AREVA

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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Response to Request for Additional Information (RAI) Regarding Topical Report BAW-10192P, Revision 2, "BWNT LOCA – BWNT Loss of Coolant Accident Evaluation Model for Once-Through Steam Generator Plants"

Ref. 1: Letter, R.L. Gardner (AREVA NP) to Document Control Desk (NRC), "Request for Review and Approval of BAW-10192, 'BWNT LOCA – BWNT Loss of Coolant Accident Evaluation Model for Once-Through Steam Generator Plants'," NRC:08:066, September 11, 2008.

Ref. 2: Letter, J.G. Rowley (NRC) to R. L. Gardner (AREVA NP), "Request for Additional Information Re: Topical Report BAW-10192P Revision 2, 'BWNT Loss of Coolant Evaluation Model for the Once Through Steam Generator Plants'," (TAC No. 9834), November 3, 2009.

Ref. 3: Letter, S. L. Rosenberg (NRC) to A. Nowinowski (PWROG), "Closeout for Review of Topical Report BAW-10192P, Revision 2, 'BWNT LOCA – BWNT Loss of Coolant Accident Evaluation Model for Once-Through Steam Generator Plants'," (TAC No. MD9834), March 24, 2010.

On behalf of the PWR Owners Group (PWROG), AREVA NP Inc. (AREVA NP) requested the NRC's review and approval of the topical report BAW-10192P, Revision 2, in Reference 1. A request for additional information (RAI) was provided by the NRC in Reference 2. The review was terminated by the NRC in March of 2010 (Reference 3) until such time the responses to the RAI could be submitted.

The response to the RAI, which is non-proprietary, is enclosed with this letter. Please reinstate the review and approval of this topical report.

AREVA NP requests that the NRC issue a Safety Evaluation Report (SER) that approves this topical report which will be used to support the B&W designed operating plants. AREVA NP requests that the NRC complete its review of the report and issue the SER by December 2010.

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If you have any questions related to this submittal, please contact Robert J. Schomaker, Project Manager, by telephone at 434-832-2917 or by e-mail at bob.schomaker@areva.com.

Sincerely,

Ronnie L. Gardner, Manager
Corporate Regulatory Affairs
AREVA NP Inc.

Enclosures

cc: J.G. Rowley
Project 694

REQUEST FOR ADDITIONAL INFORMATION
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
BAW-10192P, REVISION 2
"BWNT LOCA- BWNT LOSS OF COOLANT ACCIDENT EVALUATION MODEL
FOR ONCE THROUGH STEAM GENERATOR PLANTS"
AREVA NP, INC.
PROJECT NO. 694

RAI 1. The U. S. Nuclear Regulatory Commission (NRC) staff understands from the July 9, 2009 conference call that you did not reanalyze the demonstration analysis in Revision 0 for Revision 2. Therefore, Revision 2 does not contain quantitative justifications for the proposed changes. The staff understands that this was in part due to the fact that the Revision 0 analysis was based on the raised-loop, 205-fuel assembly design, which is a design that is not currently in operation in the U.S.

To allow the NRC staff to perform an independent evaluation for reasonable assurance, the staff requests quantitative justification of the key proposed changes in Revision 2. The NRC staff understands from the July 9, 2009 conference call that quantitative information is readily available from your operating reactor experience base to justify the proposed changes affecting the loss of coolant accident (LOCA) analysis results. For each significant change, please submit the quantitative information supporting the change. This may be in the form of either a reference to already submitted information (e.g., PSC, 50.46 report, etc.) or a summary of the applicable analysis results from your experience base. Please discuss whether each change is conservative or non-conservative.

Response: BAW-10192 Revision 0 contains two sets of large break LOCA (LBLOCA) plant demonstration analyses. One set is based on a generic 205-FA plant; it is contained in Appendix A, Section A.11 of Volume I. The second LBLOCA case is based on a representative 177-FA lower loop (LL) plant model; it was provided in response to a request for additional information (RAI) and is located in Volume III, the licensing addendum, starting on page LA-121. A small break LOCA demonstration case set, based on the 205-FA plant model, was provided in Volume II, Section A.10.

For Revision 2, the above mentioned demonstration cases and their various accompanying sensitivity studies were not rerun because the Revision 2 updates would not change the conclusions of which break location or size is most limiting, or what inputs create the most limiting results. While the limiting PCT, local oxidation, and whole-core hydrogen generation will change, case trends, outcomes and conclusions would not be expected to change; hence, the Revision 0 relative sensitivity studies and demonstration cases still remain representative of the LOCA performance for 177-FA LL, 177-FA RL, and 205-FA RL plants.

The information provided as a response to RAI 1 is divided into three categories of material: (1A) significant EM changes made under 10 CFR 50; (1B) a list of NRC-approved EM changes or topical reports approved since Revision 0 was approved; and (1C) additional EM descriptions included as text changes in Revision 2. This RAI specifically asks for information on the significant EM changes and this material is provided in Section 1A of this RAI response. AREVA summarized the NRC-approved changes that have been incorporated into Revision 2 in Section 1B of this RAI response. In Section 1C of this RAI response, AREVA provided additional information on the text changes that were incorporated into Revision 2. While items in 1B and 1C were not specifically requested in this RAI, the NRC reviewer stated during a phone call that the information provided during the PowerPoint presentation from the July 9, 2009 phone call helped focus his review, but this information was not docketed. These two supplemental sections summarize information from the presentation material to help facilitate the Revision 2 review.

1.A. Significant EM Revision 2 Changes

There are four significant changes that AREVA has incorporated into NRC-approved Revision 0 of the EM. The first three changes, which are included in Revision 2 of the EM, were changed under the provisions of 10 CFR 50.46 and reported to the NRC. The reporting documentation is listed under each of the following descriptions. Items 2 and 3 have been explicitly reviewed and approved by the NRC. Item 4 is an emergent SBLOCA question that is currently under investigation and it has been included in this RAI as a new consideration imposed on Revision 2 of the EM.

1. Initial CFT Liquid Inventory and Pressure

   In 1994, BWNT LOCA EM sensitivity studies were performed to support the first application of this EM to a 177-FA LL plant. The studies revealed that the selection of initial core flood tank (CFT) levels can adversely impact LOCA PCTs for ruptured node-limited LBLOCA analyses that have early PCT times. A Preliminary Safety Concern (PSC) 5-94 was written to identify that the results of ruptured node-limited LBLOCA analyses (e.g., the core inlet) performed with the existing CRAFT2-based LOCA EM (BAW-10103P-A Revision 3) used the incorrect CFT liquid inventory. All LBLOCA analyses were previously analyzed with a minimum CFT liquid inventory and minimum cover gas pressure. The RELAP5-based sensitivity studies revealed that higher initial CFT liquid inventory reduces the gas volume, which allows the tank pressure to decrease faster as the CFT discharges. New CRAFT2 analyses were performed and PCTs and LHR limits were changed as a result of this PSC and there were two reports sent to the NRC via the Part 21 process and 10 CFR 50.46 reports.

   At the time PSC 5-94 was written, RELAP5 LBLOCA analyses were not supporting plant operation, so no 10 CFR 50.46 changes were reported on the BWNT LOCA EM. Nonetheless, the PSC changed the method of setting the CFT initial liquid inventory and pressure. The increased initial CFT level reduced the CFT pressure (e.g. driving head) and flow to the RCS during the CFT discharge phase of the event. Consequently, the RELAP5-based EM calculated PCT increased by ~120 F versus results from a minimum CFT liquid level case. The PCT variation is plant specific and it depends on the CFT level and pressure ranges in the plant Technical Specifications including uncertainty.

   The increased initial CFT level also has a detrimental effect on SBLOCA analyses that produce a PCT after the CFT begins to discharge. With a higher initial liquid level, the CFT depressurizes faster and the flow is less. The estimated SBLOCA PCT change is between 0 F for cases that produce a PCT before CFT flow begins and variable up to ~60 F for those with a PCT during the CFT draining period.

