Tennessee Valley Authority, Post Office Box 2000, Spring City, Tennessee 37381-2000

DEC 15 2005

TVA-WBN-TS-05-09

10 CFR 50.90

U.S. Nuclear Regulatory Commission
Mail Stop: OFWNP1-35
ATTN: Document Control Desk
Washington, D. C. 20555

Gentlemen:

In the Matter of	)	Docket No. 50-390
Tennessee Valley Authority	)	

WATTS BAR NUCLEAR PLANT (WBN) - UNIT 1 - TECHNICAL SPECIFICATION (TS) CHANGE NO. TVA-WBN-TS-05-09 - ICE CONDENSER ICE WEIGHT INCREASE DUE TO REPLACEMENT STEAM GENERATORS

Pursuant to 10 CFR 50.90, TVA is submitting a request for an amendment to WBN's license NPF-90 to change the TSs for Unit 1. The proposed change, TVA-WBN-TS-05-09, increases the minimum TS ice basket weight of 1110 pounds to 1237 pounds, subsequently increasing the overall total ice weight limit from 2,158,000 pounds to 2,404,500 pounds.

The changes to the ice basket and total ice weights are due to the additional energy associated with the Replacement Steam Generators, i.e., increased metal mass, primary, and secondary volumes, and heat transfer area considered in the Loss of Coolant Accident (LOCA) mass and energy release and LOCA containment pressure analyses performed for Watts Bar Unit 1.

Enclosure 1 to this letter provides the description and evaluation of the proposed change. This includes TVA's determination that the proposed change does not involve a

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significant hazards consideration, and is exempt from environmental review. Enclosure 2 contains copies of the appropriate TS pages, marked-up to show the proposed change. Enclosure 3 contains the revised TS pages which incorporates the proposed change. Enclosure 4 provides the technical analysis by TVA's Nuclear Steam Supply System (NSSS) vendor supporting this change.

TVA has determined that there are no significant hazards considerations associated with the proposed change and that the TS change qualifies for a categorical exclusion from environmental review pursuant to the provisions of 10 CFR 51.22(c)(9). Additionally, in accordance with 10 CFR 50.91(b)(1), TVA is sending a copy of this letter and enclosures to the Tennessee State Department of Public Health.

TVA requests approval for the increased minimum ice weight approximately 30 days before the upcoming Cycle 7 Refueling Outage and that the implementation of the revised TS being effective prior to Mode 4 at startup to begin the Cycle 8 fuel cycle.

No commitments are being tracked from this submittal. If you have any questions about this change, please contact me at (423) 365-1824.

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 15th of December 2005.

Sincerely,

P. L. Pace
Manager, Site Licensing
and Industry Affairs

Enclosures

1. Proposed Technical Specification (TS) Change WBN-TS-05-09
2. Annotated Technical Specification and Bases Pages
3. Revised Technical Specification and Bases Pages
4. Vendor Technical Analysis

cc: See page 3

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Enclosures
cc (Enclosures):

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ENCLOSURE 1

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT (WBN), UNIT 1
DOCKET NO. 50-390

PROPOSED TECHNICAL SPECIFICATION (TS) CHANGE WBN-TS-05-09
DESCRIPTION AND EVALUATION OF THE PROPOSED CHANGE

1.0 DESCRIPTION

This letter is a request to amend the Operating License No. NPF-90 for WBN, Unit 1.

The proposed change would revise the WBN Unit 1 Technical Specification (TS) Surveillance Requirements (SR) to increase the minimum required average ice basket weight, and thus the corresponding total weight of the stored ice in the WBN ice condenser.

The changes to the ice basket and total ice weights are due to the additional energy associated with the Replacement Steam Generators, i.e., increased metal mass, primary, and secondary volumes, and heat transfer area considered in the Loss of Coolant Accident (LOCA) mass and energy release and LOCA containment pressure analyses performed for WBN.

TVA requests approval for the increased minimum ice weight approximately 30 days before the upcoming Cycle 7 Refueling Outage and that the implementation of the revised TS being effective prior to Mode 4 at startup to begin the Cycle 8 fuel cycle.

