Maine Yankee

RELIABLE ELECTRICITY SINCE 1972

Charles D. Frizzle
President and Chief Executive Officer

329 Bath Road
Brunswick, Maine 04011
(207) 798-4100

October 18, 1996
MN-96-145 CDF-96-180

Mr. Frank J. Miraglia, Acting Director
Office of Nuclear Reactor Regulation
UNITED STATES NUCLEAR REGULATORY COMMISSION
Washington, DC 20555

References:
(a) License No. DPR-36 (Docket No. 50-309).
(b) Letter, W.T.Russell (USNRC) to C.D.Frizzle (Maine Yankee), "Confirmatory Order Suspending Authority for and Limiting Power Operation and Containment Pressure (Effective Immediately), and Demand for Information (TAC NO. M94194)", dated January 3, 1996.
(c) Letter, C.D.Frizzle (Maine Yankee) to W.T.Russell (USNRC), "Submittal of Maine Yankee SBLOCA Licensing Analysis in Compliance with 10 CFR 50.46 and in Satisfaction of TMI Action Items II.K.3.30 II.K.3.31, and II.K.3.5", MN-96-056, dated April 25, 1996.
(d) Letter, E.H.Trottier (USNRC) to C.D.Frizzle (Maine Yankee), "Request for Additional Information - ANF-RELAP SBLOCA Analysis (TAC N0. M94834)", dated June 25, 1996.

Subject: Response to USNRC Request for Information (RAI) - Maine Yankee SBLOCA Analysis

Dear Mr. Miraglia:

By Confirmatory Order issued in January 1996, Reference (a), the Nuclear Regulatory Commission limited the maximum power operation at Maine Yankee to 2440 MWth until the completion and acceptance of a plant specific Small Break Loss of Coolant Accident (SBLOCA) analysis performed in accordance with the requirements of 10 CFR Section 50.46 and in satisfaction of the TMI Action Items II.K.3.30, II.K.3.31, and II.K.3.5. Maine Yankee had completed this new analysis and submitted the results to the USNRC Staff in late April, 1996, Reference (c). This submittal, analytical methodology, and analysis results have been under Staff review since that time.

In late June, 1996, the Staff issued a Request For Additional Information, Reference (d), on the earlier submittal. Maine Yankee has completed its response to that Request and is submitting the Attachments to this letter as documentation of that response.

Since a portion of the Response to the RAI requested by the Staff contains information considered proprietary by the Maine Yankee vendors performing this work, the first Attachment to this letter contains the necessary affidavits from the Siemens Power Corporation and Yankee Atomic Electric Company pursuant to the requirements of 10 CFR 2.790.

The second Attachment contains the full and complete proprietary response to the Staff's request. Maine Yankee requests that the information in this Attachment be withheld from public disclosure.

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The third Attachment contains the non-proprietary version of the responses to the Staff's Request for Information.

All technical information in Attachments 2 and 3 has been reviewed by Maine Yankee's independent consultant, Scientech, Inc.

If the Staff has additional questions or comments on the attached information, please contact Mr. Robert P. Jordan of the Maine Yankee staff at (207) 798-4243.

Very truly yours,

Charles D. Frizzle
President and Chief Executive Officer

ATTACHMENTS:

1. Affidavits executed by Siemens Power Corporation and Yankee Atomic Electric Company.
2. Proprietary responses to the USNRC Request for Additional Information.
3. Non-proprietary responses to the USNRC Request for Additional Information.

c: Mr. H. J. Miller
Mr. J. T. Yerokun
Mr. D .H. Dorman

c: (w/o Attachment 2): Mr. U. Vanags
L. J. Chandler, Esq.
D. Zillman, Esq.
Mr. P. J. Dostie

STATE OF MAINE

Then personally appeared before me, Charles D. Frizzle, who being duly sworn did state the he is President and Chief Executive Officer of Maine Yankee, that he is duly authorized to execute and file the foregoing response in the name and on behalf of Maine Yankee, and that the statements therein are true to the best of his knowledge and belief.

Notary Public

NRC29

BARBARA J. PADAVANA
Notary Public, State of Maine
My Commission Expires June 20, 2003

ATTACHMENT 1

Affidavits from:

Siemens Power Corporation
and
Yankee Atomic Electric Company

A F F I D A V I T

STATE OF WASHINGTON)
) ss
COUNTY OF BENTON)

I, R. A. Copeland being duly sworn, hereby say and depose:

1. I am in the Product Licensing section, for Siemens Power Corporation ("SPC"), and as such I am authorized to execute this Affidavit.

2. I am familiar with SPC's detailed document control system and policies which govern the protection and control of information.

3. I am familiar with the Siemens Power Corporation information in Attachment 2 to the letter from C. D. Frizzle of the Maine Yankee Atomic Power Company dated October 18, 1996, file number MN-96-145, referred to as "Document." Information contained in this Document has been classified by SPC as proprietary in accordance with the control system and policies established by SPC for the control and protection of information.

4. The Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by SPC and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in the Document as proprietary and confidential.

5. The Document has been made available to the U.S. Nuclear Regulatory Commission in confidence, with the request that the information contained in the Document will not be disclosed or divulged.

6. The Document contains information which is vital to a competitive advantage of SPC and would be helpful to competitors of SPC when competing with SPC.

7. The information contained in the Document is considered to be proprietary by SPC because it reveals certain distinguishing aspects of SPC licensing methodology which secure competitive advantage to SPC for fuel design optimization and marketability, and includes information utilized by SPC in its business which affords SPC an opportunity to obtain a competitive advantage over its competitors who do not or may not know or use the information contained in the Document.

8. The disclosure of the proprietary information contained in the Document to a competitor would permit the competitor to reduce its expenditure of money and manpower and to improve its competitive position by giving it valuable insights into SPC licensing methodology and would result in substantial harm to the competitive position of SPC.

9. The Document contains proprietary information which is held in confidence by SPC and is not available in public sources.

10. In accordance with SPC's policies governing the protection and control of information, proprietary information contained in the Document has been made available, on a limited basis, to others outside SPC only as required and under suitable agreement providing for nondisclosure and limited use of the information.

11. SPC policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

12. Information in this Document provides insight into SPC licensing methodology developed by SPC. SPC has invested significant resources in developing the methodology as well as the strategy for this application. Assuming a competitor had available the same background data and incentives as SPC, the competitor might, at a minimum, develop the information for the same expenditure of manpower and money as SPC.

THAT the statements made hereinabove are, to the best of my knowledge, information, and belief, truthful and complete.

FURTHER AFFIANT SAYETH NOT.

R A Copeland
____

SUBSCRIBED before me this 11th
day of October, 1996.

Sue M. Galpin
____

Sue M. Galpin
NOTARY PUBLIC, STATE OF WASHINGTON
MY COMMISSION EXPIRES: 2/27/00

SUE M. GALPIN
COMMISSION EXPIRES
NOTARY
PUBLIC
FEB. 27, 2000
STATE OF WASHINGTON

AFFIDAVIT PURSUANT

TO 10CFR2.790

Yankee Atomic Electric Company)
Nuclear Services Division)
Commonwealth of Massachusetts)
Worcester County) SS:

I, S. P. Schultz, depose and say that I am the Vice President of Yankee Atomic Electric Company, duly authorized to make this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary. I am submitting this affidavit in accordance with the provisions of 10CFR2.790 of the Commission's regulations for withholding this information.

The information for which proprietary treatment is sought is the response to RAI number 8 contained in the proprietary enclosure to Maine Yankee letter MN 96-145, Maine Yankee Atomic Power Company to U. S. Nuclear Regulatory Commission, dated October 18, 1996.

Pursuant to the provisions of Paragraph (b)(4) of Section 2.790 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the referenced document, should be withheld.

1. The material contained in this transmittal was obtained at considerable expense to Yankee Atomic Electric Company and Maine Yankee Atomic Power Company and the release of which would seriously affect our competitive position.

2. The material contained in this transmittal is of the type customarily held in confidence and not customarily disclosed to the public.

3. This information is being transmitted to the Commission in confidence under the provisions of 10CFR2.790 with the understanding that it is to be received in confidence by the Commission.

4. This information is for Commission internal use only and should not be released to persons or organizations outside the Directorate of Regulation and the ACRS without prior approval of Yankee Atomic Electric Company. Should it become necessary to release this information to such persons as part of the review procedure, please contact Yankee Atomic Electric Company.

Further deponent sayeth not.

Sworn to before me this
17th day of October, 1996

Stephen P. Schultz
S. P. Schultz
Vice President

Kathryn Gates
Kathryn Gates Notary Public
My Commission expires 1/24/97

ATTACHMENT 3

Non-Proprietary Responses[1]
to
USNRC RAI on SBLOCA Analyses

[1] Empty brackets indicate that proprietary information has been removed.

1. TOODEE2 Documentation

Please provide the following information for the TOODEE2 heat conduction model used in the SBLOCA analysis for Maine Yankee: the differential equations relating temperature, time, radial position and heat generation rate, and a discussion of mathematical methods used to solve the differential equations. For any simplifications assumed in solving the differential equations, please provide a basis to justify the adequacy of the simplifications. Also, explain how the record of the mathematical methods for the TOODEE2 fuel conduction model meets your QA requirements.

Maine Yankee Response:

TOODEE2 solves the time dependent heat conduction equation in either one or two dimensions. The heat conduction equation is given as Equation 1 (cylindrical coordinates) of the USNRC TOODEE2 Report (NUREG-75/057). This equation is taken from the text book, Conduction of Heat in Solids, H. S. Carslaw and J. C Jaeger, Oxford: Clarendon Press , 1947. The difference equations used to approximate the differential equations are given in Appendix A of NUREG-75/057. Solution of the difference equations is obtained by application of the Peaceman-Rachford method ("The Numerical Solution of Parabolic and Elliptic Differential Equations," Journal of the Society of Industrial Applied Mathematics, 3 March 1955.) The conduction model and its solution are standard text book techniques. [ ] SPC has not altered the basic conduction equations and solution method from the original TOODEE2 code obtained from the USNRC in 1975.

Simplifications are also described in the TOODEE2 NUREG-75/057 report, and include: (1) constant thermal properties over a time step; however, thermal properties can be temperature dependent, (2) constant heat source in any node over a time step; however, the heat source can be space and time dependent, and (3) fluid conditions are assumed constant over a time step. The treatment of the gap and cladding must be as specified in the TOODEE2 report to properly calculate gap and metal-water reaction effects. The USNRC reviewed and approved this TOODEE2 model in conjunction with the original SPC SBLOCA evaluation model (XN-NF-82-49(P)(A) Revision 1, April 1989) and the revised SBLOCA evaluation model (XN-NF-82-49(P)(A) Revision 1, Supplement 1, December 1994).

For the Maine Yankee SBLOCA analysis it was necessary to model annular pellets. Therefore, SPC made minor changes to the TOODEE2 code to model annular pellets. The changes are described in Appendix A to Report EMF-96-043. No changes were made to the basic TOODEE2 conduction solution. Changes made to the TOODEE2 code prior to USNRC approval for the SBLOCA model have been discussed and documented to USNRC: (see letter, Maine Yankee to USNRC, "Transmittal of Information in Support of the Maine Yankee SBLOCA Analysis Review," MN-96-029, March 8, 1996; Letter, Maine Yankee to USNRC, "Transmittal of Viewgraphs: February 15th Meeting with the USNRC on SBLOCA Analysis," MN-96-013, February 15, 1996; and Letter, SPC to USNRC, "Small Break LOCA Code Changes," RAC:96:015, February 7, 1996).

A demonstration that the mathematical models within the TOODEE2 code are conservative and appropriate is provided in the comparison with the LOFT LP-SB-03 benchmark which was included in the USNRC review and approval of XN-NF-82-49(A), Revision 1, Supplement 1, "Exxon Nuclear Company Evaluation Model Revised EXEM PWR Small Break Model," dated December 1994.

With regard to compliance with QA records and requirements, when SPC obtains a code such as TOODEE2 from the USNRC, the code is installed on SPC computers, incorporated into the methodologies as appropriate, and submitted to the USNRC for review. Documentation supplied with the code is referenced to describe the basic features of the as-received code. SPC's QA record begins with the installation of the as-received base code . Any changes made by SPC to the base code are justified and documented with appropriate verification and validation as required by SPC QA procedures. The mathematical methods for the TOODEE2 fuel conduction model are part of the base code obtained from USNRC in 1975.

SPC has established and rigidly follows a QA program that has been reviewed and approved by the USNRC as satisfying the requirements of 10 CFR 50 Appendix B. Part of the QA program addresses the control and use of computer codes. TOODEE2 has been developed and modified in accordance with these QA procedures. Implementation of the SPC QA program for the Maine Yankee SBLOCA analysis has been documented in: "Transmittal of Interim SBLOCA Reviews," MN-96-037, March 1996.