The current approach used in all BWNT LOCA EM analyses (for both large and small break applications) considers the transient and uses sensitivity studies or comparisons to applicable studies to set the limiting CFT initial conditions. The guidance that is confirmed by sensitivity studies is that, if the PCT occurs during the CFT discharge phase, then the minimum pressure and maximum liquid inventory configuration is generally limiting. However, if the PCT occurs after the CFT empties, then a minimum liquid inventory with maximum pressure is limiting. The net result is that initial inventories set by nominal CFT levels that were permitted based on the text in Table 9-2 and the demonstration analyses in the EM were changed as a result of PSC 5-94 and its 10 CFR 50.46 report. This occurred before the first RELAP5-based licensing analysis was ever completed. This practice is captured in Revision 2 on the generic inputs in Table 9-2 of both large and small LOCA EM Volumes.

PSC 5-94 Letter References:

JHT-95-12, J. H. Taylor, Manager, Licensing Services of the B&W Nuclear Technologies to the U.S. NRC. Document Control Desk, "Report of Preliminary Safety Concern Related to Large Break LOCA ECCS Analyses," January 27, 1995. (Accession Number 9502030105)

JHT-95-89, J. H. Taylor, Manager, Licensing Services of the B&W Nuclear Technologies to the U.S. NRC. Document Control Desk, "Final Report on the Evaluation of Preliminary Safety Concern Related to Large Break LOCA ECCS Analyses (PSC5-94)," August 25, 1995.

2. Plant Type-Specific LOCA Two-Phase RCP Degradation Models

There have been two preliminary safety concerns (PSCs) written in 1999 and 2000 that were partially related to the two-phase RCP head degradation models used in LBLOCA and SBLOCA. The resolution of these PSCs included changes to the pump degradation curves to ensure the EM results were conservative and in compliance with Appendix K.

In 1999, PSC 1-99 was written to identify that the 177-FA LL plant LBLOCA analyses was performed using an incorrect RCP degradation model. BWNT LOCA EM (BAW-10192P-A) sensitivity studies (Section

A.2.6 of Volume I) and previous CRAFT2 EM (BAW-10103P-A) studies were used incorrectly to conclude that the M1 or maximum RCP head degradation model was limiting. New sensitivity studies performed with the M3-modified (minimum) and M1 (maximum) head degradation curves showed that the M3-modified or minimum degradation curve is limiting.

Appendix K states that the "pump model resistance used for analysis should be justified. The pump model for the two-phase region shall be verified by applicable two-phase pump performance data." The EM approach used took applicable pump performance data and skewed the head degradation multipliers to a minimum and maximum range of values. Sensitivity studies determine the limiting value that is used in the LBLOCA analyses.

Revised LOCA analyses were performed with the limiting RCP two-phase head degradation model. The PCTs increased differently at every core elevation, but the limiting increase associated only with the RCP degradation modeling change was approximately 100 F. During the reanalysis effort for this PSC, several other changes in inputs or errors were discovered and they were corrected in the final analyses that also corrected the RCP degradation analyses. The cumulative PCT change associated with all the reanalyses ranged from 0 to 186 F, but all remained within the 10 CFR 50.46 acceptance criteria and did not require reporting under 10 CFR 21.

In 2000, a PSC 2-00 was written to identify that the results of some of the larger SBLOCA break scenarios could be more limiting when the RCPs are manually tripped at 2 minutes following the loss of subcooling margin (LSCM). It was reported to the NRC via Letter FTI-00-2433 on September 26, 2000. This delayed RCP trip increased the RCS liquid inventory loss over the loss-of-offsite power (LOOP) cases or cases that were tripped sooner than two minutes. It was determined that the consequences were especially limiting for plants without automatic cross-tie of low pressure injection (LPI) flow paths for a core flood line break. Those plants that did not have the LPI cross-tie or additional high pressure injection (HPI) (from a second HPI pump or high flow intermediate head HPI) were required to credit operator action prior to 2 minutes. The emergency operating procedures (EOPs) instruct the operators to trip the RCPs immediately following the LSCM and some plants demonstrated that this action could be accomplished and credited within one minute following LSCM. With a one-minute RCP trip, the results of the continued RCP operation cases are acceptable and the results were similar to those obtained with LOOP occurring at the time of turbine trip.

Included in the assessment of PSC 2-00 was the evaluation of the adequacy of the two-phase pump head degradation model since the

RCPs could be operating for a period of up to two minutes under two-phase flow conditions. A letter report was sent to the NRC (FANP-01-988, ADAMS ML010950222, April 2, 2001) and the NRC reviewed the material and provided a SER on April 10, 2003, with an open item that each plant needed to justify that the M3-modified RCP degradation model was applicable to their plant (Reference 12 of the EM in Volume II). AREVA provided additional information (NRC:04:050/OG:04:1854 dated September 21, 2004) and the NRC revised the SER on January 10, 2005. The revised SER, which is listed below, was not included as a reference in Revision 2 of the EM. It is included now by virtue of this response. It was included as Reference 80 in the AREVA Topical Report "Safety Criteria and Methodology for Acceptable Cycle Reload Analyses" (BAW-10179P-A Revision 7, January 2008).

Letter from R. A. Gramm (NRC) to J. S. Holm (Framatome ANP), Subject: Request for Amendment of Safety Evaluation for "Report of Preliminary Safety Concern (PSC) 2-00 Related to Core Flood Line Break with 2-Minute Operator Action Time," January 10, 2005. (TAC No. MA9973) (Accession Number ML043550355)

The changes in the RCP two-phase head degradation inputs were corrected for large and small LOCA applications and reported to the NRC via multiple letters listed below this response. The approach of using applicable plant type sensitivity studies to determine limiting inputs was incorporated into Revision 2, Table 9-2 of the large and small LOCA Volume I and II, respectively.

PSC 1-99 Letter References:

OG-1740, J. J. Kelly, Manager, B&W Owners Group Services to the U.S. NRC Document Control Desk, "10 CFR 50.46 Thirty-Day Report on Significant Change in ECCS Analyses," February 4, 1999.

OG-1746, J. J. Kelly, Manager, B&W Owners Group Services to the U.S. NRC Document Control Desk, "Report of Preliminary Safety Concern Related to Use of an Inappropriate RCP Two-Phase Degradation Model," March 5, 1999.

OG-1765, J. J. Kelly, Manager, B&W Owners Group Services to the U.S. NRC Document Control Desk, "Interim Report for PSC 1-99 Related to Use of an Inappropriate RCP Two-Phase Degradation Model," August 16, 1999.

OG-1781, J. J. Kelly, Manager, B&W Owners Group Services to the U.S. NRC Document Control Desk, "Final Report of Preliminary Safety Concern (PSC 1-99) Related to Use of an Inappropriate Reactor Coolant Pump Two-Phase Degradation Model," February 1, 2000. (Accession Number ML003681781)

NRC:02:007, James F. Mallay, Director Regulatory Affairs, Framatome ANP to U.S. NRC Document Control Desk, "Requested Reference Material for Evaluation of PSC 1-99," January 25, 2002. (Accession Number ML020320585)

PSC 2-00 Letters References

FTI-00-2433, J. J. Kelly, Manager, B&W Owners Group Services to the U.S. NRC Document Control Desk, "Report of Preliminary Safety Concern Related to Core Flood Line Break with 2-Minute Operator Action Time," September 26, 2000.

