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10 CFR 50.46

TMI-10-118
November 29, 2010

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Three Mile Island Nuclear Station, Unit 1
Renewed Facility Operating License No. DPR-50
NRC Docket No. 50-289

Subject: 10 CFR 50.46 30-Day Report - Response to Request for Additional Information

References:

1) Letter from Pamela B. Cowan (Exelon Generation Company, LLC) to U.S. Nuclear Regulatory Commission, "10 CFR 50.46 30-Day Report," dated September 7, 2010

2) Letter from P. Bamford (U.S. Nuclear Regulatory Commission) to M. Pacilio (Exelon Generation Company, LLC), "Three Mile Island Nuclear Station, Unit 1 - Request for Additional Information Regarding 30-Day Notification of Changes to an Emergency Core Cooling System Evaluation Resulting in a Peak Cladding Temperature Difference in Excess of 50 Degrees Fahrenheit (TAC NO. ME4666)," dated October 22, 2010

In the Reference 1 letter, Exelon Generation Company, LLC (Exelon) submitted a 10 CFR 50.46 30-day report for Three Mile Island Nuclear Station (TMI), Unit 1. In the Reference 2 letter, the U.S. Nuclear Regulatory Commission requested additional information. Attached is our response to this request.

As discussed in the Reference 1 letter, the estimated Peak Cladding Temperature (PCT) increase of 225°F was assigned to the TMI, Unit 1 limiting small break LOCA (SBLOCA) PCT of 1444°F with Mark-B-HTP fuel, resulting in a limiting estimated PCT of 1669°F. This PCT increase was conservatively applied to all times in the cycle for the current and future fuel cycles until new SBLOCA analyses are performed. Additionally, the licensing basis SBLOCA analyses for TMI, Unit 1 have been performed at a power level of 2827 MWt (to support future

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power uprate) which represents a power uprate of 7.9% over the current licensed power level of 2619 MWt (considering uncertainty). For this reason, and the fact that there is a margin of 531°F to the 10 CFR 50.46 acceptance criteria of 2200°F for the PCT, there are no current plans for revised SBLOCA analyses for TMI, Unit 1.

No new regulatory commitments are established in this submittal.

If any additional information is needed, please contact Tom Loomis at (610) 765-5510.

Respectfully,

Pamela B. Cowan
Director – Licensing & Regulatory Affairs
Exelon Generation Company, LLC

Attachment: Response to Request for Additional Information

cc: USNRC Region I, Regional Administrator
USNRC Project Manager, TMI, Unit 1
USNRC Senior Resident Inspector, TMI, Unit 1

ATTACHMENT 1

Response to Request for Additional Information

Attachment 1

Paraphrased Generic Form of the Plant Specific Requests for Additional Information

The NRC has asked for additional detailed information regarding the evaluation of the impact of the axial power shape on the PCT modeling error for each plant. This information should include, but not be limited to, a discussion of the causes of the error and evidence to support a conclusion that the model as a whole remains adequate to predict PCT. Please include a discussion of the impact of this error on the full spectrum of postulated break sizes, as well as any planned corrective actions, and actions to prevent recurrence. If a plant-specific assessment regarding the modeling errors was not performed, please justify the use of any generic evaluation.

Response:

Identification of the Problem

AREVA wrote condition report (CR WebCAP 2010-4150) questioning the validity of the axial power shape used in BWNT LOCA Evaluation Model (BAW-10192) small break loss-of-coolant accident (SBLOCA) analyses. The axial power shape used in the SBLOCA analyses was bounding for limiting, hot rod, beginning-of-cycle (BOC) peaking, but it was unclear if it was bounding for hot rod, end-of-cycle (EOC) peaking. At the time the CR was written, AREVA was also responding to requests for additional information (RAIs) on Revision 2 of BAW-10192. This axial power shape CR was described in the RAI responses to the NRC (AREVA Letter 10-02213, NRC:10:069 on July 27, 2010, ADAMS Accession No. ML102100201) and a commitment was added to evaluate the adequacy of the SBLOCA axial power peak based on cycle-specific peaking evaluations to confirm the validity of the SBLOCA analyses.