2. TOODEE2 Mathematical Methods

Equation (1) of NUREG-75/057 is a heat conduction equation used in TOODEE2 for rod heatup calculations. In solving this equation, TOODEE2 uses the first order difference approximation (accounting for the first order derivative terms in Taylor expansions) to calculate the temperature distribution in the fuel rod as a function of radial position and time. All terms with second and higher order derivatives in the Taylor expansions were assumed to be small and neglected. The staff is concerned that the terms with the second order derivatives may not be small enough to be neglected in the vicinity of the fuel rod centerline (i.e., (delta T)/R is of order unity near R approaching zero.) In light of this information, the licensee is requested to assess and quantify the effects of truncation errors of the terms with second and higher order derivatives on the calculated PCT for Maine Yankee, and justify the adequacy of the first order difference approximation by showing small truncation errors.

Maine Yankee Response:

The heat conduction equation in cylindrical coordinates (Equation 1 of NUREG-75/057) is solved numerically in the TOODEE2 code. The numerical difference equations used in the TOODEE2 solution are given as Equations A-3 through A-9 in Appendix A of NUREG-75/057. Since delta R can be made as small as desired relative to R except at the centerline, this algorithm can be shown to be convergent and to converge to the original partial differential equation. At the centerline, the problem of reaching the limit is avoided because the heat flux is set to zero and the term is not evaluated. Thus, even though the diffusion term may be difficult to evaluate in the limit as R approaches zero, the term does not have to be and is not evaluated at the centerline.

Any problems associated with truncation are mitigated as the centerline is approached because the volume and the associated energy go to zero as a function of R^2. The solution algorithm was not generated using Taylor series approximations; however, it does employ the standard engineering practice of ignoring higher order effects. These omissions are second order in magnitude and are dealt with in the standard manner of assuring adequate convergence. Nodalization convergence is demonstrated in the following paragraph, and time step convergence is addressed in the response to Question 4.

Further confidence in the TOODEE2 calculation was demonstrated during the review of the Revised EXEM PWR small break model. With the revised methodology, the hot rod heatup is calculated with two different formulations in two different codes, ANF-RELAP and TOODEE2. [ ] The similarity in the calculated cladding temperature transients from both codes was explicitly documented during the USNRC review of the revised SBLOCA model in the April 21, 1994 response to USNRC questions on XN-NF-82-94(A), Revision 1, Supplement 1. Both codes give the same basic temperature results until swelling and rupture causes divergence. This comparison demonstrates the adequacy of the TOODEE2 conduction solution by comparison with an independent conduction calculation using another USNRC approved code.

3. Nodal Schemes

Figures 5-1 and 2 (pages 51 and 52 in the correspondence section) of Siemens Power Corporation (SPC) Topical Report XN-NF-82-49(A), show nodal diagrams for the ANF-RELAP and TOODEE2 codes. The licensee is requested to discuss the nodal schemes used in the Maine Yankee SBLOCA analysis. If the nodal schemes used are different from that shown in Figures 5-1 and 2, the licensee is requested to identify the differences and provide technical bases to justify the adequacy of the nodal schemes used.

Maine Yankee Response:

The nodalizations used for ANF-RELAP and TOODEE2 for the Maine Yankee SBLOCA analysis are very similar to those shown in Figures 5-1 and 5-2 of the methodology Topical Report XN-NF-82-49(A), Supplement 1. Changes relative to the nodalization in the methodology report are described in the following sections. A technical basis is given for each change, justifying why it is acceptable.

Table 3-1 provides a summary of the comparison of the nodalization used in the Maine Yankee ANF-RELAP model with the nodalization shown in the methodology report. Only one change in nodalization was made to the TOODEE2 model relative to the methodology report.

Reactor Vessel Downcomer. The number of nodes in the reactor vessel downcomer was increased [ ] the height and volume of the downcomer are preserved in order for the code to properly model pressure drops and mass inventory in the downcomer.

Reactor Vessel Core. The number of nodes used to model the core in both ANF-RELAP and TOODEE2 was increased over that shown in the methodology report to allow the model to be used for all four of the axial power profiles used in the analysis. The ANF-RELAP model increased the number of core nodes [ ] to be able to cover all of the elevations where peak power nodes occurred[ ]. The SPC SBLOCA methodology allows the use [ ] axial nodes to model the core. The TOODEE2 methodology is required to use 3-inch nodes close to where rod rupture occurs. The number of core nodes in the TOODEE2 model was increased [ ] such that 3-inch nodes covered the elevations where rupture occurs.

Reactor Vessel Core Bypass. This region represents the volume between the core baffle plates and core barrel. The number of nodes in this region was increased [ ] the height and volume of the core bypass region is preserved in order for the core to properly model pressure drops and mass inventory in this region.

Core Exit Volume. In the ANF-RELAP model, the core nodes include [ ] This allows the code to model pressure drops and mass inventory in this region.

Reactor Vessel Upper Head. [ ] This allows the correct modeling of the drainage of liquid from the upper head, through the CEA guide tube shrouds, into the upper plenum.

Pressurizer. During the SBLOCA event, the pressurizer empties rapidly and does not refill. The pressure response of the primary system is not dependent on the details of the pressurizer nodalization. [ ] The total volume and height of the pressurizer is preserved.

Hot Leg Piping. The number of nodes representing the hot leg piping was increased [ ] These nodes were added in order to properly model the elevation change from the hot legs to the steam generator inlet plenum, to properly model the location of the attachment of the pressurizer surge line to the hot leg, [ ] This increased detail does not affect the drainage of liquid from the hot legs and pressurizer back to the reactor vessel after the primary coolant pumps have tripped.

Pump Suction Piping. The number of nodes representing the pump suction piping was increased [ ] to more accurately model the static pressure heads in this piping which leads to loop seal clearing.

Cold Leg Piping. The number of nodes representing the cold leg piping was increased [ ] to properly model the location of the attachment of the ECCS line, to preserve the location of the break, and [ ] This increased detail does not affect the modeling of the drainage of liquid from the cold legs to the reactor vessel and break.

Steam Generator Downcomer. The number of nodes representing the steam generator downcomer was increased [ ] the height and volume of the downcomer are preserved in order for the code to properly model pressure drops and mass inventory in the downcomer.

Table 3-1. Comparison of Maine Yankee ANF-RELAP Model Nodalization with Methodology Document

[ ]

Table 3-1. Comparison of Maine Yankee ANF-RELAP Model Nodalization with Methodology Document (continued)

[ ]

4. Time-Step Sensitivity

Some of the correlations (such as the Baker-Just metal-water reaction correlation) used in ANF-RELAP and TOODEE2 are very sensitive to time-step selection. The metal-water reaction rate is calculated at the beginning of the time-step. This means that during a temperature rise, the metal-water reaction rate is systematically underpredicted. Explain how the convergence of the equations is achieved. Quantify the energy error from this systematic underprediction of the metal-water reaction rate for the Maine Yankee application.

Also, the time-step will affect the accuracy of the solutions to the differential equations used in ANF-RELAP for system response calculations and in TOODEE2 for rod heatup calculations. The licensee is requested to provide a discussion of the method of selection of the time-step used in ANF-RELAP and TOODEE2 for the Maine Yankee SBLOCA analysis. This discussion should include the results of time-step sensitivity calculations to show that for a time-step used in the licensing applications, the mass and energy calculations will obtain convergent solutions, and further changes (either increase or decrease) in the time-step will not significantly change the calculated PCT.

Maine Yankee Response:

The Baker-Just reaction rate correlation has an exponential dependence for which the metal-water reaction rate increases with an increase in absolute temperature. The solution for the Baker-Just equation uses an integral form but assumes isothermal or constant temperature conditions over a time step. When cladding temperatures are increasing, the zirconium-water reaction rate over a time step will be underestimated if the absolute temperature of the cladding changes significantly during the time step, and when cladding temperatures are decreasing (as predicted during most of the SBLOCA transient for Maine Yankee) the zirconium-water reaction rate over a time step will be overestimated if the temperature decreases significantly over a time step. The isothermal assumption is valid when sufficiently small times steps are taken such that the change in reaction rate due to the change in absolute temperature over a time step can be neglected.

The zirconium-water reaction rate as calculated by the Baker-Just correlation is dependent on the absolute temperature level. At high temperatures (above 2200°F) the metal-water reaction heat source will typically be calculated to become the dominant energy source. When this happens, very small time steps would be required to assure that the approximation of assuming an isothermal reaction rate over a time step is valid. At temperature levels of 1600 to 1800°F or lower, the metal-water reaction rate is substantially slower. Under these conditions, the metal-water reaction is not the dominant energy source, and the validity of the metal-water reaction calculation is relatively insensitive to time step size. For example, at the time of the maximum PCT calculated for the Maine Yankee SBLOCA analysis, the metal-water reaction heat on the ruptured PCT node is only about 10% of the total heat source. For non-rupture nodes this factor is decreased by more than a factor of 2.0. The maximum error in the metal-water reaction rate due to assuming isothermal conditions was computed for the maximum PCT conditions calculated for the Maine Yankee SBLOCA based on the absolute temperature at the beginning

of the time step and the temperature rise during the time step. The calculated maximum error is 0.1 to 0.2% of the metal-water reaction heat source. This results in a maximum error in the total heat source of 0.01 to 0.02%. Therefore, for the Maine Yankee SBLOCA analysis, the total metal-water reaction heat is small compared to the dominant decay heat source, and the energy error in computing this small heat source is negligible. The overall effect of the constant temperature approximation on the final PCT is demonstrated by the time step sensitivity calculation reported below in which the time step size was decreased by a factor of 2.0 and PCT increased by only 0.3°F. Therefore, for the Maine Yankee SBLOCA analysis the metal-water reaction approximations are valid and result in a negligible change in PCT.

In addition, during the review of XN-NF-82-49(A), Revision 1, Supplement 1, the USNRC noted the possibility for non-convergence due to the metal-water reaction. As a result, Siemens imposed two additional restrictions (approved by the USNRC) to determine when an additional time step sensitivity study is needed: (1) when PCT is greater than 2050°F and (2) when the temperature rise rate is greater than 0.75°F in a maximum time step of 0.05 seconds. For the Maine Yankee application, the PCT was less than 1800°F and the temperature rise was about 0.20°F in a time step size of 0.1 sec. The Maine Yankee SBLOCA results are well below the restrictions requiring additional time step sensitivity studies.

The time step sizes used in the Maine Yankee SBLOCA analysis were selected based on SPC experience in performing SBLOCA analyses. SBLOCA analyses on other plants have shown relatively small variations in PCT and system behavior when using time step sizes equal to or less than [ ] seconds in ANF-RELAP. However, system behavior has been slightly more repeatable when using time step sizes in the range of [ ] seconds. Therefore, the time step size selected for use in the Maine Yankee SBLOCA calculations was [ ] seconds. This time step size was used throughout the ANF-RELAP transient calculation. Since the SBLOCA SER does not require a time step sensitivity calculation if the PCT is less than 2050 °F, a time step sensitivity calculation was not performed in the original analysis

Time step sensitivity calculations for Maine Yankee have been performed in response to the NRC question to confirm the validity of using a time step size of [ ] seconds in ANF-RELAP. Time step sensitivity calculations were performed for the limiting case documented in EMF-96-043 (0.10 ft^2 break, 73% axial power shape, and minimum crossflow loss coefficient) using time step sizes of [ ] seconds. (The analysis documented in EMF-96-043 used a time step size of [ ] seconds.) Figures 4-1 through 4-5 compare primary system pressure, break flow rate, total primary system mass, reactor vessel mass, and core collapsed liquid level, respectively, for the various time step sizes analyzed. The system pressure, break flow rate, and total system mass are nearly direct overlays. There are only minor differences in reactor vessel mass and collapsed core liquid level due to minor differences in loop seal clearing behavior. The cladding temperature at the PCT location is plotted as a function of time in Figure 4-6 for the cases analyzed.

Since there is no particular trend in PCT with time step size over the range of time step sizes analyzed and the variation in PCT is relatively small, the case with a time step size of [ ] seconds reported in EMF-96-043 is a valid calculation of the PCT for the Maine Yankee plant.

The maximum mass error ratio in the ANF-RELAP calculation is less than 2.5×10^{-4} for all cases analyzed. The mass error ratio is the ratio of the cumulative error in the total mass due to truncation error to the total mass. Therefore, conservation of mass is demonstrated for all cases analyzed. Conservation of energy is demonstrated by the fact that there are no significant differences in the system response over the range of time step sizes analyzed.

Based on previous SPC SBLOCA experience, a time step size of [ ] seconds was used in the base TOODEE2 calculation. Convergence of the TOODEE2 calculation was demonstrated by running the limiting TOODEE2 calculation with a time step size of [ ] seconds. An increase in PCT of only 0.3°F was observed. Thus, the TOODEE2 calculation with a time step size of [ ] seconds is adequately converged.