FTI-00-3085, Dave J. Firth, Manager, B&W Owners Group Services to the U.S. NRC Document Control Desk, "Interim Report of Preliminary Safety Concern (PSC 2-00) Related to Core Flood Line Break with 2-Minute Operator Action Time," December 20, 2000. (Accession Number ML010020098)

FANP-01-988, Dave J. Firth, Manager, B&W Owners Group Services to the U.S. NRC Document Control Desk, "Transmittal of Final Report on the Evaluation of PSC 2-00 Relating to Core Flood Line Break with 2-Minute Operator Action Time," April 2, 2001. (Accession Number ML010950222)

Letter from H. Berkow (USNRC) to J. Mallay (B&W Owners Group), Subject: Evaluation of Framatome ANP Preliminary Safety Concern (PSC) 2-00 Relating to Core Flood Line Break and Operator Action Time," April 10, 2003. (TAC No. MA9973) (Accession Number ML031010143)

NRC:04:050/OG:04:1854, James F. Mallay, Director Regulatory Affairs, Framatome ANP to U.S. NRC Document Control Desk, "Request for Amendment of Safety Evaluation for Preliminary Safety Concern (PSC) 2-00," September 21, 2004. (Accession Number ML042720519)

3. Hot Pin Modeling for LOCA

   The original LBLOCA methodology did not use separate hot pins because the hot bundle was modeled as though it was comprised of all hot pins. The hot bundle used the hot pin peaking and the fuel temperatures used a fuel temperature uncertainty that was developed for the local hot spot 95/95 value consistent with that of the hot rod with input from an NRC-approved steady-state fuel code. The current UO_2 steady-state fuel code used in the BWNT LOCA EM is TACO3 (BAW-10162P-A). In TACO3, the fuel temperature uncertainty is lower for the hot bundle and average core than for the hot spot of the hot pin. A method was developed to separate the hot pin from the hot bundle and apply the hot spot 95/95 uncertainty to the hot rod, but apply a lower fuel temperature uncertainty to the hot bundle and average core channel for LBLOCA applications. This revised analysis method was submitted to the NRC for the RELAP5/MOD2-B&W code topical (pg 5-463) via a letter FTI-00-551 on February 29, 2000. Included in that submittal was a sensitivity study showing that the calculated PCTs decreased by approximately 150 F for the hot rod. The NRC approved the use of the hot pin methodology with revised fuel temperature uncertainties for the BWNT LOCA EM LBLOCA modeling in its SER for the RELAP5 code (Revision 4 of BAW-10164P-A). The link to this change is contained in Sections 4.3.2.3 and 10 of Volume I of Revision 2 of the EM.

4. Adequacy of the Axial Power Shape Used in SBLOCA Analyses

   Recent work for a lowered-loop plant extended power uprate (EPU) effort, identified that the SBLOCA axial shape may not be bounding for the entire fuel cycle (AREVA Condition Report WebCAP 2010-4150). The EM states that a 1.7 axial peak at the midpoint between spacer grids surrounding the 10 foot core elevation will be used for SBLOCA analyses. This defined axial peak is bounding for beginning-of-cycle (BOC) axial peaks. It remains reasonable-to-bounding up to a time near middle of cycle (MOC). However, after MOC, the higher duty of the central region of fuel pin length and the reduced rod insertion limits allow core axial peaks to be skewed higher in the core. In some cases the elevation of the axial peak may be higher than the ones applied in the SBLOCA analyses. Some preliminary maneuvering analyses studies show that the location of the peak may move to an elevation closer to 10.5 feet. The normalized axial peak that was observed is considerably below the 1.7 axial used in SBLOCA analyses; however, the elevation of the peak is skewed higher in the core. These two partially trade-off against each other; however, additional work is needed to establish a reasonable-to-bounding axial peak that is applicable for the entire fuel cycle.

Unlike the LBLOCA, reduction of the LHR limit and fuel temperature decrease via axial peaking decreases are not effective in limiting SBLOCA PCT increases. The reduction needed is more significant. In lieu of a LHR limit decrease, there are two viable options for addressing the axial power shape used for SBLOCA. One option is to perform SBLOCA analyses at different times in cycle (TIC), with different core power peaking analysis normalized peaks and elevations with applicable augmentation factors included. The second option is to use the 1.7 normalized peak at a higher core elevation. The first option is analysis intensive and the second imposes additional conservatism because it bounds the entire cycle. Regardless of the option selected, the normalized peaking and elevation used in the SBLOCA analyses may be unique for each plant and it may be different for partial power or off-nominal SBLOCA applications for each plant. The axial peaking selected should be bounding of the realistic peaks that can be achieved by the core power distribution analyses.

Based on the elevation shift that was predicted for the CR-3 plant-specific EPU power distribution analyses it was concluded that the SBLOCA axial peak of 1.7 at 9.5-feet in the core is not bounding at the end of cycle (EOC). The option selected for the EPU was to retain the 1.7 normalized axial and move it to a higher core elevation and make the results independent of TIC. In cases where the 1.7 normalized axial peak is shifted up to 11 feet in the core, the increase in the SBLOCA PCT for this peaking elevation change is estimated to be as much as 225 F. This PCT increase can be reduced if the TIC SBLOCA analysis option is used.

Tabular Summary of 1.A. Responses

As requested, Table 1-1 herein provides a list of the significant EM changes that have been made and reported in Revision 2. A brief discussion of each of the changes is included to show the significance relative to the 10 CFR 50.46 PCT. The locations in the topical report were provided for use in confirming the changes. A quantitative assessment of their effect has also been made and these estimates are included in the Table 1-1.

Table 1-1: BAW-10192 Revision 2 Significant EM Changes to 177-FA Plant Results

Item	Location in BAW-10192 Revision 2 LBLOCA Volume 1	Location in BAW-10192 Revision 2 SBLOCA Volume 2	Change Classification	Estimated Range of LBLOCA PCT Assessment, F	Estimated Range of SBLOCA PCT Assessment, F
CFT Initial Conditions	Table 9-2	Table 9-2	Non-Conservative PSC 5-94	+120	0 to +60
RCP Minimum Two-Phase Degradation	Table 9-2	Table 9-2	Non-conservative PSC 1-99 and PSC 2-00 (NRC Approved)	Variable +100 to +186 (1)	Highly Variable (2) 0 to > +1400
Hot Pin Modeling	4.3.1, 4.3.2.3 & 4.3.2.7	4.3.4	Reduced LBLOCA HB Fuel SS Temperatures (NRC Approved)	-150	Not Applicable
Upper Skewed Axial Power Shapes	4.3.2.2 & Appendix Section A.5 (3)	4.3.1.2 as supplemented by this RAI response	Potentially Non-Conservative for EOC SBLOCA Analyses	0	0 to +225

1. The initial 177-FA applications incorrectly used the results of the 205-FA EM study and the results of previous CRAFT2 EM study to conclude, which pump two-phase head degradation model was most conservative. When the limiting RCP degradation model was used for the 177-FA applications, there was a significant change in the PCT. The PCT change listed here relates to the maximum PCT change obtained in the applications to address the concerns identified in PSC 1-99.

2. No delayed RCP trip analyses were included with the 205-FA demonstration cases. For the 177-FA SBLOCA analyses, the delayed RCP trip was found to be important for larger SBLOCAs and for the CFT line break. If the plant did not have LPI cross-ties or additional HPI flow with a RCP trip time two minutes after LSCM, the results can change from little to no core uncovering to unacceptable PCT values greater than 2200 F. With a one-minute RCP trip, pump two-phase head degradation is not important because the limiting results are produced by the LOOP scenario. The estimated PCT change for SBLOCA is given as a range from 0 to greater than 1400 F based on the work performed to address the concerns identified in PSC 2-00. The NRC reviewed and approved the SBLOCA RCP two-phase head degradation modeling used in the BWNT LOCA EM.

3. The evaluation of the LBLOCA axial power shapes is included in the EM and core maneuvering analysis and it is discussed in these sections of the LBLOCA EM Volume I. The LBLOCA axial power shape is not a significant EM change. It is included in this table for completeness.

1.B. NRC-Approved Changes or Additions Incorporated into the EM

This RAI specifically asks for AREVA to provide quantitative information on the significant EM changes incorporated into Revision 2. This information was provided previously in Section 1.A. The material in this subsection was not explicitly requested in the RAI, but it is provided as information to help facilitate the Revision 2 review.