In brief, the apparent cause of the error can be traced to an oversight during the BWNT LOCA EM development. At that time, the focus was on reporting the limiting peak cladding temperature (PCT), which was set by the large break LOCA (LBLOCA). While the evaluation model (EM) consists of calculational frameworks for both LBLOCA and SBLOCA, the much lower SBLOCA PCTs and the availability of significant margin between the generated peaks and the linear heat rate limit at the core exit did not appear to spur the same methodological rigor as the LBLOCA EM. Since that time, changes in plant parameters (power uprates, emergency feedwater (EFW) flows, high pressure injection flows, core flood tank initial conditions, steam generator tube plugging, EFW wetting for replacement steam generators, etc.) and fuel cycle designs (gadolinia rods, extended cycle lengths, etc.) have increased the calculated SBLOCA PCTs and reduced the peaking margins at the top of the core. Further, the 10 CFR 50.46 reporting requirements were expanded to include the SBLOCA PCT separately. In retrospect, once separate PCTs were required to be reported, the SBLOCA framework should have been revisited since both events are treated separately and can no longer be used to bound the other.

Subsequent reviews of the core power distribution analyses (or maneuvering analyses) for all 177-fuel assembly (FA) plants concluded that all achievable EOC axial power shapes were not bounded in elevation by the axial peak used in the SBLOCA analyses of record. It was concluded that an axial shape skewed higher in the core is needed to bound the axial peaks that could be achieved at the EOC for all B&W-designed plants following certain maneuvers. Specifically, the maneuver consists of partial control rod insertion with a subsequent full withdrawal. The normalized axial power peak is also increased by timing the rod withdrawal to coincide with the peak xenon spatial power redistribution.

A spreadsheet was developed based on a first principles approach to assist in the initial estimation of the peak cladding temperature (PCT) changes. It used the quasi-steady state steaming rate, minimum core mixture level, and representative surface heat transfer rates all at the conditions and time of the PCT to develop the initial PCT estimates. The quasi-steady state approximation predicts a conservative estimate for SBLOCA PCT changes with the axial power shape change. It is a reasonable yet conservative tool that is applicable provided the PCTs do not reach ranges with significant metal water reaction contribution changes (e.g. >1800 F). Several cursory RELAP5/MOD2-B&W cases were initially performed to confirm the validity of the bounding spreadsheet approximations. The spreadsheet estimations, cursory RELAP5 cases, and recently completed RELAP5 analyses support the conclusions that the PCT could increase up to a maximum of 225 F for some cases. As a result, SBLOCA 10 CFR 50.46 30-day reports with this bounding, generic, 225 F PCT increase were prepared for each B&W-designed 177-FA plant that used the BWNT LOCA EM SBLOCA method (BAW-10192).

Evaluation of the SBLOCA Axial Peak Changes

There are two components associated with the SBLOCA PCT changes. They include: (1) the time-in-cycle axial power shapes, and (2) the PCT differences realized with an axial power shape change for the spectrum of break sizes. Additional information is provided for each of these in the following paragraphs.

Generally, core total peaks are the highest for fresh fuel at the limits of allowable operation. The key peaking component at BOC is the high radial peaks predicted at this time in life. When combined with the axial peaks, the highest total peaking predictions are produced. The radial peaks generally decrease with increasing burnup. As the cycle progresses the total peaking decreases and there are larger margins to the allowed LOCA linear heat rate (LHR) limits. When the total peaking is lower, the maximum PCT should also decrease.

The initial questions on the validity of the axial power shape originated with SBLOCA scoping analyses performed for a 177-FA plant considering an extended power uprate (EPU, consisting of a 17% power uprate). It was observed that the upper regions of the core were uncovered for a longer time period with the uprated core power. As a result, the maneuvering analyses were reviewed to determine if the radial and axial peaks used in the SBLOCA were bounding. The questions led to review of some preliminary EPU cycle designs. The conclusion was that the radial and the 1.7 axial were bounding, but the elevation of the axial peak could be higher than the current EM SBLOCA axial peak (9.5 ft). The key observation was the increase in the elevation of the axial peak for SBLOCA. It had been considered and accounted for in the LBLOCA analyses and limits, but it had not been considered for the SBLOCA cases. Given that the large and small break spectrum PCTs are now reported separately, it was concluded that these new SBLOCA peaking considerations need to be incorporated into the BWNT SBLOCA EM analyses.

Review of the representative core power distributions showed that at BOC the top-skewed axial power profile was bounded by the 9.5-ft axial power shape used in the current SBLOCA analyses. Figure 1 provides this comparison. Also, shown in this figure is a MOC axial power shape at 375 effective full power days (EFPD). The peak locations coincide with the MOC case and the axial shape is also reasonably bounded by the SBLOCA analysis shape. With increasing core burnup, the margins between the maneuvering analysis peaks and the LOCA normalized axial peak increases, but the axial peak elevations are no longer bounded by the shape used in the previous SBLOCA analyses. In Figure 2 the 575 EFPD burnup axial peak is just barely bounded by the 9.5-ft SBLOCA axial shape, but the 715 EFPD elevation of the axial peak is not bounded.