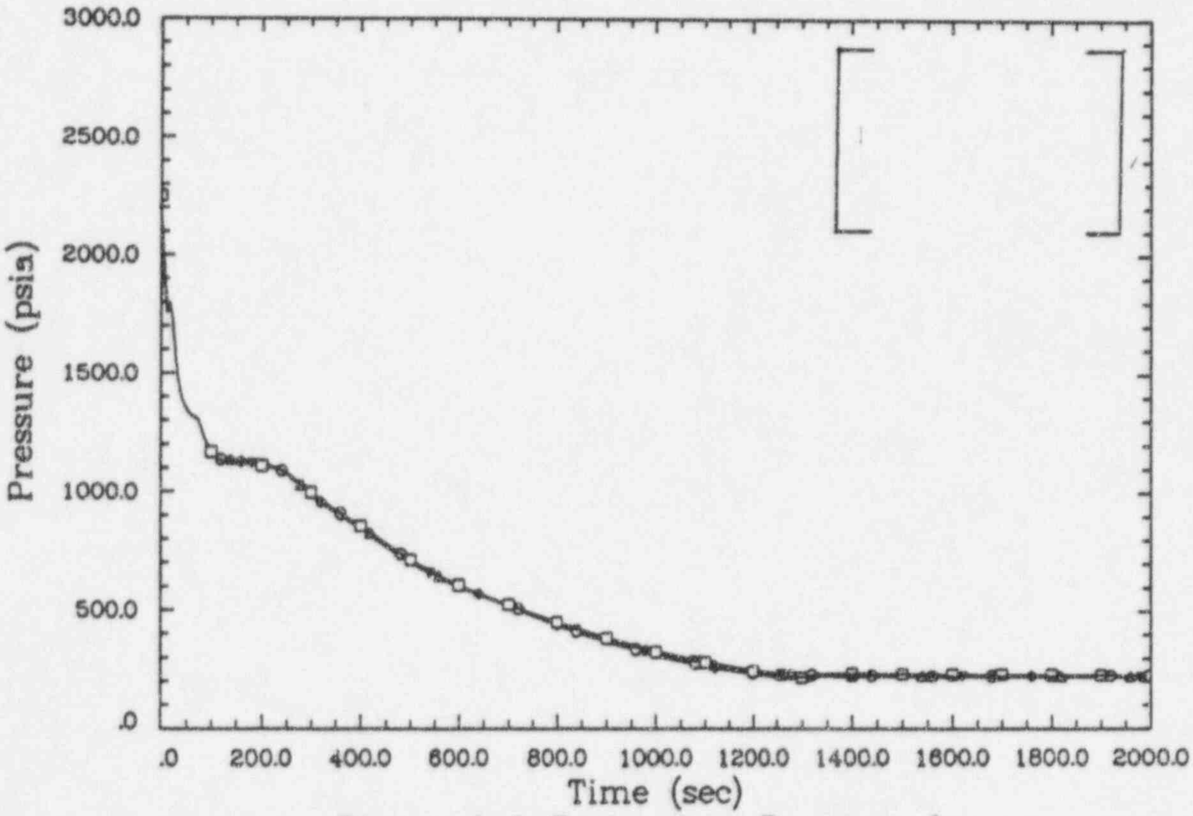

Figure 4-1 Pressurizer Pressure for Time Step Sensitivity

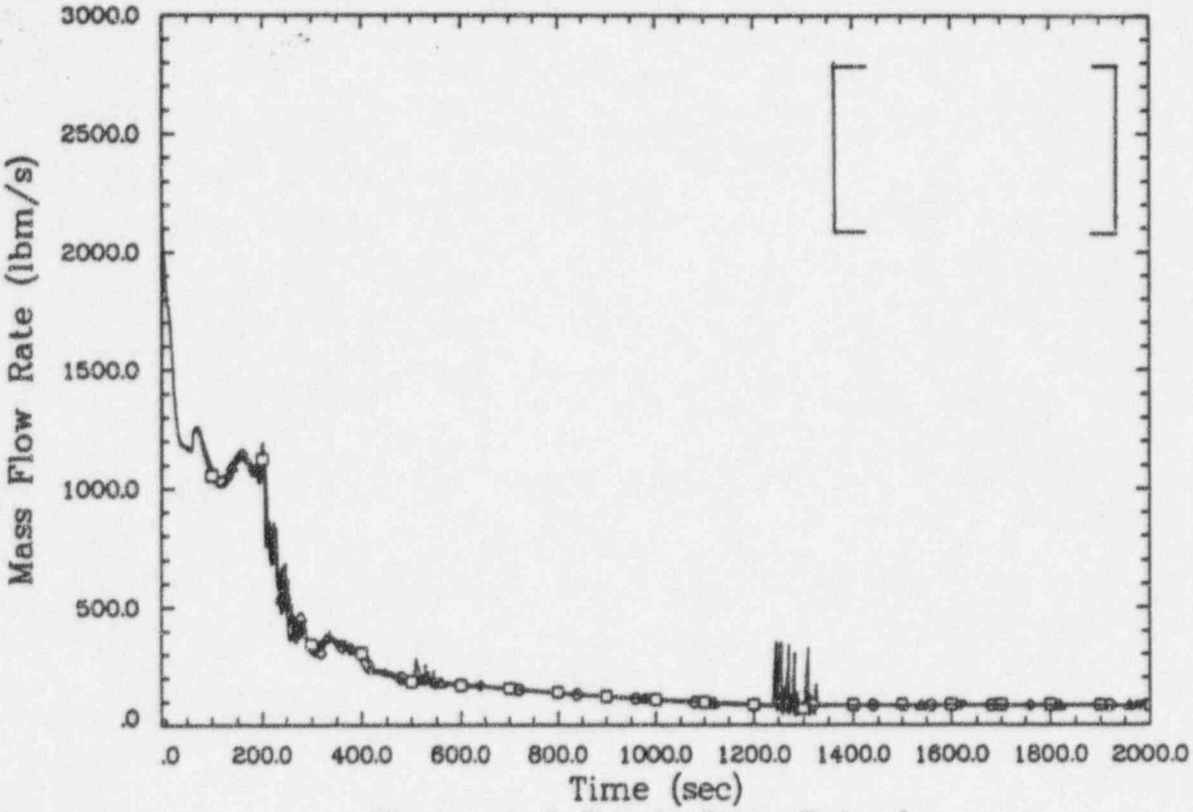

Figure 4-2 Break Flow Rate for Time Step Sensitivity

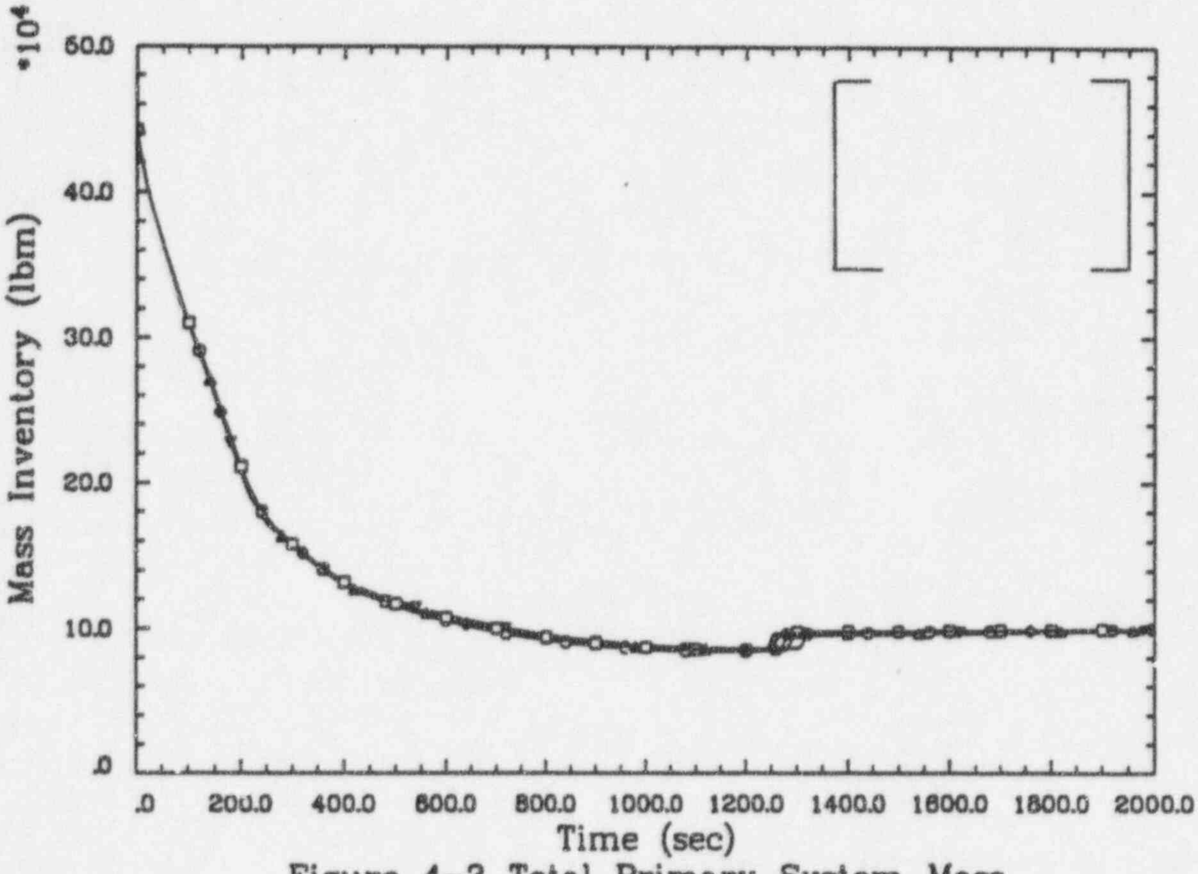

Figure 4-3 Total Primary System Mass Inventory for Time Step Sensitivity

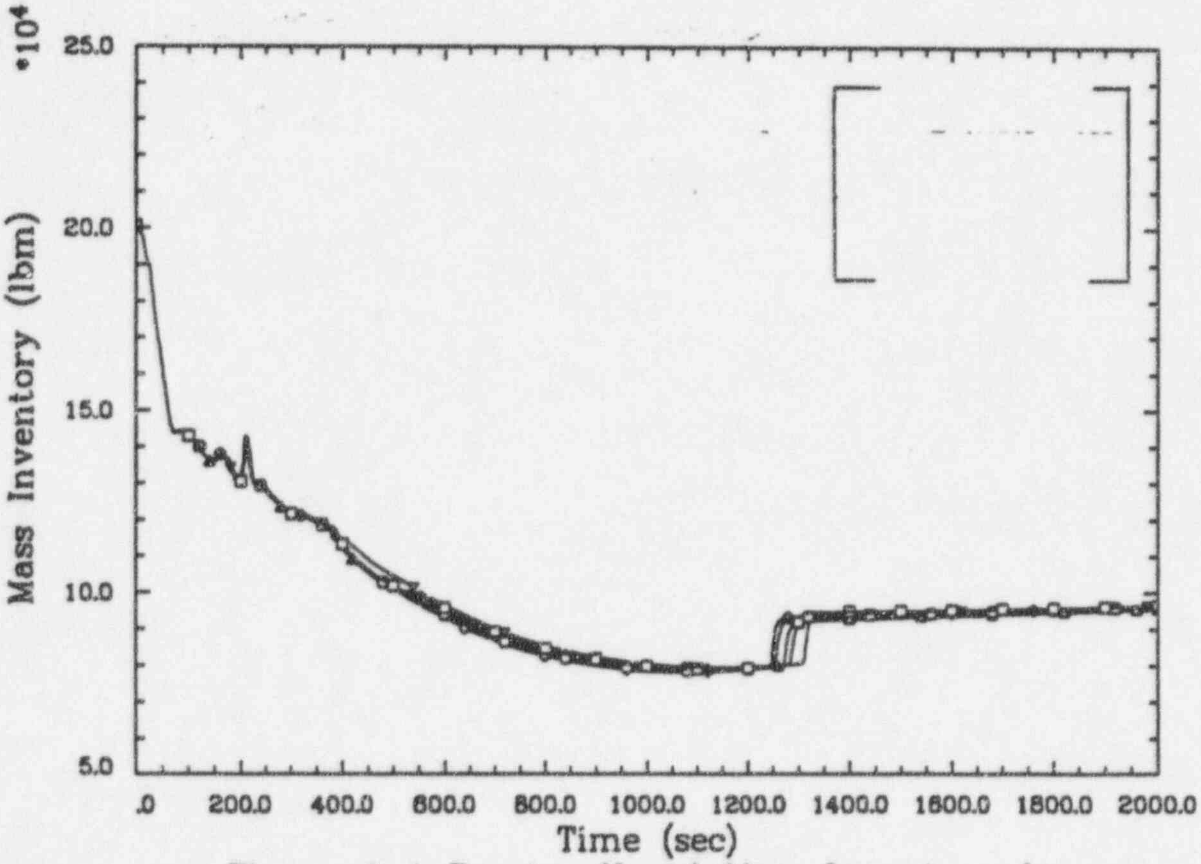

Figure 4-4 Reactor Vessel Mass Inventory for Time Step Sensitivity

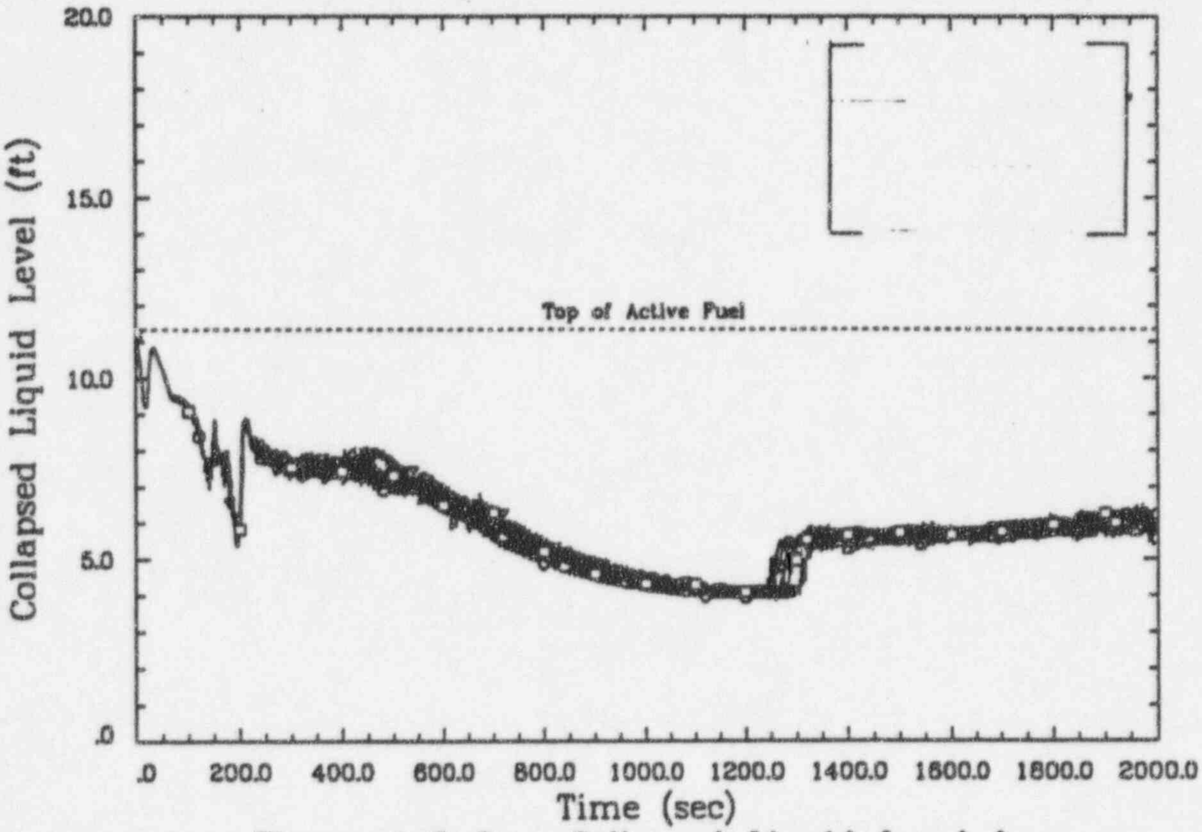

Figure 4-5 Core Collapsed Liquid Level for Time Step Sensitivity

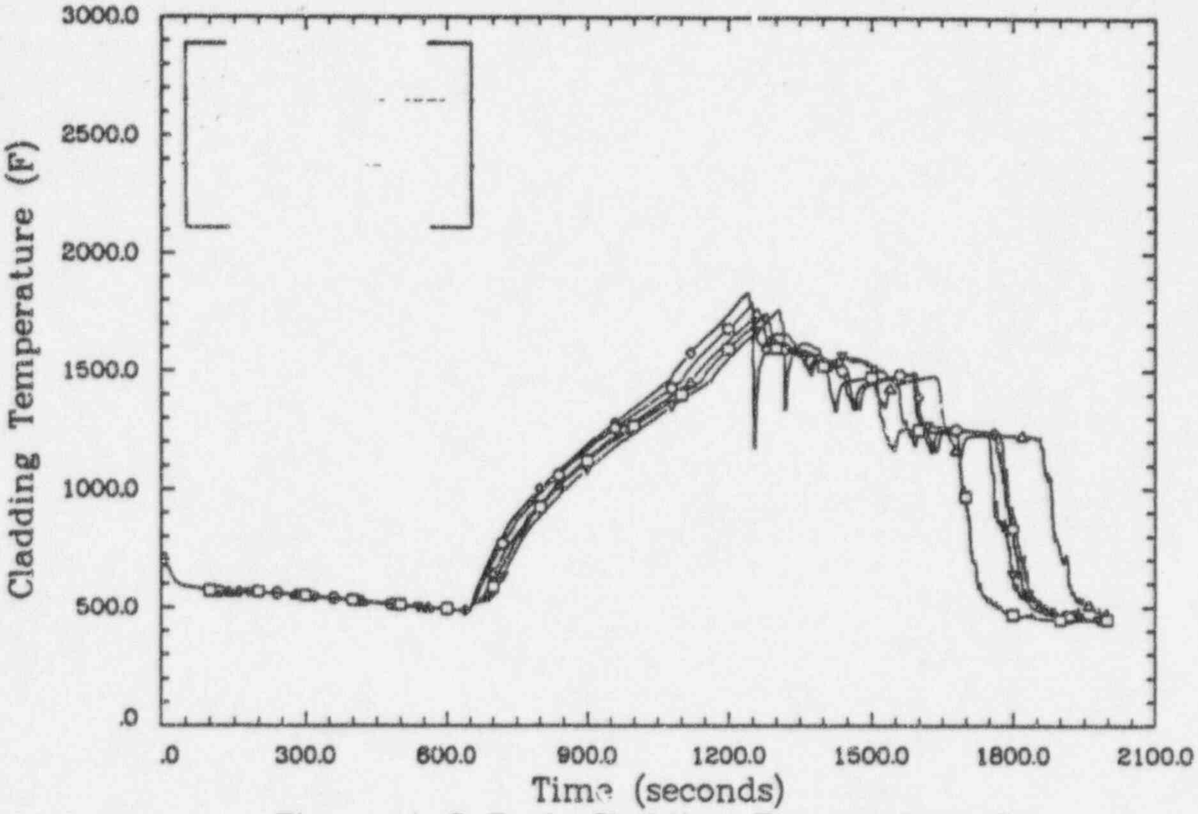

Figure 4-6 Peak Cladding Temperature for Time Step Sensitivity

5. Data Transfer Between ANF-RELAP and TOODEE2

The SPC SBLOCA method involves data transfer between two codes: ANF-RELAP and TOODEE2. [ ]. As shown in Figure 5-2 (page 52 in the correspondence section) of SPC's Topical Report XN-NF-82-49(A), the numbers of the nodes representing the hot pin in ANF-RELAP and TOODEE2 are different. The sizes of time step used in both codes may also be different. Under the conditions of different nodal numbers and time-step sizes, how was the data transfer between the two codes achieved? Describe any measures that were taken to assure that the data transfer process is smooth and adequate.

Maine Yankee Response:

With the revised EXEM/PWR SBLOCA model, substantial data are transferred from the ANF-RELAP results as input to TOODEE2. To assure that the data transfer process is smooth and accurate, this process is computerized and automated. These modifications to transfer the data were made in accordance with Siemens' QA requirements, and the data transfer process was thoroughly checked and verified. This model was then reviewed and approved by USNRC.

[ ].

Matching of TOODEE2 and ANF-RELAP nodalizations is based on the center elevation of the TOODEE2 node. That is, the ANF-RELAP hot assembly boundary conditions calculated to occur at the elevation of the center of the TOODEE2 node are applied over that TOODEE2 node. The user supplied input to TOODEE2 includes the number and heights of the core nodes used in the ANF-RELAP calculation. With these data and the TOODEE2 node input, TOODEE2 calculates the ANF-RELAP core volume adjacent to the axial center elevation of each TOODEE2 node. Fluid conditions for this ANF-RELAP node are applied as boundary conditions on the TOODEE2 node. If the elevation of the center of the TOODEE2 node is at the boundary between two ANF-RELAP nodes, then fluid conditions for the lower ANF-RELAP node are applied. Thus, the axial nodalization used in TOODEE2 need not be consistent with that used for ANF-RELAP.

The output of the TOODEE2 subroutine is a set of parameter-versus-time tables which are used as input by TOODEE2. These parameter-versus-time tables are linearly interpolated to give time values corresponding to the TOODEE2 time step. The number of allowed data points was increased to include every point from the ANF-RELAP plot restart file in the parameter-versus-time tables rather than the limited number of data points used in prior methodologies. As noted, this automated data transfer process was developed in accordance with SPC's QA procedures which require verification and detailed checking to assure the correct transfer of data. The model has been reviewed and approved by the USNRC.

6. Bypass Flow

Bypass flow from the downcomer to the upper plenum is important in determining the system response and loop-seal clearing time for a SBLOCA analysis. Discuss the method that was used to model this bypass flow for Maine Yankee. Specifically, the determination of the flow resistance of this bypass flow path should be discussed, the uncertainties associated with the design bypass flow should be included, and the effects of the uncertainties on the calculated PCT should be quantified for the limiting SBLOCA cases.

Maine Yankee Response:

The bypass flow from the downcomer to the upper plenum is modeled in ANF-RELAP as a [ ] This flow corresponds to a small fraction (0.2%) of the total system design flow and is calculated at hot pressurized system conditions similar to the current Maine Yankee operating conditions. Additionally, as would be standard engineering practice at the time these values were determined, the design bypass flow areas would [ ] the bypass flow.

The as-built values for the bypass flow areas, as based on Maine Yankee QA records, are substantially less than the design values. Correspondingly, the steady state as-built bypass mass flow rate through these areas would also be substantially less than the design value.

An additional case was analyzed to determine the sensitivity of bypass flow rate on PCT. The base analysis for this sensitivity calculation was the limiting case reported in EMF-96-043: 0.10 ft^2 break size, 73% axial profile, and minimum crossflow coefficient. The sensitivity case used a 20% <u>increase</u> in downcomer-upper plenum bypass flow rate. The system response for this sensitivity was practically identical to the limiting case. The sensitivity calculation yielded a PCT of 1795°F, an increase of 14°F from the base calculation.

Based on the as-built measurements, use of the [ ] bypass flow rate in the limiting case analysis, and the sensitivity calculation, it is concluded that the existing limiting case represents a conservative and bounding treatment with respect to bypass flow.

7. Steam Generator Tube Plugging

During a postulated SBLOCA, the heat transfer from the primary side to the secondary side is an important path to remove the decay heat. Because the effects of plugging steam generator (SB) tubes were considered in the SBLOCA analysis, the licensee is requested to describe the assumptions used in the analysis to account for SG tube plugging effects (such as changes in the RCS flow and SG heat transfer area) and discuss the adequacy of the assumptions.

Maine Yankee Response:

In SPC's SBLOCA model, [ ] For the Maine Yankee SBLOCA analysis, 1000 out of a total of 5703 tubes were assumed to be plugged in each steam generator. This is incorporated in the ANF-RELAP model [ ]

During the SBLOCA event, energy removed by the steam generators decreases the amount of energy that must be removed out of the break. It is[ ] the heat transfer from the primary system to the secondary system because this [ ] the energy that must be removed by the break mass flow, which [ ] the mass loss from the primary system. [ ] the heat transfer to the secondary also [ ] the primary depressurization rate, which [ ] the mass flow rate out of the break, [ ] These effects lead to [ ] These effects are most pronounced before the time of loop seal clearing, when the SG tubes contain liquid.

After loop seal clearing, the primary system pressure drops below the secondary system pressure, and heat begins to flow from the secondary system back to the primary system. However, the primary side of the SG tubes is filled with steam. The flow rate of the steam is low, and the heat capacity of steam is also low, resulting in greatly reduced heat transfer between the primary and secondary systems. Therefore, the effect of [ ] after the time of loop seal clearing is outweighed by the effects prior to loop seal clearing described above.

A [ ] the initial primary system liquid inventory. This leads to [ ] throughout the event, which leads both to[ ] and an increased PCT.

The primary system loop flow rate is set to the minimum flow allowed by the Technical Specifications. The primary effect of using this minimum primary system loop flow rate is [ ] All of these effects lead to increased core uncovery and an increased PCT.

8. Supporting Information for FROSSTEY2 Changes

Attachment 4 to J.R. Hebert's letter of March 8, 1996, documents the changes to FROSSTEY2. Provide the technical bases (including test data and code calculational comparisons) to justify the adequacy of changes in gap conductance iteration logic, the helium generation model, and modeling of annular pellets as used in the Maine Yankee analysis.