Since Revision 0 of the EM was completed, several revisions of the codes that make up the BWNT LOCA EM have been completed. In addition, new topical reports or letters were submitted to the NRC to obtain approval for the changes that were incorporated into the BWNT LOCA EM methods without explicitly updating the EM. These items along with the Appendix K steady-state core power uncertainty regulatory change are included in the following list of things that the NRC has reviewed and approved for use in the BWNT LOCA EM.

1. GDTACO Steady-State Fuel Code
2. M5™ Cladding
3. SBLOCA Void-Dependent Core Cross-Flow Model
4. LBLOCA Hot Pin Methodology
5. BEACH Initial Cladding Temperature Range
6. Core Power Heat Balance Uncertainty
7. SBLOCA Two-Phase RCP Degradation Models
8. BHTP CHF Correlation Implementation into RELAP5/MOD2-B&W

Each of the submittals and SERs contain the docketed information for each of these changes included in Revision 2 of the EM. AREVA has included a brief summary of these items and identified the locations in the EM where the approved material has been included.

1. GDTACO Steady State Fuel Code

   The methods to perform steady-state fuel pin analyses with gadolinia fuel are described in the NRC-approved version of GDTACO. The approved version was obtained after Revision 0 of the EM was developed and released. It is included in Revision 2 of the EM to support LOCA applications with gadolinia fuel in the text and references for EM Volumes I (Sections 4.3.1, 4.3.2.3, 4.3.2.7, 10, and A.7) and II (4.3.1.3, 4.3.1.7, and 10).

2. M5™ Cladding

   AREVA developed the performance characteristics, physical properties, and methods for analysis for a new cladding material called M5™ cladding in BAW-10227P-A. LOCA demonstration cases were provided in Appendix F of that report. The SER for the M5™ cladding and methods used in LOCA analyses were approved for use in the BWNT LOCA EM. This reference was included in Section 10 of Volumes I and II, and the links to this topical report were included in the text for Revision 2 of the BWNT LOCA EM topical report. The M5™ material is cross-referenced in the metal-water reaction calculations (Volume I Section 4.3.2.8), swelling and rupture (Volume I Section 4.3.3 and Table 9-2, Volume II Section 4.3.4 and Table 9-2), and coolable core geometry (Volume I and II Section 7.1). The links and code changes to model M5™ cladding were also included in the approved RELAP5/MOD2-B&W code topical report (Revision 4 of BAW-10164P-A).

3. SBLOCA Void-Dependent Core Cross-Flow Model

   The SBLOCA methods included an elevation-specific core cross-flow resistance model to: (1) minimize cross-flow diversion in the two-phase regions below the core mixture level and, (2) maximize the steam cross-flow diversion above the mixture level. A fixed resistance model was selected by the user before the case was run. If the minimum mixture level predicted by the analysis was not consistent with the location chosen, a new case was performed. To preclude this iterative approach, a void-dependent core cross-flow model was developed and included as a RELAP5/MOD2-B&W code option. It was submitted to the NRC and approved for use in SBLOCA analyses for the BWNT LOCA EM in Revision 4 of BAW-10164P-A. Use of this modeling approach was described in Volume II, Section A.4 of Revision 2 of the EM.

4. LBLOCA Hot Pin Methodology

   The NRC-approved LBLOCA UO_2 hot pin methodology change was described in Item 3 of Section 1.A of this RAI response and is listed in this section for completeness. It should be noted that the hot pin method is also used for the gadolinia fuel analyses. If gadolinia fuel pins are being analyzed, the hot pin and these gadolinia pins are separated from the hot bundle. The hot pin fuel temperature uncertainty applied to the UO_2 fuel is also applied to the gadolinia pins with the appropriate changes in fuel properties and fuel initial temperatures computed with the NRC approved steady-state fuel code GDTACO (BAW-10184P-A). The EM links to GDTACO and the hot pin approach is included in Sections 4.3.1 and 4.3.2.7 of Volume I and Section 4.3.1.7 of Volume 2.

5. LBLOCA BEACH Initial Cladding Temperature Range

   The SER limitation for the Revision 4 of the BEACH code used for the LBLOCA reflooding heat transfer calculations placed a limit on the initial cladding temperature to a maximum value that was included in the code benchmarks of 1640 F. B&W-designed plants have temperatures higher than this value and those temperatures were included in the LBLOCA demonstration cases for Revision 0 of the EM. Nonetheless, AREVA performed a benchmark of FLECHT Test 34420 to extend the initial temperature range, which was successfully benchmarked, to 2045 F. The SER for the BEACH code topical report (BAW-10166P-A, Revision 5) extends the acceptable initial temperature range up to 2045 F. This range covers the application ranges for the BWNT LOCA EM, and this revision of BEACH topical is included in Section 10 for Volume I of Revision 2 of the EM.

6. Core Power Heat Balance Uncertainty

   The NRC modified the core power measurement uncertainty in Appendix K after the original EM was submitted and approved. The modified regulations allow LOCA analyses to be performed at the licensed plant power plus uncertainties that may be reduced via equipment and instrumentation modifications that reduce the heat balance uncertainties. This change in the regulation was reflected in the text in Section 4.3.2.1 of Volume I Revision 2 of the EM.

7. SBLOCA Delayed RCP Trip and Two-Phase RCP Degradation Models

   The NRC-approved the SBLOCA two-phase RCP head degradation model used in the EM as a result of the PSC 2-00 resolution efforts. This was described in Item 2 of Section 1.A of this RAI response and is listed in this section for completeness.

8. BHTP CHF Correlation Implementation into RELAP5/MOD2-B&W

   Section 4.3.4.8 of the BWNT LOCA EM Volume I stated that LOCA analyses will use the same CHF correlation that is used for the fuel pin DNB analyses. The Mark-BHTP fuel uses a new CHF correlation called the BHTP CHF correlation. It was installed into RELAP5/MOD2-B&W (BAW-10164P-A Revision 6) as required by the EM. The SER on this revision concluded it was correctly implemented into the code and it could be used for LOCA analyses with the BWNT LOCA EM. This CHF correlation is described in Section 4.3.4.8 and Table 9-1 of Volume I and Section 4.3.3.1 and Table 9-1 of Volume II.

1.C. Expanded EM Descriptions for LOCA EM Applications

This RAI specifically asks for AREVA to provide quantitative information on the significant EM changes incorporated into Revision 2. This information was provided previously provided in Section 1.A. This section, which includes the background on expanded EM text modifications, is not explicitly part of the RAI, but it is provided as information to help facilitate the Revision 2 review.

The EM is general in nature but conforms to the specific requirements of 10 CFR 50 Appendix K. It contains high level descriptions of key methods and considerations for how to evaluate plant parameter variations on the LOCA results. Revision 0 has been used to support core reload licensing, define acceptable ranges of plant operation, address cycle design evolutions, evaluate fuel design changes, characterize required operator actions, and evaluate plant input changes. Some of these EM-related efforts were not described in the original text. The Revision 2 text was expanded to describe more fully the process, which resides within and is considered part of the EM as it is used to perform evaluations supporting such issues. The expanded EM text descriptions were split between the LBLOCA and SBLOCA applications for clarity of discussion, even though the topic may be applicable to only one of these two break categories.

1.C.1. Expanded EM Descriptions for LBLOCA EM Applications

Since Revision 0 of the EM was completed, a variety of evaluations and analyses were performed to support plant operation with changes to plant or fuel-related inputs for a variety of fuel types and designs. The types of changes related herein are typical cycle specific variations of fuel pin enrichments, peaking variations, and loading variations with mixed-core fuel batches possibly with re-caged fuel assemblies. However, these inputs are included in the PCT analysis so the effects are captured in the EM application and they were not included in previous 10 CFR 50.46 PCT change notifications. The LBLOCA items included in Revision 2 of EM are listed below, followed by a discussion of each item.

