition is expressed as

$$w_{g_{Z_{1,MIN}}} = \sqrt{\frac{2\rho_g \rho_f (Z_{CL} - Z_{LS}) g}{(K/A^2)_{BYP}}}$$

   The steaming rate is directly related to decay power and the time after shutdown. The densities are taken at saturation. The two-phase mixture level needs to rise only 0.1 ft above this minimum collapsed liquid level to assure coverage of the active fuel.

The flow resistance (K/A^2) is highly uncertain. The two resistance values used in the analysis bound an expected minimum and maximum resistance. If the leakage path is closed, steam is vented only through the loop seal and a minimum is not achieved. A lower than expected resistance produces a minimum core collapsed level earlier in time at higher decay power. The higher decay power produces more level swell and higher two-phase mixture level. Thus, while the uncertainty of K/A^2 affects the timing of Z_{1min}, the core remains covered with a two-phase mixture in the post-reflood period as is shown in the computed results that follow.

3) A further decrease of decay power reduces the steam generation rate and steam does not vent through the loop seal (Path 2). It only vents through the bypass (Path 1). The void fraction in the vertical leg of the loop seal remains at zero. A reduction of steam generation rate reduces the steam pressure at the steam generator side of the loop seal, and using the static balance pressure drops, the water elevation on the steam generator side of the loop seal, Z_3, increases above the top of loop seal elevation, Z_{LS}. The core collapsed liquid level also rises because $Z_1 = Z_3$. The water level Z_3 needs to rise only 0.1 ft for the collapsed liquid level to be at the TAF. The core is well covered in this late post-reflood period after the transition.

The static-balances define the elevation of collapsed liquid level, Z_1, and the energy balance defines the elevation at the start of boiling, Z_0. The two-phase mixture elevation, Z_2, is defined by using the void-fraction correlations together with the vapor generation rate in the active core. The mixture level, Z_2, is always above the collapsed liquid level, Z_1.

By assuming a uniform power distribution in the core, it is possible to develop a closed form analytical solution for the two-phase mixture level (i.e., Z_2) in terms of the collapsed liquid level (i.e., Z_1), start of boiling elevation (i.e., Z_0), and decay power. The closed form solutions for the Wilson and Cunningham-Yeh correlations are shown in Reference 1. The solutions for the Wilson and Cunningham-Yeh correlation are re-derived for this revised analysis starting with the original correlations presented in References 3 and 4. The new derivation corrects some inconsistencies found in References 1 and 2. The closed form solutions for this analysis include subcooling at the core inlet and are used to define Z_0. The inclusion of subcooled water produces a lower two-phase mixture level, Z_2, and its inclusion is conservative for this analysis. The vapor generation rate is set to zero in the two-phase mixture above the top of the active fuel. The flow area change above the fuel assembly is also not modeled. Solutions for the mixture level, Z_2, greater than Z_{CORE}, imply that the mixture level is above the TAF. The Wilson and Cunningham-Yeh void fraction correlations are compared with experimental data in Reference 2. Those comparisons suggest that the Cunningham-Yeh correlation may under-predict Z_2. The Wilson correlation appears to be the closest to experimental data for its application in Reference 2. Both correlations are included to show the range of variation using two common correlations.

Table 15.06.05-51-2 shows the input selections for a nominal case and offsets for selected parameters of interest.

Table 15.06.05-51-3 presents a summary of results. The minimum collapsed liquid, Z_1, is 13.68 ft, which is 0.1 ft below the top of the active core. The time it takes to reach the minimum level depends on parameters that affect the flow split between the bypass and the loops. Pressure and bypass flow resistance are two parameters of interest. Using nominal bypass flow resistance and atmospheric pressure for Case 1, the minimum collapsed liquid level occurs beyond the 1157 days of the computation. Increasing the pressure in Case 2 increases the steam density and bypass flow rate. The minimum collapsed liquid level, Z_1, is reached in 603 days. Decreasing the bypass flow resistance coefficient in Case 3 increases the bypass flow further and the minimum is reached in 145.4 days. While there is variability in the bypass flow resistance, the impact of the variability affects only the time necessary to reach the minimum collapsed level. A break at a lower initial power would change these times because it would change the decay power.