Maine Yankee Response:

Gap Conductance Iteration Logic Modification

The FROSSTEY-2 code employs a set of nested iteration loops in the calculation of the fuel rod thermal behavior. These iteration loops are described on pages 8 through 10 of YAEC-1249P[1]. The segment gap conductance iteration is known as the "inner" iteration and it was the convergence criteria for this loop which was revised by the modification.

The modification adjusted the gap conductance iteration convergence logic to improve the timestep to timestep convergence. The modification was developed to improve convergence in calculation of gap conductance values. This improvement was first identified during code conversion for a related version of FROSSTEY-2 to the YNSD (Yankee Nuclear Services Department) Distributed Computing (HP workstation) environment. The changes in gap conductance also lead to small changes [ ] in the predicted centerline temperatures. Fuel rods operating with a closed gap are not impacted by this modification.

Within the inner iteration, FROSSTEY-2 calculates the axial segment density based on the initial fuel density and present fuel dimensions. The current fuel dimensions include the impact of [ ] The addition of these new criteria results in improved convergence for gap conductance values.

Changes to the gap conductance iteration logic have the potential to impact the code benchmark predictions which can potentially impact the code uncertainty. Therefore, the code was reassessed against data from the Halden test rod [ ] This case was chosen because [ ] operated at power levels which are similar to those analyzed in LOCA analyses. The [ ] demonstrated that the code benckmark cases are not impacted by this modification [ ] The results of the [ ] run are identical before and after implementation of the modification.

Other non-LOCA analyses which are performed at lower LHGR have also been evaluated and improvements in predicted response was demonstrated in these cases as well. Figure 8-2 and Figure 8-3 demonstrate the change in centerline temperature.

Helium Generation Model Modification

This modification was required to support Integral Fuel Burnable Absorber (IFBA) fuel rod coating. The inclusion of IFBA in the newest Maine Yankee fuel design resulted in the need to provide a time varying helium source. The FROSSTEY-2 code already included a constant

helium inventory. The FROSSTEY-2 code evaluates the gap gas conductivity as a function of the gas component quantities in the gap. Previous to this update, the amount of helium was determined at the start of the run and remained constant. The update changes the helium fill gas quantity by augmenting it with the helium released from the IFBA coating as the B^{10} undergoes an (n,α) reaction.

The benchmarking of the FROSSTEY-2 IFBA model was performed in two steps. The first step verified the B^{10} reaction calculation and the second step verified the change in helium inventory.

The first portion of the IFBA model benchmarking employed the CASMO-3 code. CASMO-3 is employed to generate cross-sections for use in SIMULATE-3 and calculates the B^{10} concentration as a function of exposure as part of this process. [2,3] CASMO has been reviewed and accepted by the NRC[4]. This portion of the benchmarking consisted of a comparison of the unreacted B^{10} concentration prediction of the FROSSTEY-2 IFBA model and the CASMO-3. Figure 8-1 shows a comparison of the unreacted B^{10} concentration from FROSSTEY-2 and CASMO-3 predictions based on results obtained from YAEC documentation records. The FROSSTEY-2 IFBA model's B^{10} concentration agrees closely with the CASMO-3 predictions.

The second portion of the benchmarking compared the FROSSTEY-2 helium inventory difference between beginning of life (BOL) and an exposure later in life to a manual calculation of the additional helium released to the gap as a result of the B^{10} reaction. The rod initially contained [ ] gram-moles of helium in the fill gas. After a period of operation to a rod average exposure of [ ] GWD/MTU, the IFBA B^{10} depletion was essentially complete and the helium inventory was determined to be [ ] gram-moles. The additional [ ] gram-moles is the amount of helium that would be expected in the gap from reacting the B^{10} in the IFBA coating. Therefore, the modification is correctly calculating the IFBA helium generation and release.

<u>Modeling of Annular Pellets Modifications</u>

FROSSTEY-2 has always had the capability to model annular pellets. This capability was exercised in the FROSSTEY-2 assessment against the IFA experimental rods which contained embedded thermocouples. The benchmarking of FROSSTEY-2 against test data was reviewed by the USNRC in the FROSSTEY-2 review process. [ ] This allowed more accurate modeling of the Maine Yankee fuel for Cycle 15 which contains annular pellets only in the low power axial blanket regions of the fuel rods.

The FROSSTEY-2 annular pellet modifications involved changes to the FROSSTEY-2 internal data structures to track information on an axial segment basis. FROSSTEY-2 physical models were not changed as a result of this modification. The modification was a benchmarking against a portion of the Halden test rods employed in the original benchmarking of the FROSSTEY-2 code. The benchmarking employed the following test rods:

[ ]

Figure 8-4 through Figure 8-7 show a comparison of the predicted centerline temperature for the four cases with both code versions. (SCL FROSSTEY-2 refers to the code version without the annular pellet modifications.) [ ] showed a negligible change of approximately [ ] ^{0}F. [ ] showed a maximum decrease of [ ] ^{0}F which occurs between [ ] and [ ] GWD/MTU. The temperature prediction difference decrease after this interval. The [ ] test rods showed a maximum temperature increase of [ ] and [ ] ^{0}F. respectively. The temperature increase occurs after a power increase at approximately [ ] GWD/MTU. The maximum temperature changes for these rods all occurred in FROSSTEY-2 uncertainty exposure intervals which are not limiting.

The differences in predicted temperature response between the two code versions have been reviewed and can be explained. The input to the SCL version incorrectly assigned an annulus diameter to all pellets including axial segments which contained solid pellets. Therefore, the SCL version essentially ignored the fuel within this region. The modified version did account for this region which has the highest temperature in each axial segment. The fuel volume in this region could experience additional gas release which degrades the gap conductivity. This results in the SCL version underpredicting fuel temperatures for IFA experimental rods. The underprediction of the fuel temperature would result in a larger calculated code penalty. Therefore, the actual FROSSTEY-2 code penalty has been overestimated.

In addition to the higher gas release, a second difference between the two code versions is the calculation of the internal rod free volume. The modified version of FROSSTEY-2 correctly models annular void volume. The original FROSSTEY-2 benchmark runs did not have any annular void volume since the annular void length input was specified as 0.0. This results in a lower calculated initial fill gas inventory for the SCL case. The combination of different gas release and gas volume produce changes in the fuel pellet temperature. The impact on any given rod varies based on the relative importance of the two competing effects.

The results for case 1 show a very small difference in temperature between the runs. This rod was irradiated to a low exposure at a relatively low LHGR. The impact of the solid segment temperature increase was not detected. The additional helium slightly improved the thermal conductance of the gap gas mixture since the additional helium required more fission gas to dilute it. The rod remained in an open gap condition through the run. Therefore, the rod temperature predictions for the modified version was slightly lower than the SCL version.

The second case experienced the largest temperature underprediction compared to the SCL version. The temperature decrease can be explained by the additional helium present in the relatively larger annular volume of this rod. At the time when the maximum difference occurs, the modified version predicted a larger helium inventory. The additional helium would not be present in the actual experimental rod since the thermocouple will be occupying the annular volume. Therefore, the rod will contain less helium allowing faster fill gas dilution and reduce the underprediction. The difference diminished with time as the fission gas release continued to degrade the gap gas conductivity with the fuel in soft contact.

The third case showed a relatively modest increase in predicted temperatures. This trend is unlike the Case 2 rod because the [ ] has a longer fuel stack length with the annular void being

The third case showed a relatively modest increase in predicted temperatures. This trend is unlike the Case 2 rod because the [ ] has a longer fuel stack length with the annular void being a smaller fraction of the stack volume. Here the additional gas release exhibited by the modified code version from the solid segments becomes more important. This additional release compensates for the additional helium present in the rod.

The remaining rod, case 4, shows the largest temperature overprediction. As with the previous rod, the solid pellets are operating at a much higher temperature and have a high gas release. At the time of the maximum temperature difference the rod average gas release is a factor of three higher. This leads to degradation of the gap gas conductivity and subsequent temperature increase at the thermocouple location. This rod also has a smaller relative annular void volume compared to the second rod.

In summary, three modifications have been made to FROSSTEY-2 since the USNRC issued their SER.[5] The modifications were performed in accordance with YAEC QA requirements. These modifications have been validated against either test data or other USNRC accepted methods. The validations show that the modifications allow the code tc function as expected and that the code predictions are consistent and explainable. The potential impact of the modifications on the previously determined FROSSTEY-2 code uncertainty was evaluated and the modifications tends to reduce the code uncertainty. However, the SBLOCA application was based on the larger code uncertainty associated with the original code version. This is conservative.

References

1. S P. Schultz and K E. St.John, "Methods for the Analysis of Oxide Fuel Rod Steady-State Thermal Effects (FROSSTEY) Code/Model Description Manual," YAEC-1249P, April 1981.
2. A. S. DiGiovine, et al., "CASMO-3G Validation," YAEC- 1363, April 1988.
3. A. S. DiGiovine, et al., "SIMULATE Validation and Verification," YAEC-1659, September 1988.
4. Letter, A. C. Thadani (USNRC) to G. Papanic, Jr. (YAEC), "Acceptance for Referencing of Topical Report. 'CASMO-3G Validation'," dated March 21, 1990.
5. Letter, P. Sears (USNRC) to L. A. Tremblay (VYNPC), "Vermont Yankee Nuclear Power Station, Safety Evaluation of FROSSTEY-2 Computer Code (TAC No. M68216)," September 24, 1992.

[ ]

Figure 8-1 Comparison of B^{10} Concentrations

Figure 8-2 Centerline Temperature Prior to Converge Modification

Figure 8-3 Centerline Temperature Subsequent to Converge Modification

Figure 8-4 [ ] Temperature Comparison (Case 1)

Figure 8-5 [ ] Temperature Comparison (Case 2)

Figure 8-6 [ ] Temperature Comparison (Case 3)

[ ]

Figure 8-7 [ ] Temperature Comparison (Case 4)

9. Break-Size Spectrum for SBLOCA

Tables 4.2 and 4.3 of your April 25, 1996, ANF-RELAP submittal show the results of the SBLOCA analysis for break sizes of 0.05, 0.10, 0.15, 0.20, 0.25 and 0.61 ft^2. The staff notes that the analysis for the 0.05^2 break predicted no heatup and thus showed a low PCT. The analysis for the next break size is the 0.10 ft^2 break, which results in the highest calculated PCT and is therefore identified as the limiting break size. Please analyze at least one more break size between 0.05 and 0.10 ft^2 that results in core heatup to verify that no break size in the stated range will be more limiting than the 0.1 ft^2 break.

The staff also notes that the calculated PCTs decrease as the break sizes increase from 0.10 to 0.25 ft^2 and then increase as the break sizes increase from 0.25 to 0.61 ft^2. Furthermore, the previous analysis using RELAP5YA failed to predict PCTs for break sizes larger than 0.35 ft^2. To confirm that the code will calculate reliable results without oscillations in the predicted PCTs and no limiting break size will occur between 0.35 and 0.61 ft^2, the licensee is requested to analyze at least two break sizes (for example, 0.35 and 0.50 ft^2) in the range and submit the results for review.

Maine Yankee Response:

The SBLOCA analysis for Maine Yankee reported in EMF-96-043 indicated no cladding heatup for the 0.05 ft^2 break and the limiting PCT for the 0.10 ft break. The report stated that "The limiting break size is characterized by an equilibration between the break flow rate and HPSI flow rate, with a slowly decreasing system pressure to the SIT actuation setpoint, maximizing the time to reach the SIT pressure. This equilibration is demonstrated for the 0.10 ft^2 break size with stagnation of the core collapsed liquid level from 1200 seconds until the initiation of SIT flow, as shown in Figure 4.8. Thus, the 0.10 ft^2 break case is the limiting case for the Maine Yankee SBLOCA analysis."

The 0.10 ft^2 break was confirmed to be the limiting break by analyzing two other break sizes between 0.05 ft^2 and 0.10 ft^2. First, a calculation was performed for a break size of 0.075 ft^2. No heatup was observed because the core level was recovered by HPSI flow without significant core uncovery. An additional case was analyzed with a break size of 0.09 ft^2. This case was analyzed with an axial peaked at 73% of core height and a nominal crossflow resistance, similar to the other base break spectrum calculations. This case was characterized by a slowly decreasing system pressure and a fairly stagnant core liquid level, as shown in Figures 9-1 and 9-2, respectively, similar to the 0.10 ft^2 break case. The core level for the 0.09 ft^2 break recovers with HPSI flow alone, without flow from the SITs. However, the core level for the 0.10 ft^2 break case reported in EMF-96-043 does not quite recover on HPSI flow alone, but recovers on a small amount of SIT flow. These two cases bound the system behavior for the limiting break size. The PCT for the 0.09 ft^2 break case is 1449°F, which is less than the PCT for the 0.10 ft^2 break size. Thus, the 0.10 ft^2 break is clearly representative of the limiting break size.