1. Partial Power LBLOCA Analyses with a Positive MTC
2. LBLOCA LHR Limits at the Core Inlet or Core Exit
3. LBLOCA Analyses Above the Licensed Core Power Level
4. LBLOCA Core Power Flattening / Energy Deposition Factors
5. SGTP Considerations for LBLOCA
6. Radial Versus Axial Power Peaking EM LBLOCA Restriction
7. LBLOCA Gadolinia Fuel
8. LBLOCA Mixed-Core Considerations
9. LBLOCA EOC T_{ave} Reduction with Negative MTCs
10. LBLOCA Stainless Steel or Natural Uranium Replacement Rods
11. Actinide Decay Heat for LBLOCA

12. Additional LBLOCA Discussion on Coolable Core Geometry and Long-Term Core Cooling

A brief discussion on the Revision 2 LBLOCA items that were added is provided in the following paragraphs. Since these items do not result in a PCT change, they simply reflect analysis considerations and are not designated conservative or non-conservative unless stated otherwise. The location in the EM where the text was updated is also included.

1. Partial Power LBLOCA Analyses with a Positive MTC

   Plant Technical Specifications require the plants to be at or below a zero moderator temperature coefficient (MTC) above 95 percent full power (FP). It was identified in Preliminary Safety Concern PSC 4-94 that the LBLOCA PCT results could be worse if the plant was less than 95 percent FP with a positive MTC. The safety concerns were addressed by defining an MTC versus power level curve to ensure that the LBLOCA results performed at FP with a zero MTC remain bounding for partial power conditions. The core reload process incorporates a check to ensure that each fuel cycle is bounded by the MTC versus power level curve supported by LBLOCA analyses. This discussion is incorporated into Section 4.3.2.4 in Volume I of the EM

2. LBLOCA LHR Limits at the Core Inlet or Core Exit

   The fuel maneuvering analyses are performed to demonstrate that there is margin between the analyzed fuel LHR limits and the peaks that can be achieved by the core for each fuel cycle. The LBLOCA LHR limits used in this margin check are explicitly analyzed at the core elevations corresponding to the midpoint of the spacer grids surrounding the 2 to 10 foot core elevations (generally between 2.5 and 9.5 feet). The core maneuvering analyses consider the entire core elevation from 0 to roughly 12 feet. While it is difficult to push the core peaks to LOCA analyzed LHR limit peaks below 2 or above 10 feet, if it occurs, a LBLOCA related limit should be established. A plant-type specific method was developed based on a general EM sensitivity study with skewed power peaks at lower and upper core elevations to establish a conservative basis for extrapolating the LHR limits to the core inlet (0 feet) and core exit (~12 feet) for use in the reload core power peaking analyses. The extrapolation of these LHR limits is supported by LBLOCA sensitivity studies with axial peaks at approximately 1 and 11 feet to ensure the limiting PCT is determined by one of the five specifically analyzed LOCA LHR cases between 2 and 10 feet. This information is contained in Section 4.3.2.2 of Volume I of the EM.

3. LBLOCA Analyses Above the Licensed Core Power Level

   At times LOCA analyses may be performed in anticipation of a future core power uprate and the EM supports this application (See Section 4.3.2.1 in Volume I of the EM). For B&W-designed plants, the LBLOCA analyses are not as strongly impacted by a power uprate. If analyses are performed at uprated core power levels, AREVA confirms that the reported PCTs and the LHR limits that are established, remain applicable and bounding for the plant at all power levels up to its rated power level. AREVA also confirms that the full power PCT results remain bounding for the partial power analyses.

4. LBLOCA Core Power Flattening / Energy Deposition Factors

   The EM states that the fraction of the power lost from the hot channel (sometimes referred to as power flattening) is deposited uniformly in the fluid of the average channel. Power flattening is also expressed as the energy deposition factor (EDF), defined as the ratio of the thermal energy deposited in fuel pin to nuclear source generated in the fuel. The EM gives the steady-state and blowdown values of this power flattening or EDF as 0.973 and the reflood EDF as 0.96. The primary EDF contribution at steady-state conditions is controlled by the thermalization of the neutrons in the fluid. After the reactor is shut down and the neutron flux depleted, the primary EDF contribution is from gamma energy being absorbed by unheated structures or fluid. When the core is voided, there is little fluid available to absorb any gamma energy. If gamma leakage or absorption by unheated structures is not considered, the EDF in a high powered bundle with a flat power profile approaches a value of unity. The EDF for a lower power gadolinia rod or UO_2 rod near the corner of a lower power high-burnup bundle is also considered based on the limiting peaking values with bounding fuel loading patterns. In some cases the EDF increases above 0.973 at steady-state and above 1.0 during the limiting transient conditions. These increases in the EDF, due to in-leakage from higher power rods, have been applied to all plant licensing LBLOCA analyses because the EM states that the reported values may be amended by specific calculations. The EDFs are higher and result in more conservative PCTs than would be predicted if the default values described in Revision 0 of the EM were used. Since conservative EDFs have always been applied via an input to the analyses, there is no PCT change identified. The EDF considerations are discussed in EM Volume I Section 4.3.2.7 and Table 9-2.

5. SGTP Considerations for LBLOCA

   The EM demonstration cases for the RL 205-FA plant were developed for a plant that was under construction so no steam generator tube plugging (SGTP) was included in the modeling. However, a verbal request was made to provide a demonstration LBLOCA analyses for the LL 177-FA plant. The one provided in Volume III of the EM beginning on page LA-103 contained SGTP for the TMI-1 plant. A unit-average SGTP of 15 percent was included with a maximum value of 20 percent in a single steam generator. The LBLOCA analyses are adversely affected by the SGTP, so these analyses model a level of SGTP for LOCA analyses that matches or exceeds the actual plant SGTP fraction. Use of higher SGTP input is conservative relative to the effect on PCT for a plant with no SGTP. The EM descriptions were modified to include SGTP considerations in Section 4.3.1 and in Table 9-2 of Volume I in the EM.

6. Radial Versus Axial Power Peaking EM LBLOCA Restriction

   The EM Revision 0 SER limitation Number 3 places a restriction on evaluating the validity of the radial versus axial peaking for LBLOCA. A method for evaluating the adequacy of the limiting LOCA PCT results regarding radial and axial peaking that may be achieved during plant operation was developed on a plant type specific basis. It addresses the SER restriction using the information provided in the response to the NRC RAI beginning on page LA-77 of Volume III of the EM. Section 4.3.2.2 of Volume I of the EM Revision 2 was modified to contain a pointer to this information.

7. LBLOCA Gadolinia Fuel Analyses

   Fuel cycles have evolved since the EM was written and some plants have increased the fuel cycle length from 18 to 24 months. These longer cycles need higher fuel enrichments to support the higher energy requirements. The higher enrichment increases core power peaks and core designers use gadolinia-doped fuel pins interspersed in the UO_2 fuel pin matrix to manage this power peaking. No LOCA demonstration analyses were performed in the original release of the BWNT LOCA EM with gadolinia-doped UO_2 fuel pins included in a UO_2 assembly. Use of gadolinia fuel and the analyses to support it was briefly mentioned in a previous RAI response on page LA-104 of Volume III. Gadolinia was previously described in Section 1.B Items 1 and 4 of this RAI response.

8. LBLOCA Mixed-Core Considerations

   The EM demonstration cases for the RL 205-FA plant were developed for a plant that was under construction so no mixed-core considerations were included in the modeling. Mixed-core analyses were briefly mentioned in a previous RAI response on page LA-104 of Volume III. Mixed-core analyses are performed or evaluated when fuel assemblies with different pressure drops are used as a batch reload or as a lead test assembly. The high resistance assembly is placed in the hot channel and the remainder of the core is modeled in the average channel as the lower resistance fuel assemblies. This modeling conservatively maximizes the core flow diversion out of the hot channel and maximizes the PCT for the high resistance fuel. Generally, the cooling of the lower resistance fuel is improved and its PCT would decrease. Unless the beneficial cooling of the lower resistance fuel is analyzed or evaluated, the benefit of a reduction in PCT or increased LHR limit is not credited. Since mixed-core is explicitly analyzed, there is no PCT change because the results reflect the input that was provided. Discussion of the mixed-core modeling that produces conservative results is included in Section 4.3.4.6 in Volume 1 of the EM.