In all cases, and for both two-phase flow correlations, the two-phase mixture level, Z_2, is always above the TAF. The Cunningham-Yeh correlation produces the lowest two-phase levels; thus, it is the most conservative.

Figure 15.06.05-51-2 shows the results of the nominal Case 1. The core collapsed liquid level, Z_1, is initially near the elevation of the cold leg and then decreases with power. However, there is no minimum for Z_1 during the time of this computation and Z_1 remains above the TAF. The minimum occurs beyond 1157 days. The bypass is highly restrictive; therefore, steam is vented through both the loops and bypass for this computation. The two-phase mixture levels are above the TAF for both void fraction correlations. The Wilson correlation is designated as Z_2_W2 and Cunningham-Yeh correlation is designated as Z_2_CY.

Figure 15.06.05-51-3 shows a plot of the two-phase mixture elevations at the increased pressure of 32 psia. The increased pressure increases the density of the steam and the steam bypass flow rate, which creates a minimum collapsed liquid level that is reached in 603 days and reduces the two-phase mixture levels from those in nominal Case 1. The minimum Z_1 is at the top of the cross-over pipe U-bend (loop seal) and only 0.1 ft below the TAF. The power at minimum Z_1 is the transition power where the loop steam flow stops because the loop seal blocks steam flow. Steam is only vented through the bypass. As the core power decreases below the transition power, Z_3 increase and Z_1 follows. The two-phase mixture levels are above the TAF for both void fraction correlations.

Figure 15.06.05-51-4 shows a plot of the two-phase mixture elevations when the bypass flow resistance is decreased from the nominal resistance to the minimum resistance. The collapsed liquid level is initially near the elevation of the cold leg, and then decreases to the minimum value within 145.4 days. The overall result is similar to Case 2, but with earlier timing of Z_{1min}. The two-phase mixture levels, Z_2, are above the TAF using both void correlations.

Table 15.06.05-51-4 shows a list of parameters that affect the modeling used for this analysis. The design elevations are of high importance to the analysis. In particular, the top of the cross-over pipe U-bend (loop seal) is only 0.1 ft below the TAF.

Bypass flow resistance is uncertain and affects the timing of the minimum collapsed liquid level, Z_{1min}, in the core. The analysis shows that, while the bypass flow resistance can affect timing, Z_{1min} is always at the loop seal elevation, Z_{LS}.

The quasi-steady static-balance modeling approach, with a range of input choices, shows that the U.S. EPR fuel remains covered with a two-phase mixture during the post-reflood period for all cases studied.

In addition, hot leg injection is important and significant to long term core cooling. The injected water can condense decay heat generated steam early in the post-reflood period and establish coverage of the active core with water for an indefinite period of time.

References

1. EGG-TFM-7993, “Long Term Recovery of Westinghouse Pressurized Water Reactors Following a Large Break Loss of Coolant Accident,” C. D. Fletcher and R. A. Callow, Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, ID, February 1988.

2. K. H. Sun, R. B. Duffey and C. M. Peng, “The Prediction of Two-Phase Mixture Level and Hydrodynamically-Controlled Dryout under Low Flow Conditions,” Int. J. Multiphase Flow, Vol. 7, No. 5, pp. 521-543, 1981.

3. John F. Wilson, Ronald J. Grenda, John F. Patterson, “The Velocity of Rising Steam in a Bubbling Two-Phase Mixture,” Transactions of the American Nuclear Society, Vol. 5, pp 151-152, 1962.

4. J.P. Cunningham and Hsu-Chieh Yeh, “Experiments and Void Correlation for PWR Small Break LOCA Conditions,” Transactions of the American Nuclear Society, Vol. 17, pp 369-370, 1973.