Additional calculations were performed at break sizes of 0.35 ft^2 and 0.5 ft^2 to assure that there is no limiting break size between the previously analyzed break sizes of 0.25 ft^2 and 0.61 ft^2. The PCTs calculated for break sizes of 0.35 ft^2 and 0.5 ft^2 were 1148°F and 1291°F, respectively. Figure 9-3 shows a plot of PCT versus break size for all of the break spectrum calculations. It can be seen that the trend of PCT versus break size for the 0.35 ft^2 and 0.5 ft^2 break sizes is as expected.

The 0.10 ft^2 break remains the limiting break size for the SBLOCA.

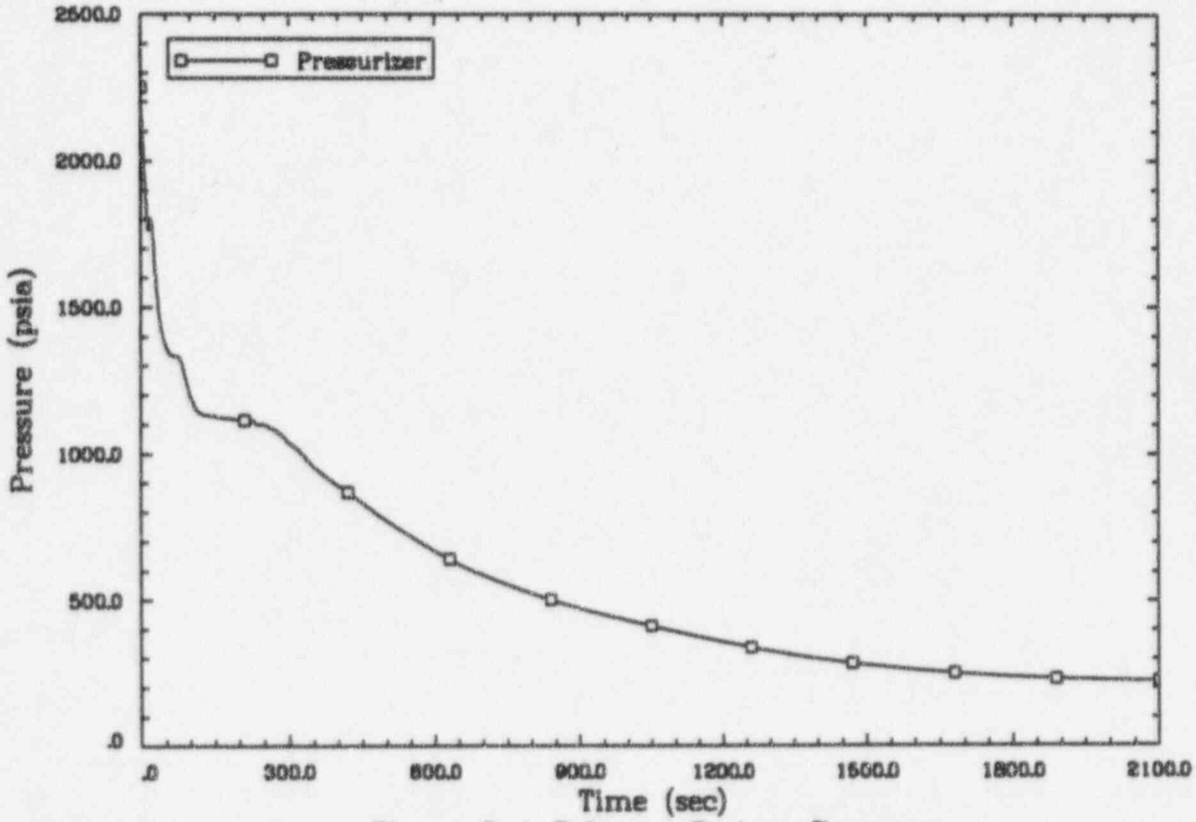

Figure 9-1 Primary System Pressure for 0.09 sq. ft. Break

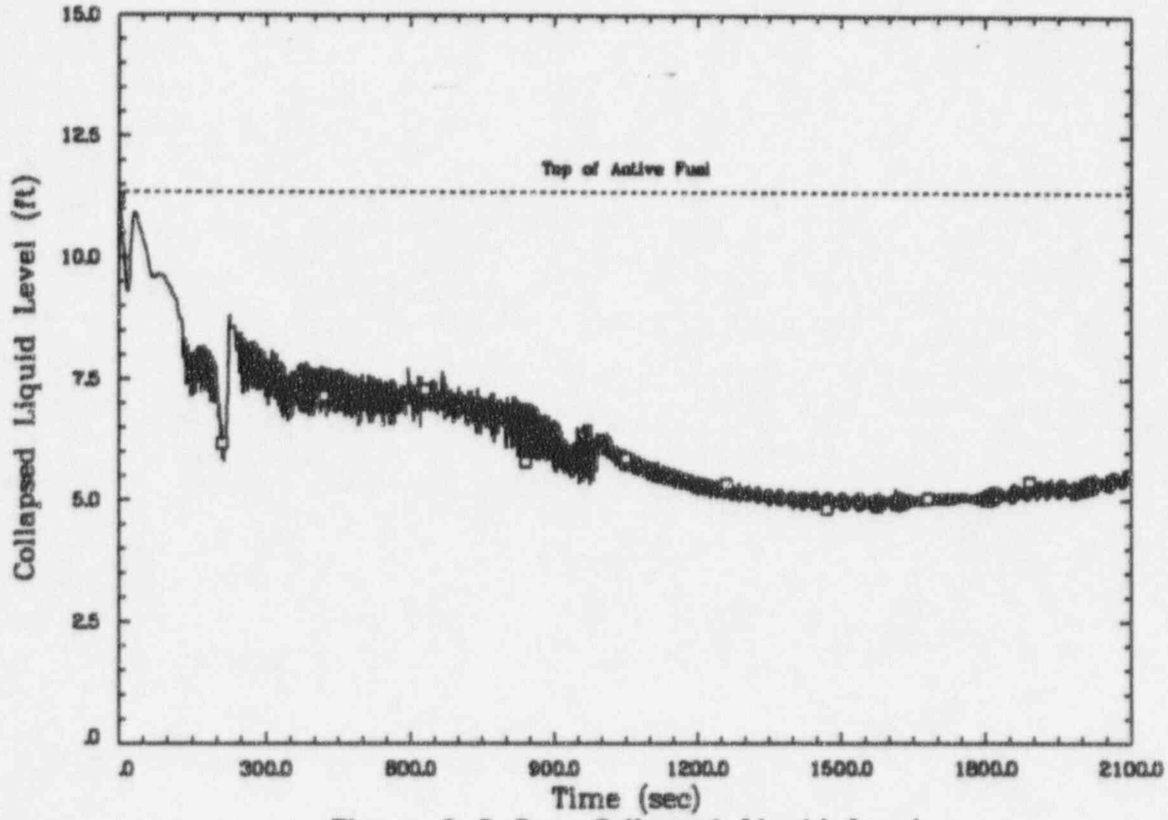

Figure 9-2 Core Collapsed Liquid Level
for 0.09 sq. ft. Break

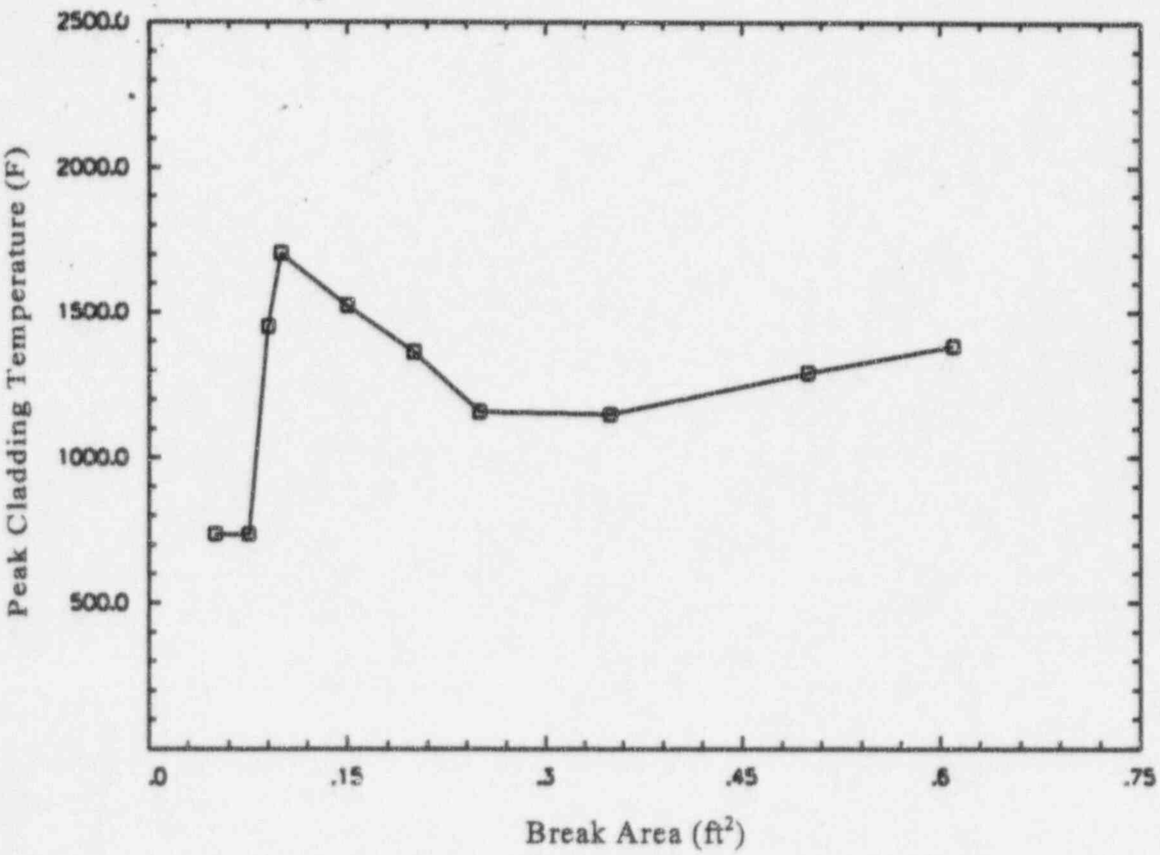

Figure 9-3 Peak Cladding Temperature Versus Break Size

10. Break-Size Spectrum for LBLOCA

Attachment 2 of your April 25, 1996, submittal shows the results of LBLOCA analyses for breaks from the discharge cold-leg guillotine break to the break of 1.22 ft^2. To complete the full break spectrum of the LOCA analysis, the licensee is requested to analyze at least two breaks (for example, 1.0 and 0.61 ft^2) between 1.22 and 0.61 ft^2 to show that no limiting large break will occur in this range.

Maine Yankee Response:

Maine Yankee has performed an additional LBLOCA analysis to supplement the LBLOCA results provided to the USNRC in the April 25, 1996 submittal (Maine Yankee letter to the USNRC, MN-96-056). These calculations were performed assuming a reactor coolant system piping break equivalent to 10% (0.61 square feet) of the cold leg piping flow area. This break size corresponds to the largest assumed break in the Siemens SBLOCA analysis of Maine Yankee, as documented in the report EMF-96-043 and as previously submitted to the USNRC with the LBLOCA results.

The LBLOCA analysis at 10% of the break area was performed with the approved Yankee Atomic Electric Company WREM-based PWR ECCS Evaluation Model, as referenced in the Maine Yankee Technical Specification 5.14. This methodology incorporates the limiting power shape (73%) that bounds the plant operating LOCA limits. The LBLOCA break spectrum analyses performed since Cycle 13 have consistently shown that the 73% axial power peak shape results in the highest peak cladding temperatures.

The results of this analysis, along with the Cycle 15 LBLOCA break spectrum and largest break SBLOCA analysis, are provided below:

Maine Yankee LOCA Spectrum (Break Sizes above 0.61 ft^2)				
No.	Break Size (% Cold Leg Area)	Break Size (Square Feet)	Peak Clad Temperature (F)	Notes
1	200	12.24	2126	
2	160	9.79	2126	
3	120	7.34	2154	
4	80	4.90	1904	
5	20	1.22	1498	
6	10	0.61	1366	
7	10	0.61	1402	SBLOCA calculation

In examining the above results, it should be noted that the LBLOCA and SBLOCA are calculated with different USNRC approved methodologies. Despite this difference, review of the LBLOCA and SBLOCA cases at a break size of 0.61 square feet indicate that the phenomena that contribute to the heatup and then core recovery and quench are predicted to be very similar. The peak clad temperature in either case remains approximately 800 F below the 10 CFR 50.46 Appendix K limit.

Based on the examination of the behavior of the LBLOCA calculation at the 10% cold leg flow area, the closeness of the predicted peak clad temperatures between this case and the corresponding SBLOCA case, the substantial margin to the regulatory limit, and the results from the remainder of the LBLOCA analyses, Maine Yankee has determined that the limiting LBLOCA has been analyzed and that additional calculations between the 10% and 20% break sizes are not warranted.