Figure 3 combines all the power shapes and shows the increasing elevation of the axial peaks with increased burnup. In order to bound the EOC peak elevations, a new SBLOCA normalized axial power shape was created. The 11-ft axial peak selected for use in new SBLOCA analyses is shown in Figure 4 along with the BOC and EOC shapes. The 11-ft shape covers all times in cycle; however, it is very conservative for the BOC case. It is also noted that the EOC peaks were generated by core power distribution cases that typically produce imbalances larger than those allowed by Technical Specifications for plant operation. If the Technical Specification allowable axial power imbalance limits were used, the elevations of the axial peaks would not change but the magnitude of the axial peak would decrease. It was concluded that unless cycle-specific SBLOCA analyses were undertaken, the 1.7 normalized axial shape peaked at the 11-ft elevation should be used to bound all current and future cycles. The magnitude of the peak is bounding for EOC peaks and its use in the SBLOCA analyses with maximum allowed LHR limits (total peaks) will not impact the plant LOCA limits specified in the Core Operating Limits Report (COLR) or add considerable efforts to the cycle-specific maneuvering analyses. In essence, the selection described imposes additional conservatism on the SBLOCA calculated PCTs by imposing higher axial peaks to avert LHR limit reductions and minimize the burden on the future cycle-specific core peaking design checks.

Each B&W-designed plant has different high pressure injection (HPI), emergency feedwater (EFW), and low pressure injection (LPI) flows and piping arrangements as well as different core flood tank (CFT) initial conditions. Several plants have analyses performed at uprated core power levels to support future EPU transitions. These plant

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and analysis differences result in PCT variations over the spectrum of small break sizes. Generally, the SBLOCA PCT is produced by an intermediate to smaller break size (~0.07 – 0.15 ft^2). For most plants the PCTs occur 10 to 20 minutes after break opening and slightly after the CFTs begin to inject. One plant has a limiting PCT case for a much smaller break size that does not have CFT injection and the PCT occurs later in the transient. If the transient evolves slowly, then the fuel pin temperature distribution approaches a quasi-steady-state condition in which the temperature differences established near the time of PCT are sufficient for the superheated steam to remove the core decay heat generation rate. The integrated decay heat energy generated below the mixture level creates a steaming rate that can be used to determine the enthalpy rise of the steam surrounding the PCT location.

The core power at the time of the quasi-steady state conditions determines the temperature difference between the cladding and steam. If the decay heat is lower, the PCT is lower. The core power decreases above the original 9.5-ft axial peak in the core; therefore, the cladding temperature decreases with increasing elevation. Figure 5 shows a representative steam and cladding temperature approximation when the 9.5-ft axial peak is used with a 10-ft mixture level. In this case the peak power location is below the mixture level and the PCT is predicted at approximately 10.3 ft with a steam temperature that is closer to the saturation value. The PCT occurs at a location in the rod with a power level that is considerably lower than the total peak. Since the power peak is lower, the PCT is lower.

When the 11-ft axial peak is used for a similar case, the PCT occurs near the peak power location. Figure 6 adds the cladding and steam temperatures for the 11-ft axial peak along with the 9.5-ft temperatures from Figure 5. The two key differences are that the steam temperature and power generation are higher. Consequently, the steam temperature plus the temperature difference between the cladding and steam, results in the maximum PCT value at the 11.3-ft core elevation. This resultant PCT is approximately 225 F higher than the 9.5-ft axial PCT based on the quasi-steady state prediction.

Several cursory SBLOCA RELAP5 cases were performed with the axial power shape changed from 9.5-ft to 11-ft peak elevation. These EM-method based cases also confirmed that the 225 F increase was a bounding value for the PCT cases. Since the time when the SBLOCA CR was written, one revised SBLOCA spectrum has been completed and documented for one 177-FA lowered loop plant. These new SBLOCA analyses used the 11-ft axial power shape and two other slight input changes to the actinide decay heat contribution and the steam generator tube plugging (SGTP) fractions. Both of these changes do not significantly change the PCTs, but they would both tend to increase the PCTs slightly. Figure 7 shows the PCT differences for the two cold leg pump discharge (CLPD) spectrums.