2.0 PROPOSED CHANGE

The proposed changes affect the following sections:

1. TS Section 3.6.11, "Ice Bed," SR 3.6.11.2, SR 3.6.11.3, and the associated Bases are being revised to raise the minimum required average ice basket weight from 1110 pounds to 1237 pounds, and the corresponding total weight of the stored ice in the ice condenser from 2,158,000 pounds to 2,404,500 pounds.

Enclosure 2 provides the TS page markups of these changes.

In summary, TVA is proposing to increase the minimum TS ice basket and total ice weight requirements. The changes to the ice basket and total ice weights are due to the additional energy associated with the Replacement Steam Generators, i.e., increased metal mass, primary, and secondary volumes, and heat transfer area considered in the Loss of Coolant Accident (LOCA) mass and energy release and LOCA containment pressure analyses performed for WBN.

In addition, the revised containment pressure analysis (performed to evaluate effects due to Steam Generator Replacement) resulted in a change to the peak containment pressure. This will result in a change in the associated TS bases as described below:

2. TS Bases Section 3.6.4, "Containment Pressure," is being revised to raise the peak containment pressure from 10.64 to 11.03 pounds per square inch gauge (psig) which resulted from the revised containment pressure analysis.

3. TS Bases Section 3.6.6, "Containment Spray Systems," is being revised to raise the peak containment pressure from 10.64 to 11.03 psig which resulted from the revised containment pressure analysis.

Enclosure 2 provides the TS Bases (for information only) page markups of these changes.

3.0 BACKGROUND

The ice bed consists of ice stored in 1944 baskets within the ice condenser. The primary purpose of the ice condenser is to provide a large heat sink in the event of a release of energy from a design basis loss-of-coolant (LOCA) or high energy line break (HELB) in containment. The LOCA requires the greatest amount of ice compared to other accident scenarios; therefore, the increase in ice weight is based on the LOCA analysis. The amount of ice in the bed has no impact on the initiation of an accident, but rather on the mitigation of the accident.

The ice would absorb energy and limit the containment peak pressure and temperature during the accident. Limiting the pressure and temperature reduces the release of fission product radioactivity from containment to the environment in the event of a design basis accident. The design basis ice mass is supported by the containment integrity analysis documented in the WBN Updated Final Safety Analysis Report (UFSAR), Section 6.2, "Containment Systems." The Technical Specification surveillance limits on total ice weight, and on average basket ice weight by row-group, are intended to ensure that sufficient ice is present in an appropriate distribution to perform this function. The Technical Specification surveillance limits are currently an "as-left" measurement and include margin for ice sublimation.

Recently, LOCA long-term containment mass and energy release and containment integrity analyses have been performed to support the steam generator replacement at WBN Unit 1. The objective of this effort was to provide revised containment mass and energy release data using current WBN specific information and the calculated RCS inventory based upon the new steam generators. The analyses used the Westinghouse mass and energy release model which was documented in WCAP-10325-P-A, "Westinghouse LOCA Mass and Energy Release Model for Containment Design," and approved by NRC in a Safety Evaluation to Westinghouse dated February 17, 1987.

4.0. TECHNICAL ANALYSIS

TVA has evaluated those postulated design basis accidents that credit the ice condenser using the revised design basis analysis. The analysis provides assurance that containment heat removal capability is sufficient to remove the maximum possible discharge of mass and energy to containment without exceeding the containment pressure acceptance criteria. A summary of the design basis accidents is discussed in the following safety analysis.

The objective of the containment integrity analyses was to determine the required ice weight due to installation of the new Steam Generators to ensure that the calculated peak pressure is less than the design pressure. The results of the analysis support a design basis ice mass of 2,260,000 pounds. The revised Technical Specification limit of 2,404,500 pounds reflects this increase. The assumed six percent sublimation rate of the ice bed is unchanged for this submittal.

Containment Integrity

The Containment Integrity Analysis is performed to ensure that the pressure inside containment remains below the Containment Building design pressure in the event of a LOCA. The analysis ensures that the containment heat removal capability is sufficient to remove the maximum possible discharge of mass and energy to containment from the Nuclear Steam Supply System (NSSS) without exceeding the containment pressure acceptance criterion (13.5 psig) or any other accidents that would increase the pressure in containment.