5. Email to Getachew Tesfaye (NRC) from Russel D. Wells (AREVA NP), “Response to U.S. EPR Design Certification Application RAI No. 241, FSAR Ch 15, Supplement 1,” November 25, 2009

FSAR Impact:

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

Table 15.06.05-51-1—Elevations Relative to Bottom of the Active Fuel

Location	Elevation from BAF, ft
Bottom of the Active Fuel (BAF)	0
Top of the Active Fuel, Z_{CORE}	13.78
Cross-over Pipe, top, loop seal, Z_{LS}	13.68
Cold Leg (center), Z_{CL}	20.87
Upper Plenum (same as cold leg), Z_{UP}	20.87

Table 15.06.05-51-2—Computational Case Matrix

	Nominal (Case 1)	Offsets from Nominal
Pressure, psia	14.7	32.0 (Case 2)
Bypass Flow Resistance, 1/ft^4	303.24 (nominal flow rate)	50.33 (maximum flow rate) (Case 3)

Table 15.06.05-51-3—Summary of Results

	Pressure	Bypass, K/A^2	$Z_{1,\ MIN}$	Time of $Z_{1,MIN}$	Z_2
Case 1	14.7 psia	303.24 ft^{-4}	13.68 ft not reached in 1157 days	> 1157 days	> Z_{CORE}
Case 2	32.0 psia	303.24 ft^{-4}	13.68 ft	603.0 days	> Z_{CORE}
Case 3	14.7 psia	50.33 ft^{-4}	13.68 ft	145.4 days	> Z_{CORE}

Table 15.06.05-51-4—List of Model Parameters

Item	Importance
Design Elevations	High - The relative elevation of the loop seal and top of the active fuel is very important to the analysis. The U.S. EPR loop seal elevation is only 0.1 ft below the top of the active core.
Bypass Flow Resistance	High - Affects steam flow split and timing
Void Fraction Correlations	High - Correlations show a range of results and all produce a two-phase mixture level that covers the fuel.
LHSI Operation	High - The operation of LHSI is fundamental to the assumptions of this analysis.
Decay Heat Table	Moderate - Decay heat table places the solution in time.
Pressure	Moderate - Affects steam flow split and timing. Near atmospheric pressure late in post-reflood period.
Subcooled Core Inlet	Moderate - Subcooling reduces the two-phase mixture level.
Elevation of Water in Primary Piping	Low - Affects the hydrostatic head before and after the transition power. Minor affect on flow split.
Void Fraction in Vertical Pipe on Pump Side of Loop Seal	Low - Affects the hydrostatic head before the transition power. Minor affect on flow split.