11. Condensation at SIT Injection Location

Previous analyses using RELAP5YA did not calculate PCTs reliably at the initiation of flow from the safety injection tank. The licensee has stated that the lack of adequate condensation models in RELAP5YA caused the code uncertainties. Discuss the condensation models used in ANF-RELAP to account for condensation at the SIT location, and describe the results of a comparison with test data and justify the adequacy of the condensation models.

Maine Yankee Response:

In the Topical Report Evaluation, "Safety Evaluation by the Office of Nucleár Reactor Regulation ANF-RELAP for Use in PWR Small Break LOCA Analysis", July 12, 1988, the issues of condensation heat transfer and accumulator behavior are particularly addressed and the models were found to be acceptable. The details are in XN-NF-82-49 (P)(A), Revision 1, Exxon Nuclear Company Evaluation Model EXEM PWR Small Break Model. Further explanations of this subject are provided below.

Condensation models of ANF-RELAP are the same as those of RELAP5/MOD2, described in the INEL RELAP5/MOD2 code manuals: RELAP5/MOD2 Models and Correlations, NUREG/CR-5194, EGG-2531, and RELAP5/MOD2 Code Manual Volume 1: Code Structure, Systems Models, and Solution Methods, NUREG/CR-4312, Rev. 1. The phenomena relevant to ECC water injection, i.e., mixing of steam and subcooled water, were assessed with two sets of test data: Bankoff Cocurrent Flow Condensation Problem and Aoki Steam-Water Mixing Problem. The calculated results agreed well with the test data and were reported in RELAP5/MOD2 Code Manual Volume 3: Developmental Assessment Problems, EGG-TFM 7952. In addition, RELAP5/MOD2 had been used extensively for SBLOCA analyses and produced acceptable results. Some references (NUREG/CR-4384 and NUREG/CR 4945) are cited in the Topical Report Evaluation mentioned above.

Included in the USNRC approved Siemens SBLOCA Methodology report, XN-NF-82-49 (P)(A), is an assessment of LOFT L3-1 SBLOCA Test. In this 2000 sec SBLOCA calculation, the accumulator injection is initiated at 655.7 sec. The calculated system pressure, hot leg pressure and cold leg pressure all agree well with the data after the accumulator injection. No significant flow or core temperature oscillations were observed in the results due to the initiation of cold accumulator water injection. This calculation provides additional verification that the ANF-RELAP condensation models are acceptable for handling the accumulator injection.

12. Differences in the EM and Best-Estimate Results

The staff notes that the calculated PCTs for II.K.3.5 analyses (Figures 4.12, 13 18, 19, 20, 25, 36, and 37) show a smooth trend after initiation of the SIT for all the EM SBLOCA calculations. However, the best estimate calculations (Figures 6.11 and 14) for the breaks of 0.45 and 0.61 ft^2 show some oscillations in the prediction of cladding temperature after the PCTs occur. Discuss the causes of the oscillations in the calculated BE-PCTs and justify that the calculated results are adequate.

Maine Yankee Response:

The comparison of PCT results listed includes both the differences due to the EM and best estimate calculations and differences in response due to different break sizes. When results from similar break sizes are compared, it can be seen that there is not a significant difference in the quench phenomena between the EM and best estimate calculations. Figures 4.12, 13, 18, 19, 24 and 25 give the hot rod temperature responses for the 0.1 ft^2, 0.15 ft^2, and 0.20 ft^2 break sizes from the break spectrum EM calculations. When these responses are compared to Figures 6.5, and 6.8, which are the responses for the 0.15 ft^2, 0.25 ft^2 break sizes from the best estimate pump trip delay calculations, both sets of responses show a smooth, uninterrupted decrease in cladding temperatures after the time of PCT. This smooth response occurs because the break cannot quickly remove the large amounts of steam that are generated when the core begins to quench. Therefore, the primary system pressure rises smoothly, and the liquid level in the core increases smoothly as the liquid from the SITs fills the core. This results in smoothly increasing steam flow rates in the top of the core, which gives steadily decreasing cladding temperatures.

Figures 4.36 and 37 show the hot rod temperature response for the 0.61 ft^2 break spectrum EM calculation. Figures 6.11 and 14 give the responses for the 0.45 ft^2 and 0.61 ft^2 break sizes from the best estimate pump trip delay calculations. Both of these sets of figures show a somewhat irregular cladding temperature response after the time that the sustained cladding temperature rise is mitigated by the introduction of SIT flow. This irregular response is caused by the interaction of the larger break with the system response. When the core begins to quench, large amounts of steam are generated. This steam generation begins to increase the primary system pressure. However, in this case the break is large enough to quickly remove the steam, bringing the primary system pressure back down. The changing system pressure and steam generation rate also cause the liquid level in the core to vary, which in turn changes the steam generation rate. The dynamics of the interaction of these parameters causes variations in steam flow rate and temperature up the hot channel, which directly affect the cladding temperature response. Therefore, the irregular response after the time that the cladding temperature rise is mitigated by the introduction of SIT flow is caused by the system response characteristic of larger break sizes, and is not caused by differences in EM and best estimate calculations.

These variations in cladding temperature response do not significantly affect the magnitude of PCT since they occur after the time that the sustained cladding temperature rise is mitigated by the introduction of SIT flow. The introduction of SIT injection immediately increases the steam

flow rates, which prevents any significant increase in the hot spot cladding temperature. The details of the core quench may differ due to the break size effects, but the calculated PCTs remain valid.

13. Crossflow Resistance (K Values) Sensitivity

[ ] The maximum and minimum flow resistances were assumed to bound the test data measured for flow crossing smooth tube banks. During the discussions of April 8, 1996, in the Siemens Richland, Washington, offices, the staff was informed that the flow resistance of the spacing grids in the fuel bundles was not considered and that the flow friction factors in the steam, two-phase, and water regions along the core's axial locations were assumed to be the same. The flow resistance of the fuel spacing grids is significant when compared to that of fuel rods, and the friction factors are different in the single and two-phase flow regions. With the results of the sensitivity study (Tables 5.3 and 4) showing that there is no consistent trend in changes of calculated PCTs by varying the flow resistances, the licensee is requested to discuss the adequacy of the sensitivity study of flow resistance using assumptions that neglect the effects of spacing grids and two-phase flow for Maine Yankee.

Maine Yankee Response:

Siemens' USNRC approved SBLOCA methodology requires specific crossflow modeling and crossflow resistance sensitivity studies (XN-NF-82-49(P)(A) Revision 1, Supplement 1). The crossflow modeling and crossflow sensitivity calculations performed for Maine Yankee are consistent with the requirements of the approved methodology and were performed for three axial profiles. [ ] Using the Siemens SBLOCA methodology, effects of spacer flow resistance are considered in the input flow resistance for the axial flow junctions, and two-phase effects on the axial flow friction factors are also calculated. Therefore, spacer and two-phase effects are not neglected in the dominant axial flow direction.

[ ] This range more than bounds the range of data shown in the text book reference. The USNRC in their review of the Siemens SBLOCA methodology recognized and accepted this approach.

With the Siemens model, the calculation results show a sharply defined mixture level with single phase steam above the level. Below the mixture level, large boiling heat transfer coefficients are calculated, and there is no heatup. Crossflow occurs below the mixture level which maintains a nearly flat level across the core. The crossflow below the mixture level is governed by small density gradients and is insensitive to the transverse flow resistance input. This behavior is demonstrated for all of the crossflow resistance cases, and as covered by the USNRC during the review of the methodology, is consistent with the SBLOCA experimental results showing core uncovery. Therefore, the analysis is not sensitive to transverse flow resistance below the mixture level.

Above the mixture level, the results show single phase steam flowing predominantly in the axial direction. There is little transverse crossflow of steam, and the transverse steam flow that is calculated varies consistently with the crossflow resistance input.

Changes in crossflow resistances also cause small variations in the calculated system event times such as loop seal clearing time, time of beginning of core heatup, and quench time. These changes in the calculated event times account for most of the variability in the PCT seen in the crossflow resistance analyses.

14. Oscillations in the Calculated Core Collapsed Liquid Level

Significant magnitudes of oscillations were observed in the calculated core collapsed liquid level for all the SBLOCA cases analyzed. Please identify the causes of the oscillations, assess their effect on the calculated PCTs, and discuss the adequacy of the calculated core collapsed liquid level.

Maine Yankee Response:

[ ]. Core collapsed liquid level is an ANF-RELAP output parameter which is useful in understanding the SBLOCA behavior; however, this parameter is not used directly in the TOODEE2 heatup calculation and does not affect final PCT results.

15. EM SBLOCA Analyses Addressing TMI Item II.K.3.5

In Section 6.1 of its April 25, 1996, submittal, the licensee used the limiting SBLOCA case to address the adequacy of the two-minute reactor pump trip delay time to satisfy the requirements of TMI Item II.K.3.5. The staff considers the licensee's analysis to be qualitatively reasonable. To quantify the RCP trip delay time effect on the calculated PCTs, the licensee is requested to perform analyses for two cases: (1) the limiting SBLOCA with an RCP trip delay time of one minute, and (2) the limiting SBLOCA with an RCP trip delay of 2 minutes. In each case show compliance with the requirements of 10 CFR 50.46.

Maine Yankee Response:

A qualitative argument was made in the original analysis (EMF-96-043) as to why RCPs tripped at scram bounded up to a 2 minute RCP trip delay time. The basic argument was that more primary inventory would be lost out the break prior to loop seal clearing if the RCPs were tripped at scram. This is due to the fact that the coolant density at the break would be greater with RCPs tripped at scram, leading to a higher break flow rate. This would result in an eventual greater core uncovery and higher PCT.

Two additional cases were analyzed to verify the above argument. The limiting case described in EMF-96-043 (0.10 ft^2 break, 73% axial power shape, minimum crossflow resistance) was reanalyzed with RCP trip delay times of 1 minute and 2 minutes. Figures 15-1 and 15-2 show comparisons of integrated break flow rate and core collapsed liquid level for the three cases, respectively. These figures verify that when the RCPs are tripped at scram, the break flow rate is higher prior to loop seal clearing and the eventual core collapsed liquid level is lower. The PCTs for the 1 minute and 2 minute RCP trip delay time cases are 1740°F and 1671°F, respectively, as compared to a PCT of 1781°F for the case with RCPs tripped at scram.

Thus, RCPs tripped at scram bound RCP trip delay times of up to 2 minutes as stated in EMF-96-043. The requirements of 10 CFR 50.46 are satisfied for the three cases analyzed.