The PCT differences observed for the spectrum of CLPD breaks in Figure 7 shows that the 225 F value assigned to the PCT is reasonable, yet bounding. The smaller break sizes for this spectrum did not have core uncovering so there was no PCT increase. The intermediate to larger SBLOCAs had PCT increases less than the 225 F value assigned generically to all plants prior to completion on any formal reanalyses. The larger SBLOCA sizes evolve rapidly and do not have time to achieve the quasi-steady state conditions used to develop the 225 F estimated increase. For these reasons, the PCT differences for larger SBLOCAs will be smaller than the 225 F value assigned to the limiting PCT case. The smaller break sizes have more potential to evolve to the quasi-steady-state conditions that were assumed. These break sizes, however, achieve those conditions at a later time, with a lower decay heat level and generally higher mixture level. When the decay heat is lower, the cladding to steam temperature difference is less and the PCT increase will be less than the 225 F assigned to all breaks with core uncovering at an earlier time period in the CR evaluation. The overall conclusion is that the PCT increase for all plants should be less than the 225 F estimate created to provide a reasonable bounding value for the limiting SBLOCA.

Conclusions

The information provided in this RAI response includes a discussion of the history of the SBLOCA axial power shape and the factors contributing to the error in determining a bounding axial power shape for use in SBLOCA analyses. Evidence is provided to show that the 11-ft axial power shape is a conservative Appendix K compliant model that is bounding for any time in cycle and it predicts bounding PCTs. The impact of this error on the full spectrum of postulated break sizes was discussed and it was shown that the 225 F increase is a bounding generic value. The error was self identified and demonstrates a questioning attitude that is effective at recognizing areas that may not have been adequately addressed in the past when new information becomes available. Evolutionary changes in plant systems, methods of analysis, and reporting parameters create differences that can change governing behavior and will prompt questions that challenge the validity of current methods of analysis. When challenges are identified, they are captured in condition reports and their resolution addressed by corrective actions. While it is expected that the 11-ft, 1.7 axial power shape is bounding for future application, any questions regarding the validity of the SBLOCA axial peaks will be prevented from future recurrence by the establishment of a reload analysis check to confirm that the axial peaking elevation and magnitude of the peak used in the SBLOCA analyses is bounding. While the current approach used a bounding axial peak of 1.7 at 11 feet, this axial peak or elevation is not explicitly fixed by the SBLOCA EM and it could be adjusted if necessary to bound future cycle-specific axial peaks.

The SBLOCA EM is a deterministic method with considerable conservatisms imposed by the regulations and additional conservatism added by the inputs selected and methods of analyses. It is as a whole conservative for the purpose of maximizing SBLOCA PCTs. The additional conservatism of imposing the 11-ft axial power shape is applied to minimize the additional burden on the time-in-cycle analyses or reload peaking evaluations.

A generic PCT increase was initially evaluated with a first principles approximation, and its validity initially supported with cursory analyses. The validity has been confirmed by recently completed RELAP5/MOD2-B&W EM analyses for the spectrum of break sizes as shown in Figure 7 for at least one plant. Analyses are in progress for other plants. The generic PCT increase of 225 F was applied to all the 177-FA plants as an immediate response to the condition report. The 225 F PCT increase is a generic, conservative estimate that can be used until plant-specific analyses for this EOC axial peaking error are completed.