Figure 15.06.05-51-1—Modeled Steam Flow Paths and Elevations

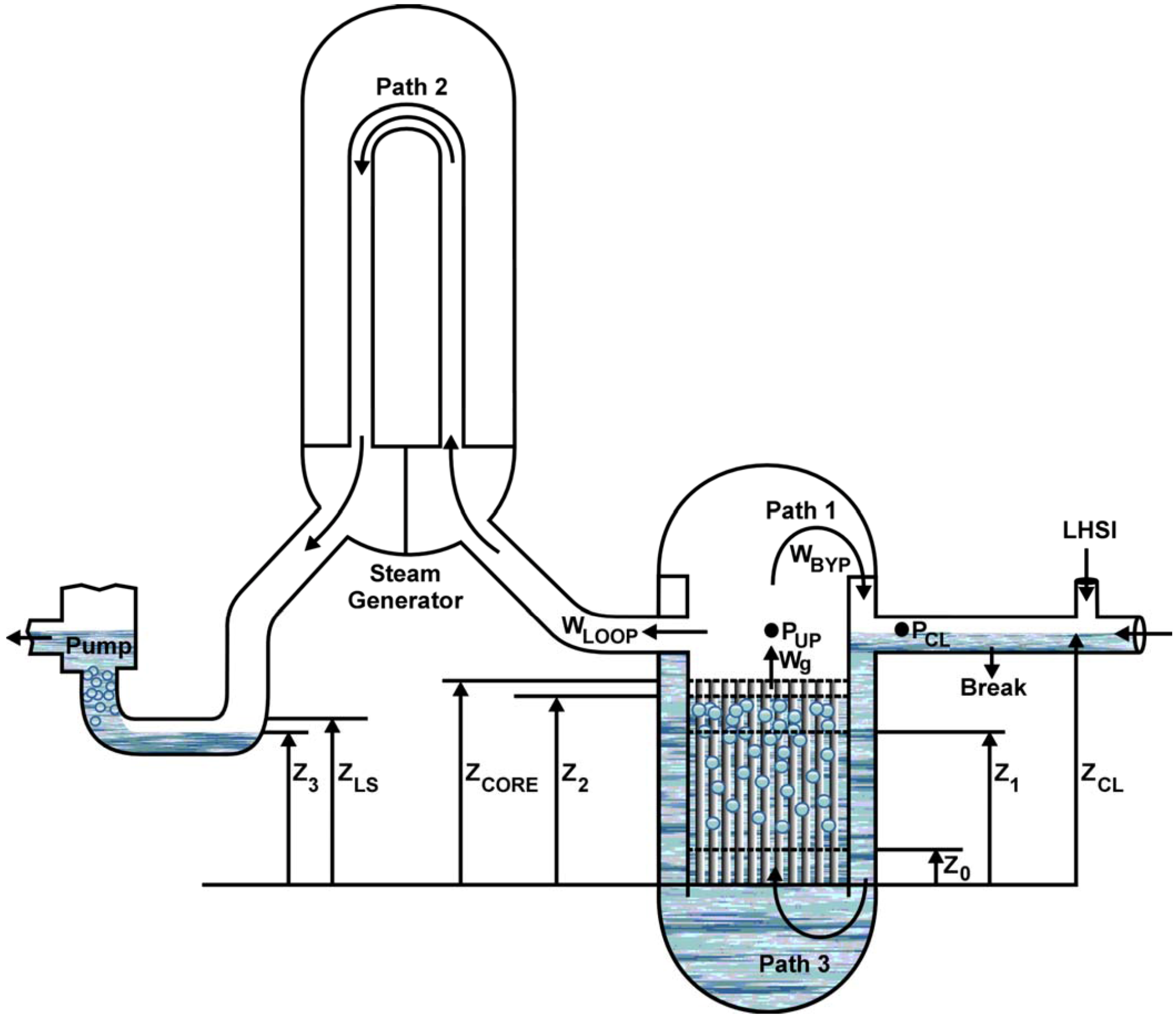

Figure 15.06.05-51-2—Coolant Elevations: P = 14.7 psia, $K/A^2 = 303.24\ ft^{-4}$