9. LBLOCA EOC T_{ave} Reduction with Negative MTCs

   Near the end of the fuel cycle (EOC), some plants are permitted to operate at a reduced core-average temperature (T_{ave}) to extend the time that the plant can remain at full power conditions. B&W plant sensitivity studies show that the limiting LBLOCA PCTs will increase when the RCS average temperature is decreased with all other parameters unchanged. Changes in the timing of departure from nucleate boiling (DNB), subtle core flow changes, and containment pressure reductions for some scenarios contribute to differences in results. Since this maneuver is only performed at EOC, credit for a negative moderator temperature coefficient is used to shut the reactor down sooner and reduce the core power contribution to ensure that the full-power nominal core average temperature cases remain bounding. The difference between the analyzed middle-of-life (MOL) case with a zero MTC with nominal T_{ave} and the EOC T_{ave} reduction MOL case with a negative MTC is analyzed to demonstrate that the PCT for the zero MTC case is bounding. This information is described in Section 4.3.2.4 of Volume I of the EM.

10. LBLOCA Stainless Steel or Natural Uranium Replacement Rods

   There are times when burned fuel assemblies are damaged during the handling or fuel transfer process or as a result of interactions with adjacent bundles or core baffle plates. If the damage is limited to a few pins or the spacer grid in an assembly (generally located on the bundle periphery), then the assembly can be reconstituted. The damaged pins or pins within the damaged grid are replaced by stainless steel rods or natural (low enriched) uranium rods to prevent a fuel pin breech when the bundle is reloaded into the core. LOCA evaluations are performed to ensure the analyzed LOCA LHR limits and PCTs are applicable to the fuel assemblies that are reconfigured and the peaking changes included as described in BAW-2149-A. The use of replacement rods was incorporated into Section 4.3.3.4 of Volume I of the EM.

11. Actinide Decay Heat for LBLOCA

   Appendix K of 10 CFR 50 requires that the post-shutdown decay heat (DH) for LOCA consider the heat from the radioactive decay of actinides, including neptunium and plutonium generated during operation, as well as isotopes of uranium. They are calculated in accordance with fuel cycle calculations and known radioactive properties. The actinide DH chosen must also be appropriate for the time in the fuel cycle that yields the highest calculated fuel temperature during the LOCA.

The basis for the highest calculated fuel temperature during the LOCA is interpreted to correspond to the highest calculated PCT during the transient. For LBLOCA, analyses are performed at three different times in life: BOL, MOL, and EOL. The actinide contributions are strong functions of both burnup and fuel enrichment. The actinide DH contributions increase with fuel burnup and are the highest for lower fuel enrichments. These relationships result in different actinide contributions for the hot pin or hot bundle at each analyzed burnup. The hot bundle or hot pin contribution can also be different than the average core for a reactor that has been operating for a number of cycles. The BWNT LOCA EM uses different actinide contributions for specific plant LOCA analyses. The reload licensing process confirms that the LBLOCA actinide contribution used is applicable for each subsequent cycle.

Some analyses use a bounding actinide model that covers all enrichments (generally 3 to 5%) and burnups up to the maximum licensed value (generally 62 GWd/mtU) for both the hot pin and average core actinide power contributions. Other analyses consider the burnup and enrichment difference between the hot channel (and hot pin) actinide DH and treats it separately from the average core actinide DH based on a core-average enrichment and core-average burnup based on BOC or EOC conditions. This option requires additional work during the reload process to confirm the actinide contribution meets the Appendix K requirements. Use of either the bounding model or the reload specific model is acceptable because they both meet Appendix K requirements. The bounding actinide option is the simplest, but it also increases the conservatism imposed on the calculations. If the second option is used, cycle-specific reload checks must be performed to confirm the reasonableness of the actinide decay heat contributions used in the LOCA application. In some cases, the tradeoff between higher actinide DH and lower initial fuel temperature at lower fuel enrichments are used to show the limiting LBLOCA PCT results remain applicable for all times in life.

The LBLOCA actinide DH is discussed in Section 4.3.2.5 and Table 9-2 of Volume I of the EM. It is also discussed in the RAI response on page LA-94 of Volume III.

12. Additional LBLOCA Discussion on Coolable Core Geometry and Long-Term Core Cooling

    The coolable core geometry and long-term core cooling sections were expanded to provide additional details on the methods of analyses and considerations that were included in evaluating these two criteria. Additional information on the analyses and evaluations that are performed to support the coolable core geometry was added to Section 7 of each EM volume in Revision 2. Additional information was also added related to long-term core cooling (Section 8 of each EM volume in Revision 2) to include considerations for GSI-191.

1.C.2. Expanded EM Descriptions for Extended EM SBLOCA Applications

Since Revision 0 of the EM was completed, a variety of evaluations and analyses were performed to support plant operation with changes to plant or fuel-related inputs for a variety of fuel types and designs. The types of changes related herein are typical cycle specific variations of fuel pin enrichments, peaking variations, and loading variations with mixed-core fuel batches possibly with reconstituted fuel assemblies. However, these inputs are included in the PCT analysis so the effects are captured in the EM application and they were not included in previous 10 CFR 50.46 PCT change notifications. The SBLOCA items included in Revision 2 of EM are listed below, followed by a discussion of each item.

Each of the previous LBLOCA discussions is included along with two SBLOCA specific items. While a number of the listed items were specifically questioned regarding LBLOCA, statements concerning their relevance to SBLOCA were included in the RAI response.

SBLOCA Expanded Considerations

1. Partial Power SBLOCA Analyses with a Positive MTC
2. SBLOCA LHR Limits at the Core Inlet or Core Exit
3. SBLOCA Analyses Above the Licensed Core Power Level
4. SBLOCA Core Power Flattening / Energy Deposition Factors
5. SGTP Considerations for SBLOCA
6. Radial Versus Axial Power Peaking EM SBLOCA Restriction
7. SBLOCA Gadolinia Fuel
8. SBLOCA Mixed-Core Considerations
9. SBLOCA EOC T_{ave} Reduction with Negative MTCs
10. SBLOCA Stainless Steel or Natural Uranium Replacement Rods
11. Actinide Decay Heat for SBLOCA
12. Additional SBLOCA Discussion on Coolable Core Geometry and Long-Term Core Cooling
13. Multiple Hot Pins for SBLOCA TIL Approximation
14. Clarification of Maximum SBLOCA Spectrum Break Size

A brief discussion on the Revision 2 SBLOCA items that were considered and added as appropriate are provided in the following paragraphs. Since these items do not result in a PCT change, they simply reflect analysis considerations and are not designated as conservative or non-conservative unless stated otherwise. The location in the EM where the text was updated is also included.

1. Partial Power SBLOCA Analyses with a Positive MTC

   This item was related specifically to LBLOCA. SBLOCA results improve due to the reduced core decay heat when the transient is initiated while the plant is at partial power. Therefore, no specific information is included. In the event the SBLOCA is performed at partial power, the potential increase in moderator temperature coefficient will be considered in the analyses; however, the control rods shut the reactor down so the positive MTC is of little consequence.

2. SBLOCA LHR Limits at the Core Inlet or Core Exit

   An EM study was performed for LBLOCA to establish LHR limits from 0 to 12 feet in the core. There was no study performed for SBLOCA because at the time the EM was developed the LHR limits and PCTs were all set by the LBLOCA analyses. Changes in fuel designs, improvements in LBLOCA methods, and changes to some key plant inputs have allowed the gap between large and small LOCA LHR limits to converge at the upper core elevations. SBLOCA PCT results remain less limiting than the LBLOCA, but based on clarified NRC reporting guidance, they are now reported separately. When the EM was developed there was only one PCT reported for all LOCAs so there was reduced emphasis on the SBLOCA LHR limit or PCT because both were set by LBLOCA.