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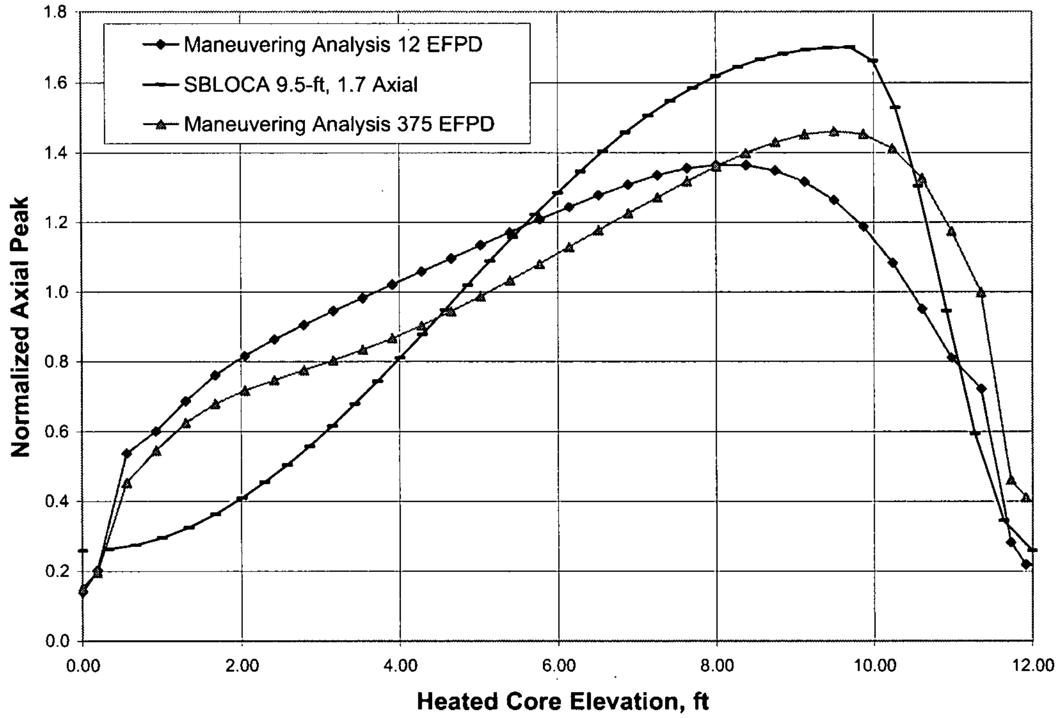


Figure 1. SBLOCA 9.5-ft Axial Shape with Characteristic BOC and MOC Limiting Axial Shapes

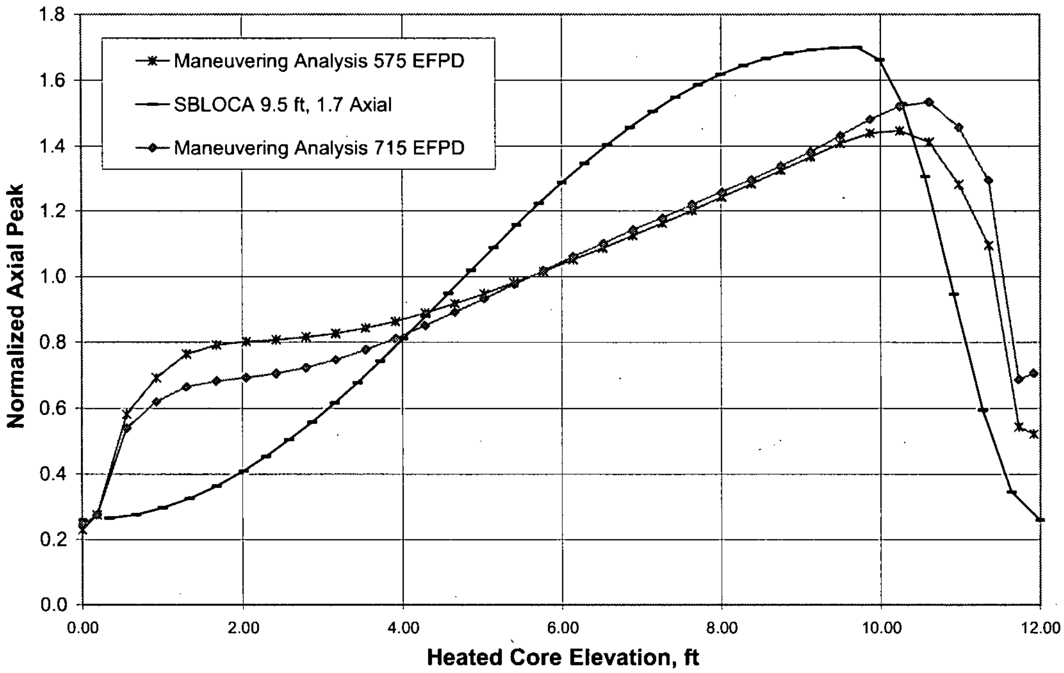


Figure 2. SBLOCA 9.5-ft Axial Shape with Characteristic EOC Limiting Axial Shapes