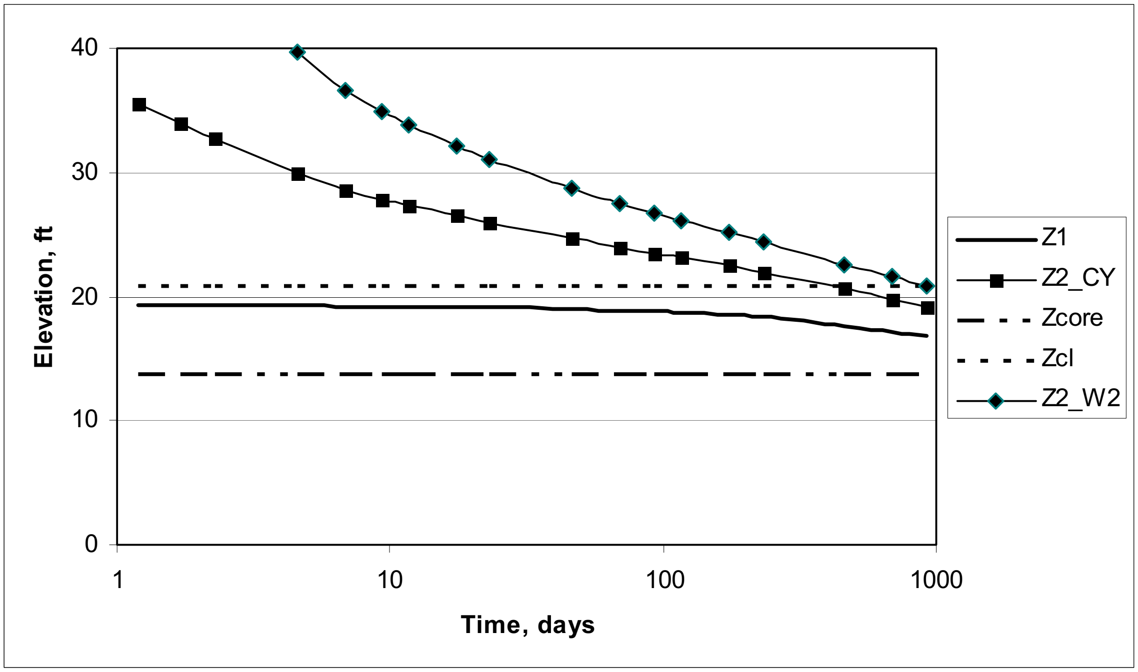

Figure 15.06.05-51-3—Coolant Elevations: P = 32.2 psia, $K/A^2 = 303.24\ ft^{-4}$

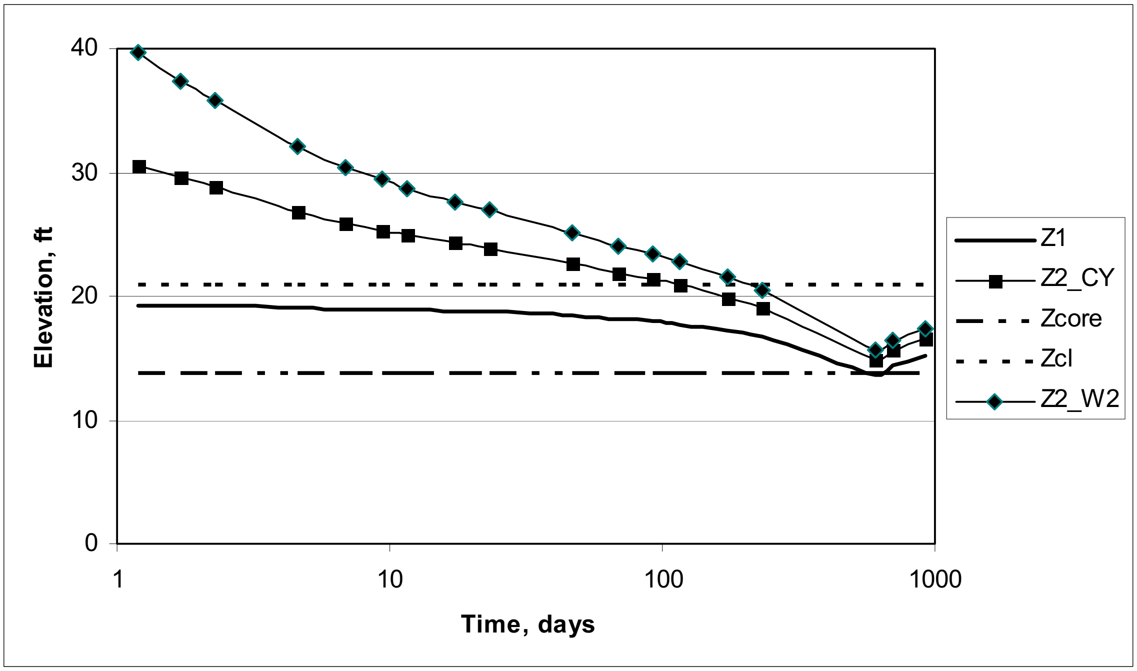

Figure 15.06.05-51-4—Coolant Elevations: P = 14.7 psia, $K/A^2 = 50.33\ ft^{-4}$