   The SBLOCA EM used the uppermost LBLOCA 1.7 normalized axial peak to perform PCT analyses. This axial peak is located at 9.705 feet from the bottom of the active core for 205-FA plants (EM demonstration cases) and 9.536 feet for the 177-FA plants. A SBLOCA analysis with a normalized axial peak at an elevation below that of the analyzed peaks will produce lower PCTs because the peak power location either remains covered by a two-phase mixture or its duration of uncovering is shorter. Therefore, lower elevation axial peaks do not need to be analyzed for SBLOCA because they will not be limiting.

   Axial peaks at core elevations above the EM peaks will be more limiting in terms of SBLOCA PCT because the duration of uncovering is the longest for a peak near 12 feet. However, developing a power peak at 12 foot is non-physical because it cannot be obtained due to neutron leakage. The use of axial blankets and partial control rod insertion also limit the magnitude and the elevation that an axial peak can be pushed to near the core exit. The plant power peaking analyses need to be used to establish a reasonable limit on the magnitude and elevations of the axial peaks. These considerations lead to the development of the SBLOCA axial power shape validation process described in Item 4 of Section 1.A of this RAI response.

3. SBLOCA Analyses Above the Licensed Core Power Level

   At times LOCA analyses may be performed in anticipation of a future core power uprate. The EM supports this application (See Section 4.3.1.1 in Volume II of the EM). SBLOCA analyses are more restrictive and will produce higher PCTs, local oxidations, and whole-core hydrogen generation rates at uprated power. Since the power level is part of the input, no change in PCT is reported, but this is a clear conservatism in the results.

4. SBLOCA Core Power Flattening / Energy Deposition Factors

   The EM states that the fraction of the power lost from the hot channel (sometimes referred to as power flattening) is deposited uniformly in the fluid of the average channel. The EM further states that the SBLOCA value of this power flattening is 2.7 percent. This power flattening, which is more commonly described as the energy deposition factor (EDF) in the fuel pin, is given as 0.973 (e.g. 1 – power flattening fraction). The primary EDF contribution at steady-state conditions is controlled by the thermalization of the neutrons in the fluid. After the reactor is shut down and the neutron flux depleted, the EDF contribution is primarily from gamma energy being absorbed by unheated structures or fluid. When the core is covered by a two-phase mixture the EDF is less than one; however, during the period of core uncovering, there is only steam available to absorb any gamma energy in the uncovered region of the core. If gamma leakage or absorption by unheated structures is not considered, the EDF in a high powered bundle with a flat power profile approaches a value of unity. Therefore, current SBLOCA analyses use an EDF of 0.973 at steady-state, but increase the value to 1.0 during the transient. This increase in the EDF is applied to SBLOCA analyses because the EM states that the reported values may be amended by specific calculations. In this case, the resultant EDF is higher and it results in more conservative PCTs than would have been predicted if the default values described in Revision 0 of the EM were used. Since conservative EDFs were always applied as an input to the analyses, there is no PCT change. The EDF considerations are general in nature. They are discussed in EM Volume II Section 4.3.1.7 and Table 9-2. No text changes were included because the general discussions were judged to be adequate.

5. SGTP Considerations for SBLOCA

   The EM demonstration cases for the RL 205-FA plant were developed for a plant that was under construction so no SGTP was included in the modeling. The SBLOCA analysis is not a flow dominated transient so the results are not altered by the increased resistance with SGTP. The initial RCS flows are, however, different and the RCS fluid conditions change as a result of the flow differences. The SGTP can also decrease the primary-to-secondary heat transfer due to plugging of tubes that are wetted by the high elevation emergency feedwater (EFW) flows. Therefore, SBLOCA results can be adversely affected by SGTP, so the EM analyses model a level of SGTP input that matches or exceeds the actual plant fraction for SBLOCA analyses. Use of higher SGTP input is slightly conservative relative to the effect on SBLOCA PCT for a plant with no SGTP. Since SGTP is an input change, there is no PCT change reported because it is simply part of the analysis. The SBLOCA descriptions were modified to include SGTP considerations in Section 4.2, 4.3.1.10, 4.3.2.1, and in Table 9-2 of Volume II in the EM.

6. Radial Versus Axial Power Peaking EM SBLOCA Restriction

   The EM Revision 0 SER limitation Number 3 places a restriction on evaluating the validity of the radial versus axial peaking for LBLOCA. No restriction is applied to the SBLOCA. Variations in radial and axial peaks are not as important for SBLOCA as with LBLOCA. The total peak and the location of the peak are more important for SBLOCA. Additional checks on the location of the axial peaks versus the peaks observed in the maneuvering analyses are considered as described in SBLOCA Item 2 and Item 4 of Section 1.A of this RAI response.

7. SBLOCA Gadolinia Fuel Analyses

   As described previously in the LBLOCA section, longer fuel cycles may use gadolinia fuel. The gadolinia pins use reduced peaking factors or LHR limits to compensate for the fuel thermal property changes that vary with gadolinia weight fraction. SBLOCA analyses are generally not needed with reduced peaking factors; nonetheless, the EM was modified to consider allowed peaking for gadolinia fuel and determine if SBLOCA analyses or evaluations are required as described in Sections 4.3.1.3, 4.3.1.7, and 10 in Volume II of the EM.

8. SBLOCA Mixed-Core Considerations

   The EM demonstration cases for the RL 205-FA plant were developed for a plant that was under construction so no mixed-core considerations were included in the modeling. Mixed-core analyses were briefly mentioned in a previous RAI response on page LA-104 of Volume III. Mixed-core analyses are performed or evaluated when fuel assemblies with different pressure drops are used as a batch reload or as a lead test assembly. For non-flow dominated applications like SBLOCA, there is little influence from the mixed-core resistance models. If there was an effect, the high resistance assemblies are placed in the hot channel and the remainder of the core is modeled in the average channel as the lower resistance fuel assemblies. This modeling conservatively maximizes the flow diversion out of the hot channel into the lower resistance fuel assemblies and maximizes the PCT for the high resistance fuel. Generally, the cooling of the lower resistance fuel is improved and its PCT would decrease. Unless the beneficial cooling of the lower resistance fuel is analyzed or evaluated, the benefit of a reduction in PCT or increased LHR limit is not credited. Since mixed-core is explicitly analyzed, there is no PCT change because the results reflect the input that was provided. In some cases, the mixed-core results are used for full-core conditions because there is effectively no penalty for SBLOCA transients. Consideration of the mixed-core operation is included in Section 4.3.2.5 of Volume II.

9. SBLOCA EOC T_{ave} Reduction with Negative MTCs

   LBLOCA results are influenced by changes to the RCS average temperature but SBLOCA results are relatively insensitive to small changes in this parameter. Therefore, no SBLOCA analyses are performed with a reduced temperature and a negative MTC that will reduce the post-trip core power response.

10. SBLOCA Stainless Steel or Natural Uranium Replacement Rods

    SBLOCA results were evaluated with unheated or cold rods and it was determined that the results are not impacted by the use of these rods. This evaluation was completed to support fuel reloads, so there is no discussion of unheated rods added to the SBLOCA EM volume. If used in a core reload evaluation, the maneuvering analysis peaking changes will be considered as described in BAW-2149-A.

11. Actinide Decay Heat for SBLOCA

    Appendix K of 10 CFR 50 requires that the post-shutdown DH for LOCA must consider the heat from the radioactive decay of actinides, including neptunium and plutonium generated during operation, as well as isotopes of uranium. They shall be calculated in accordance with fuel cycle calculations and known radioactive properties. The actinide DH chosen shall be that appropriate for the time in the fuel cycle that yields the highest calculated fuel temperature during the LOCA. This is discussed in Section 4.3.1.5 and Table 9-2 of Volume II of the EM.