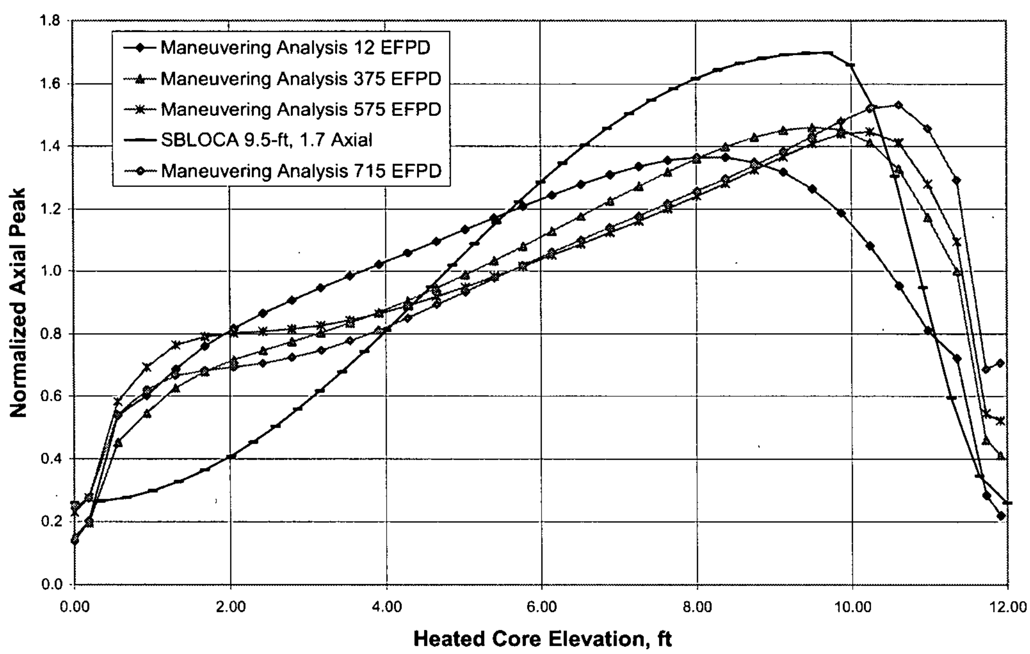


Figure 3. SBLOCA 9.5-ft Axial Shape with Characteristic Limiting Axial Shapes for all Times in Cycle

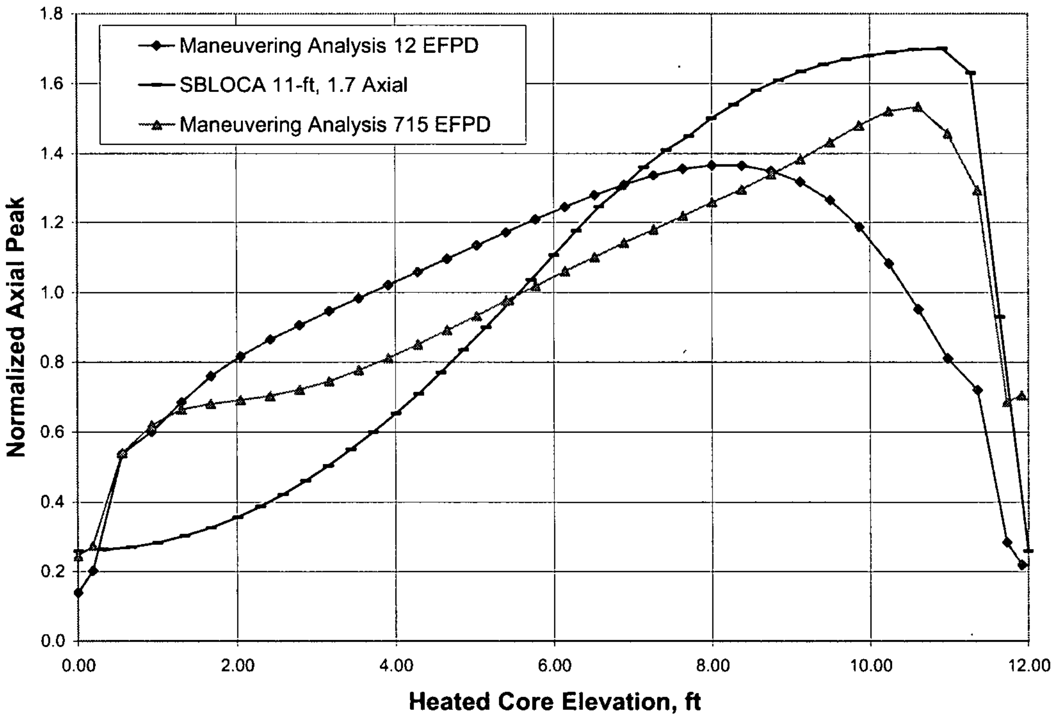


Figure 4. SBLOCA 11-ft Axial Shape with Characteristic BOC and EOC Limiting Axial Shapes