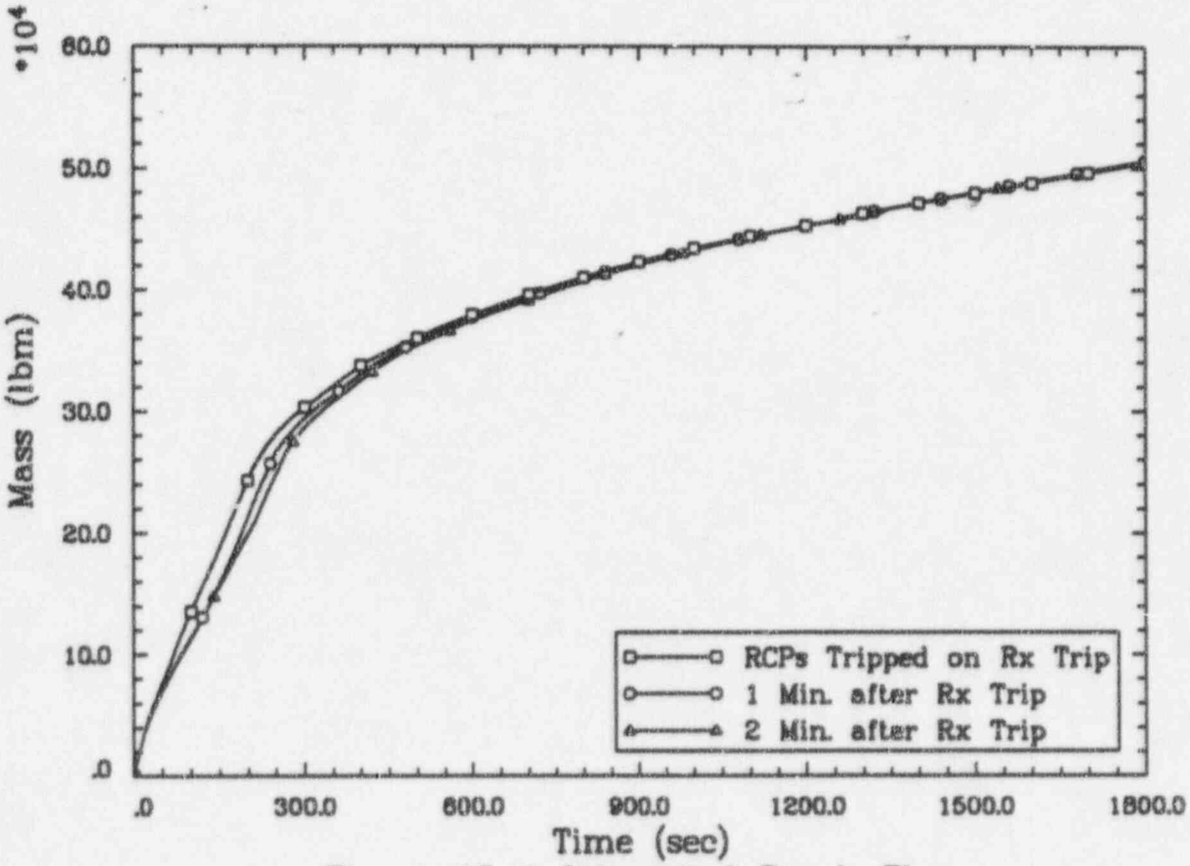

Figure 15-1 Integrated Break Flow
for RCP Trip Delay Sensitivity

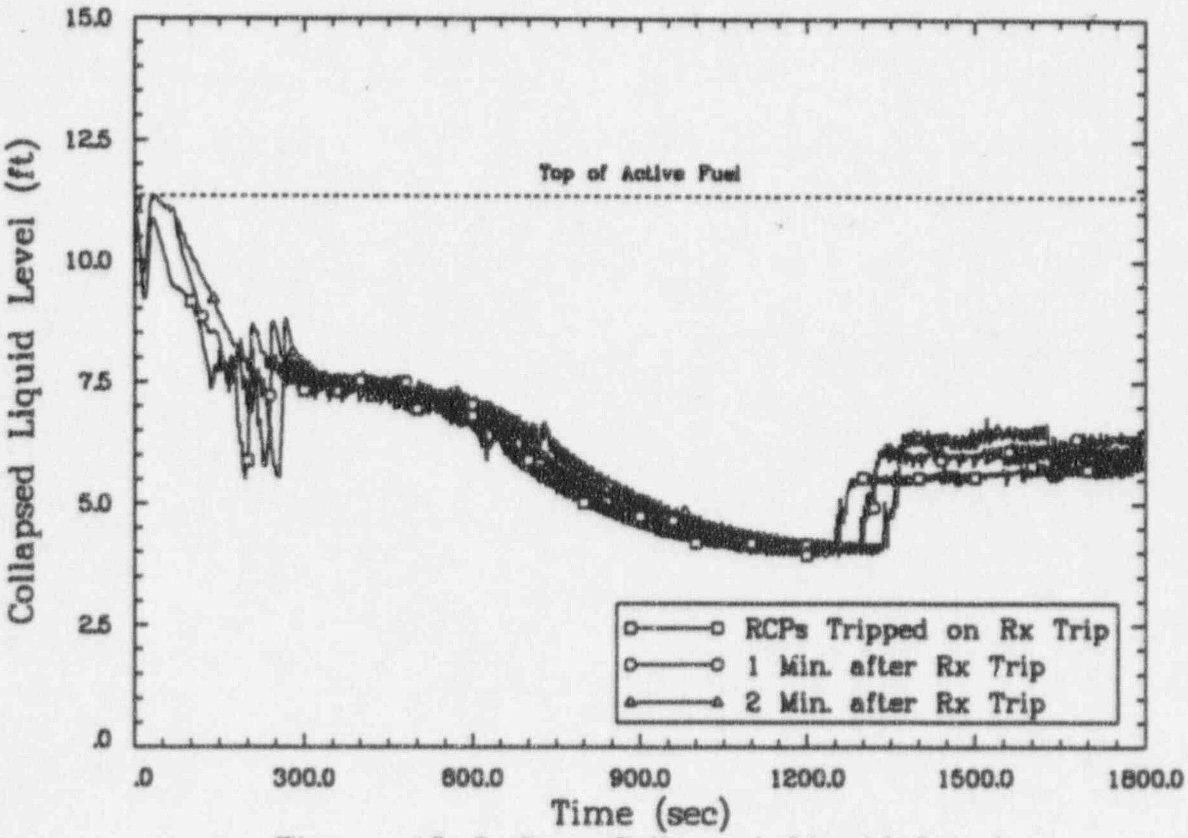

Figure 15-2 Core Collapsed Liquid Level for RCP Trip Delay Sensitivity

16. The Use of FROSSTEY2 to Replace RODEX2

The USNRC-approved version of the Siemens PWR/EM SBLOCA methods involves three computer codes: RODEX2 to initialize fuel rod parameters in the system analysis and heatup analytical codes; ANF-RELAP to calculate the reactor system response to the SBLOCA and provide boundary conditions to the fuel rod heatup analysis; and TOODEE2 to compute the SBLOCA heatup transient for the highest power fuel rod and calculate the peak cladding temperature. The staff notices that the Maine Yankee SBLOCA analysis used FROSSTEY2, instead of RODEX2, to calculate the fuel initial conditions that are provided to the ANF-RELAP and TOODEE2 code. The Siemens PWR/EM SBLOCA methods (RODEX2, ANF-RELAP and TOODEE2) were previously reviewed and approved by the USNRC. Explain why the use of the FROSSTEY2, ANF-RELAP, and TOODEE2 as a code package is acceptable for SBLOCA analyses to support Maine Yankee operation.

Maine Yankee Response:

The FROSSTEY-2 code and its associated LOCA Application Method were evaluated and approved independent of the actual LOCA methods[1]. The review and approval of FROSSTEY-2 was based on a comparison of the FROSSTEY-2 predictions with benchmark data and the inclusion within the Application Methodology of the means of assuring VAT predictions at the 95/95 level. The review was done in a "free-standing" manner without relying on "conservative" features of the LOCA Methods. Therefore. FROSSTEY-2 is not restricted to a particular LOCA Method.

FROSSTEY-2 has been incorporated into the YNSD (Yankee Nuclear Services Department) LOCA Methods. Within the YAEC LOCA analysis method, the FROSSTEY-2 code and its associated application methodology performs the same function as the RODEX2 code does in the SPC SBLOCA analysis method. Both codes are used to generate the LOCA Initial conditions for the system and heatup codes. The initial conditions calculated by the fuel performance code include items such as:

- Peak node stored energy (i.e. Volume Average Temperature, VAT)
- Gap inventory (moles of gas),
- Gap inventory composition (gas mole fractions),
- Gap dimensions, and
- Internal rod pressure.

Both codes are accepted methods for generating the above information. The generation of fuel initial conditions requires access to detailed proprietary fuel rod design information. SPC is not the current fuel vendor and, therefore, does not have access to the current fuel vendors' proprietary data. Maine Yankee and hence, YAEC, has access to the fuel design data as part of the fuel contract. Also, the current Maine Yankee fuel and SPC use different burnable absorber designs and FROSSTEY-2 includes an analytic model for the impact of the Maine Yankee burnable absorber. Therefore, YAEC performed the fuel initial condition calculations with the FROSSTEY-2 code. The FROSSTEY-2 analysis supporting the SPC analysis employed the

FROSSTEY-2 LOCA Application methodology[2,3]. This methodology is designed to assure VAT is bounding at the 95/95 level. In addition, the FROSSTEY-2 fission gas release model has been shown to be conservative. The conservative fission gas release model combined with a bounding rod power history assure that the rod internal pressure is conservatively predicted.

SPC supplied the input data requirements for their ANF-RELAP and TOODEE2 codes. The data requirements were compared with FROSSTEY-2 calculated parameters and Maine Yankee determined the required data was generated by FROSSTEY-2. Further. both the SPC and YAEC LOCA models use versions of TOODEE2 as the heatup code with their LOCA Methods and FROSSTEY-2 has been previously employed to generate TOODEE2 initial conditions. Therefore, FROSSTEY-2 is an appropriate code for use in developing LOCA initial conditions for the SPC ANF-RELAP and TOODEE2 codes.

References

1. Letter, P. Sears (USNRC) to L. A. Tremblay (VYNPC), "Vermont Yankee Nuclear Power Station, Safety. Evaluation of FROSSTEY-2 Computer Code (TAC No. M68216)," dated September 24, 1996.
2. Letter. L. A. Tremblay (VYNPC) to USNRC, "LOCA-Related Responses to Open Issues on FROSSTEY2 Fuel Performance Code," BVY 92-39, dated March 27, 1992.
3. Letter, L. A. Tremblay (VYNPC) to USNRC, "FROSSTEY2 Fuel Performance Code - Vermont Yankee Response to Remaining Concerns," BVY 92-54, dated May 15, 1992.

17. The Power Shape Adjustment Method

Page 3-4 of the April 25, 1996, submittal states that four axial power shapes were considered in the SBLOCA analysis to identify the limiting case. The axial shapes were "adjusted" to have a bounding "symmetry offset" at full power and be consistent with the Maine Yankee Technical Specifications F_r and the LHGR limits. Provide results of an example calculation to show how the "adjustment" was done. Explain why the method used for the power shape adjustment is reasonable to account for the effect of power shapes on the calculated PCT.

Maine Yankee Response:.

The Maine Yankee Core Operating Limits Report include an LHGR versus core elevation limit curve, which reduces the allowed LHGR at increasing elevations in the core. In SBLOCA analyses, increasing the elevation of the peak power location will increase calculated PCTs, but reduced LHGR limits will decrease the calculated PCTs. Four axial profiles were analyzed to bound these competing effects. Input axial profiles are determined from neutronics calculations which predict potential axial profiles during xenon transients. These axial profiles are [ ]

[ ]

Figure 17-1 shows the input axial profile, the axial profile [ ] As can be seen, these modifications conservatively move power toward the top of the core. This is conservative in that it reduces the amount of steam generated in the lower portion of the core during the core uncovery period and increases the LHGR near the top of the core where PCT occurs. The result is a conservatively calculated PCT.

[ ]

Figure 17-1 Example Adjustments to Axial Peaking Factors

18. Adequacy of the Analyses to Determine the Limiting Break Size

The results of your April 25, 1996, submittal show that the determination of the limiting SBLOCA case depends on the assumptions of break sizes, axial power shapes and core crossflow resistances. Based on the power shape sensitivity analysis in Section 5.1, Siemens claims that the effect of power shapes on the calculated PCT is small. Since the sensitivity study was done for SBLOCAs with a break size of 0.10 ft^2 only, it is not clear that the results can be applicable to break sizes other than 0.10 ft^2. Furthermore, the results of the sensitivity study (Tables 5.3 and 4) show that the combined effects of the crossflow resistances and power shapes on the calculated PCTs have no consistent trend and are significant. Because the analysis of the combined cross flow resistance and power shape effects was also performed for a break size of 0.10 ft^2 to determine the limiting case, the possibility cannot be excluded that the limiting SBLOCA case could occur for break sizes other than 0.10 ft^2, the licensee is requested to explain why the results in Tables 5.3 and 5.4 are adequate to support the conclusion that the limiting SBLOCA break size is 0.10 ft^2.

Maine Yankee Response:

EMF-96-043 and additionally the response to RAI question 9 described why the 0.10 ft^2 break is the limiting break size, i.e. equilibration of HPSI flow and break flow, a slowly decreasing primary pressure delaying the time to reach the SIT pressure, and a stagnant core collapsed liquid level. The PCT for the 0.09 ft^2 break is 255°F lower than for the comparable 0.10 ft^2 base break spectrum case. The maximum difference in PCT demonstrated for the 0.10 ft^2 break sensitivity studies was 18°F for the 65%, 73%, and 85% axials and 77°F for the range of crossflow resistances at a given axial shape. These differences are much smaller than the difference in PCT between the 0.10 ft^2 and the 0.09 ft^2 break sizes. Therefore, it is not reasonable or necessary to perform axial shape or crossflow sensitivity studies for break sizes less than 0.10 ft^2.

Similarly, the PCT for the 0.15 ft^2 break was 182°F lower than for the comparable 0.10 ft^2 break spectrum case. This difference is much larger than the difference in PCTs indicated in the axial shape and crossflow sensitivity studies for the 0.10 ft^2 break size. The PCT for the 0.15 ft^2 break is lower than for the 0.10 ft^2 break due to a larger break flow rate, faster primary depressurization, and shorter time to SIT actuation. Otherwise, the trends in system behavior for the 0.15 ft^2 break are very similar to that for the 0.10 ft^2 break. Because this overall system behavior would be very similar for axial shape and crossflow sensitivities performed at a 0.15 ft^2 break size, a similar spread in PCT results would be calculated. With a similar spread in PCT results for the 0.15 ft^2 break, the limiting PCT for the 0.15 ft^2 break would be significantly less than the limiting PCT calculated for the 0.10 ft^2 break. Therefore, performing such sensitivities for the 0.15 ft^2 break size is not warranted.

In conclusion, EMF-96-043 and the response to RAI question 9 have clearly shown the 0.10 ft^2 break to be the limiting break size and that the phenomena which make this break size limiting are understood. The axial shape and core crossflow resistance sensitivity studies performed at a break size of 0.10 ft^2 bound the PCT for the Maine Yankee plant.