The basis for the highest calculated fuel temperature during the LOCA is interpreted to correspond to the highest calculated PCT during the transient. SBLOCA analyses are performed independent of time in cycle. Therefore, the options available to demonstrate an acceptable actinide contribution for the hot pin during the reload evaluation are limited to the actual fuel enrichment and burnup. For the LBLOCA (See Section 1.C.1 Item 11), the fuel temperature decrease could be used to offset the higher decay heat contributions. For SBLOCA, the fuel initial temperature cannot be used to offset higher actinide contribution. Therefore, other approaches must be used to separate the actinide model for the hot pin/hot channel versus the average core. If the bounding hot rod actinide model is not used, then the reload evaluations may be able to tradeoff other actinide DH power against other conservatisms. Examples include use of LHR limit margin (if the analyzed SBLOCA LHR is higher than the LBLOCA LHR) or core power level (if the analyses are performed at an uprated power relative to the licensed power). If there are no tradeoffs available, then the only option is a calculation that will change the inputs used and the calculated hot rod PCT. Use of a bounding actinide model for the hot rod and average core is recommended for future SBLOCA analyses to preclude the need to perform cumbersome reload checks.

Use of the bounding actinide model will increase the calculated PCT for the SBLOCA analyses with no other changes considered. The duration of the SBLOCA event is long and an increased actinide contribution incurs additional PCT penalties that are incurred by use of a higher actinide DH model.

12. Additional SBLOCA Discussion on Coolable Core Geometry and Long-Term Core Cooling

The coolable core geometry and long-term core cooling sections were expanded to provide additional details on the methods of analyses and considerations that were included in evaluating these two criteria. Additional information on the analyses and evaluations that are performed to support the coolable core geometry was added to Section 7 of each EM volume in Revision 2. Additional information was also added to the long-term core cooling to include consideration of GSI-191.

13. Multiple Hot Pins for SBLOCA TIL Approximation

    The original SBLOCA method of analysis includes provisions to evaluate the potential for fuel pin rupture when the limiting cladding temperatures are above the ranges at which rupture could occur (generally 1400 F and above). The method of analysis included iteratively changing the internal rod pressures or heating ramp rates in subsequent analyses to force a rupture near the time of PCT to ensure that inside and outside metal-water reaction will not challenge adequate cooling of the ruptured pin. This process was streamlined; it now is considered in a single case via the use of multiple pins that cover the range of internal rod pressures from BOL to EOL. The pins each use a BOL oxide thickness with BOL pin geometry and fuel pellet initial conditions with an elevated internal rod pressure. In the event that this method is believed to produce excessively conservative temperatures, an actual detailed time-in-life analysis may be performed with burnup-dependent fuel initial conditions and increased oxide thicknesses. This material was incorporated into Section 4.3.4 of Volume II of the EM.

14. Clarification of Maximum SBLOCA Spectrum Break Size

    Section 4.2 of the BWNT LOCA EM Volume II states that: a SBLOCA does not go through DNB during the first few seconds after break opening. It continues with additional discussions about the break size for which DNB did not occur as a 0.75-ft^2 break in the EM demonstration cases. It was shown, since the EM was completed, that the break size that undergoes CHF is variable. The fuel design used and its respective DNB correlation determine the maximum SBLOCA break size. The text in Sections 4.2 and C.1.a in Volume II of Revision 2 of the EM was modified to describe the variable break area that defines the maximum break size that is considered a SBLOCA. This break size is established at nominal, full power conditions with all RCPs operating. Break sizes larger than this size that undergo DNB are characterized as a transition LBLOCA and it is analyzed with the methods described in Section 4.3.7.1 of Volume I.

RAI 2. For both small break LOCA and large break LOCA, please submit a recent analysis from your experience base that incorporated the proposed changes and showed acceptable results.

__Response__: In performing LOCA application analyses using the BAW-10192 EM, AREVA customarily reviews, for continued applicability, the varied studies provided in Appendix A of Volume I (LBLOCA) and Appendix A of Volume II (SBLOCA). The generic EM studies are reviewed and justified or repeated if necessary for application to the plant-specific analysis at hand. A similar review and evaluation is performed for the plant type-specific studies like the break spectrum or pump degradation studies. In some cases additional plant-specific studies are performed to justify the adequacy of the inputs used in the applications. Once the limiting conditions plant input parameters are established, the time-in-life, core axial peaking, and minimum versus maximum ECCS injection analyses are performed to define the LOCA LHR limits used in the core reload analyses and to determine the bounding results for the first three 10 CFR 50.46 criteria. As appropriate, Gadolinia fuel rods are factored into the plant-specific studies. This work is summarized in a comprehensive plant-specific LOCA application summary report.

Progress Energy has recently submitted a LOCA summary report (Reference 1) to the NRC in support of ongoing License Amendment work on the extended power uprate (EPU) for the Crystal River 3 (CR-3) plant. They have given permission and endorsed the use of the CR-3 EPU LOCA summary report as a demonstration of the BAW-10192P-A Revision 2 methods. This 177-FA LL plant application is the same as the Revision 0 with the changes that have been approved or incorporated into the EM. This summary report is the most recent complete LOCA analysis and it shows acceptable analysis results along with the supporting sensitivity studies and evaluations that develop the most limiting boundary conditions for use in the deterministic EM analyses to support plant licensing.

Please note that this LOCA summary document is written to communicate the inputs and results to the utility. It is not written from the perspective of supporting the EM or specifically supporting the licensing review of changes between Revision 0 and Revision 2. Nonetheless, this report is sufficient for the staff to use in understanding the comprehensive approach used in LOCA applications that confirm compliance with the 10 CFR 50.46 criteria as derived from the application of the large and small break LOCA analyses in accordance with the BAW-19192 Revision 2 EM.

RAI 2 Reference:

1. AREVA Document 86-9080901-003, "CR-3 LOCA Summary Report – EPU/ROTSG/Mark-B-HTP," May 21, 2010.

RAI 3. Currently, the raised-loop, 205-fuel assembly design is a fictitious design. Do you plan to retain the applicability of BAW-10192 to the raised-loop, 205-fuel assembly design plant? If so, please provide information showing the applicability of the proposed changes to the 205-fuel assembly design.

Response: AREVA fully intends "to retain the applicability of BAW-10192 to the raised loop, 205-fuel assembly design plant." While no 205-FA plants are currently operational, there are several 205-FA plants in various stages of suspended construction within the US. Therefore, AREVA does not consider it "a fictitious design." A raised-loop 205-FA (Mülheim Kärlich-1) was built and successfully operated in Germany by Babcock-Brown Boveri Reaktor (BBR). TVA undertook construction of two 205-FA plants at its Bellefonte site, and AREVA has prepared and submitted for licensing review a generic 205-FA SAR embodying 3,600 MWt and 3,800 MWt versions of the plant. The 205-FA design was and still remains a valid, totally matured plant design.

As noted in AREVA's response to Question 1, the Revision 0 demonstration cases were not rerun because the Revision 2 updates would not significantly affect the results or conclusions drawn from the studies. It is acknowledged that PCTs (or local and whole-core oxidations) would change, but the value—trends, outcomes and conclusions—of the cases would be undiminished. Hence, AREVA concludes that the Revision 0 205-FA LOCA demonstration cases remain representative and are equally applicable to Revision 2, and do not need to be repeated. It should be noted that if and when AREVA would perform a 205-FA plant-specific application, all studies would be reviewed for current applicability consistent with the process described in response to RAI Number 2. If necessary they would be reanalyzed to determine the limiting set of inputs for the LOCA applications. It is expected that the results of the LOCA application would be submitted in some form for the NRC to complete their licensing review in support of startup and operation for any 205-FA plant. Therefore, the EM remains valid for the 205-FA plant and it is not necessary to submit revised analyses at this time.