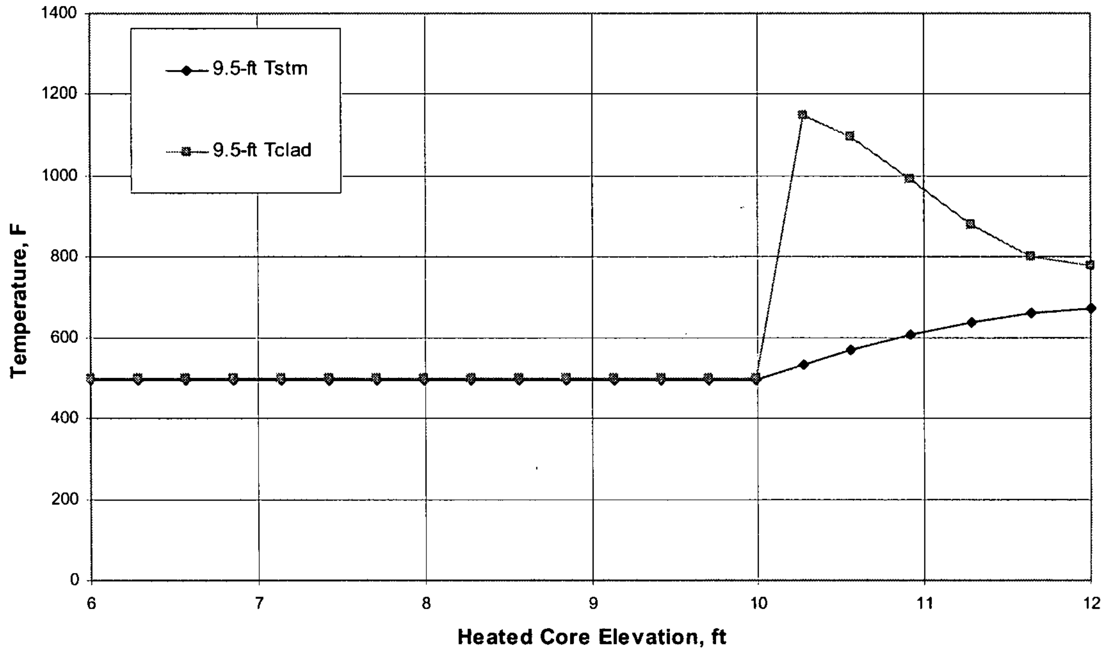


Figure 5. Quasi-SS SBLOCA Steam and Clad Temperatures with a 10 ft Mixture Level at 20 Minutes

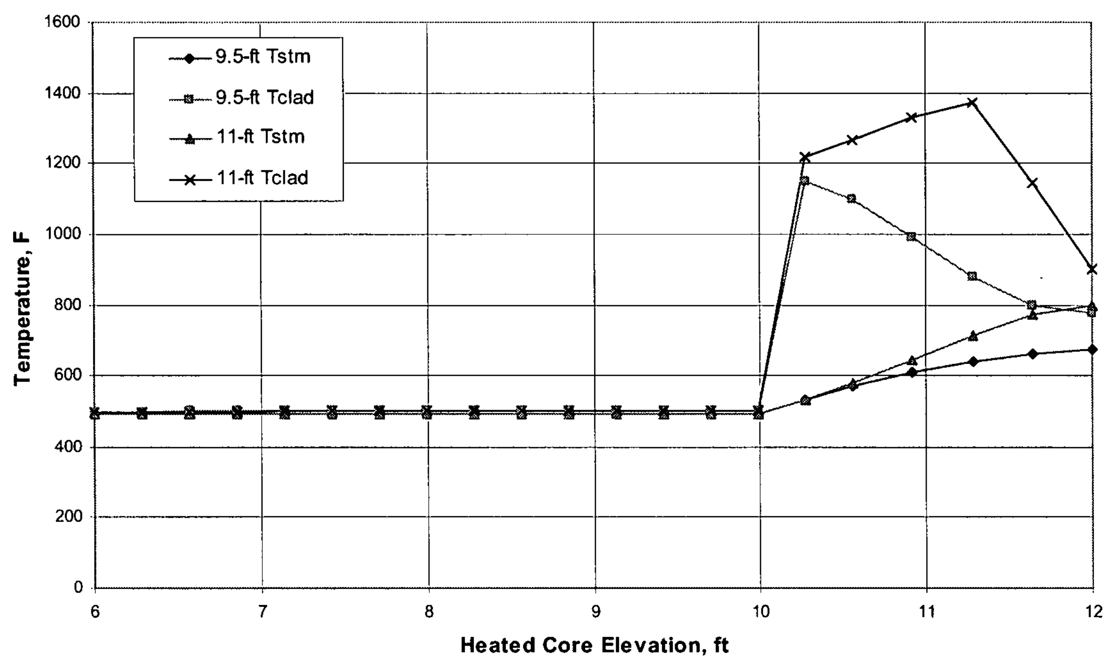
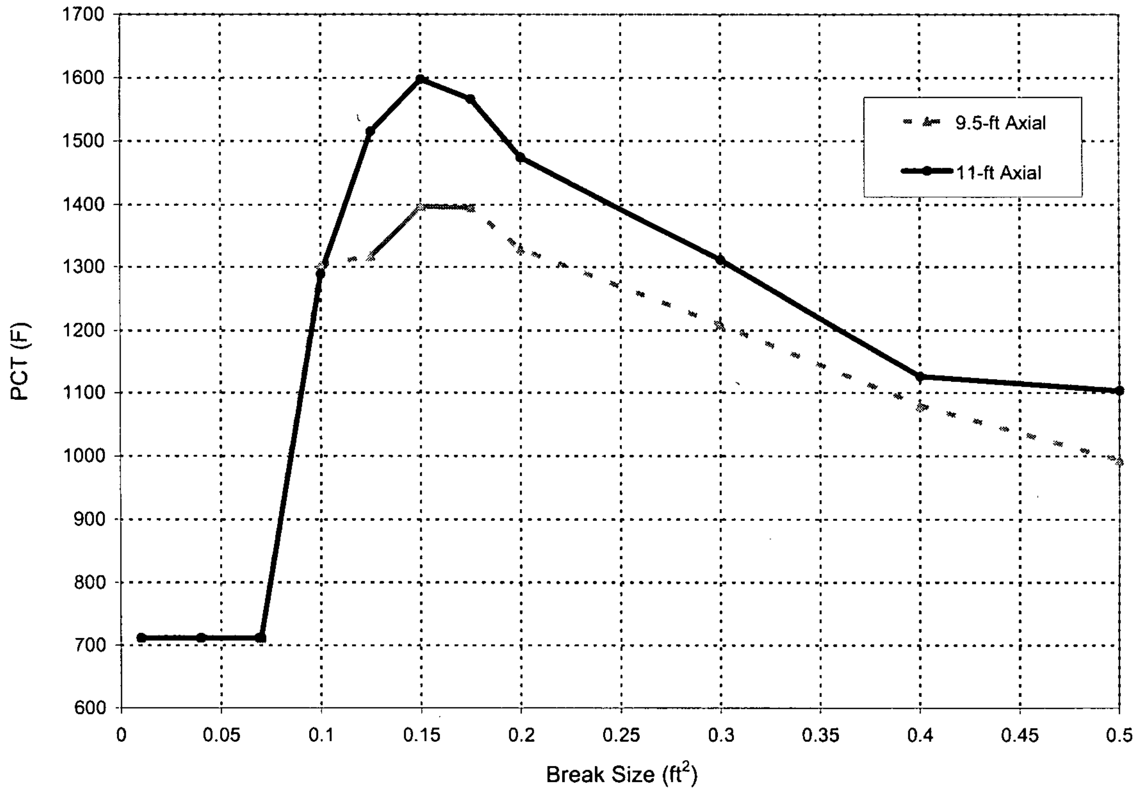


Figure 6. Quasi-SS SBLOCA Steam and Clad Temperatures with a 10 ft Mixture Level at 20 Minutes

Figure 7. Plant-Specific Mark-B-HTP SBLOCA PCT Comparison versus Break Size



Note: There are several minor input differences other than the axial power shape included in these spectrum results. In the 11-ft SBLOCA spectrum analyses, the SG tube plugging is higher by 2 percent, there was a full-core Mark-B-HTP fuel, and higher actinide decay heat contribution. It is estimated that the increase in PCT from the other changes is 20 to 40 F. In addition, the PCTs for the 9.5-ft cases other than at 0.125, 0.15, and 0.175 ft^2 were estimated based on analyses with a different fuel design. The Mark-B-HTP 9.5-ft axial analyzed cases are shown as a solid line and the estimated cases based on the Mark-B11 fuel design is shown as a dashed line.

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