The LOCA mass and energy analysis was performed in accordance with the criteria shown in the Standard Review Plan (SRP), Section 6.2.1.3, "Mass and Energy Release Analysis for Postulated Loss-Of-Coolant Accidents." In this analysis, the relevant requirements of General Design Criteria (GDC) 50, "Containment Design Basis," and 10 CFR 50, Appendix K , "ECCS Evaluation Models," have been included by confirmation both that the calculated pressure is less than the WBN containment design pressure, and that the available sources of energy have been included. These sources include reactor power, decay heat, core stored energy, stored energy in the reactor vessel and internals, metal-water reaction energy, and stored energy in the secondary system.

In addition, the containment integrity peak pressure analysis has been performed in accordance with the criteria shown in

SRP, Section 6.2.1.1.B, "Ice Condenser Containments." Conformance to GDC 16, "Containment Design," GDC 38, "Containment Heat Removal," and GDC 50, is demonstrated by showing that the containment design pressure is not exceeded at any time in the transient. This analysis also demonstrates that the containment heat removal systems function to rapidly reduce the containment pressure and temperature in the event of a LOCA.

Based on the revised LOCA mass and energy release and containment pressure analyses, it can be concluded that operation with a design basis ice weight of 2,260,000 pounds for the WBN Unit 1 is acceptable. Plant operation with a design basis ice mass of 2,260,000 pounds results in a calculated peak containment pressure of 11.03 psig, as compared to the design pressure of 13.5 psig. Thus, the most limiting case in the WBN licensing basis accident analyses has been considered, and has been shown to yield acceptable results.

Main Steamline Break

The main steamline break event does not melt the entire initial ice mass assumed in the steam line break analysis which is less than the ice weight assumed in the containment LOCA analysis. This results in the steamline break event being less limiting that the LOCA event. Therefore, the proposed increase in total ice mass to 2,260,000 pounds would have no effect on the current analysis results, or its conclusions.

LOCA

There is no adverse impact on the LOCA peak clad temperature, (PCT) analyses. The short-term containment pressure calculation is relatively insensitive to the initial ice mass in the ice bed. At the time that the peak cladding temperature was obtained, a relatively minor amount of ice would be melted and there would only be a minor affect on containment pressure, and thus, a negligible effect on the calculated PCT. Therefore, no PCT penalty would be applied to the Best Estimate LOCA analysis due to this amendment.

The post-LOCA subcriticality calculation conservatively assumes a maximum initial ice mass in the ice bed in order to minimize the sump boron concentration. As the new total ice weight requirement remains substantially less than the value assumed, the increase in ice inventory would have no effect on the calculation. The hot leg recirculation switchover time calculation is performed to determine the time at which hot leg recirculation should be initiated in order to preclude boron precipitation in the core post-LOCA. This calculation assumes a minimum initial ice mass in the ice bed in order to conservatively maximize the boron concentration resulting in a shorter switchover time. Increasing the ice weight would not impact the calculated switchover time. However, the reduction in hot leg switchover time due to the reduced ice mass would be less than the margin between the calculated switchover time and the switchover time in the WBN emergency operating procedures (EOP). There would be no change to the hot leg switchover time in the EOPs as a consequence of this amendment. In addition, it has been determined that the minimum post-LOCA sump pH value will remain above 7.5. The sump pH above this value will not create a corrosion issue, and is acceptable with respect to minimizing the potential for chloride induced stress corrosion cracking and maintaining iodine retention in the sump solution. The sump pH change is the same as those proposed for the Tritium Program. The higher ice weight results in a reduction in pH and the Tritium Program increases the RWST boron concentration which further reduces the pH. The evaluation done for the Tritium Program included both effects and therefore, bounds the reduced ice weight when considered separately. [Reference TVA's letter dated August 20, 2001, concerning Technical Specification Change Request WBN-TS-00-015 for the Tritium Production Core.]

Finally, the results of this analysis bound the small break LOCA analysis with respect to the amount of ice mass melt.

Other Safety Related Analyses

The following analyses were also reviewed and determined not to be impacted by the proposed increase in ice weight because the ice weight is not modeled in the analyses:

LOCA forces
Non-LOCA transients
Steam Generator Tube Rupture
Protection System Setpoints

Comparison of Basis for Ice Weight

The following table summarizes the differences in the current minimum allowable ice weight requirement and the proposed allowable ice weight requirement.

	Current[1]	Proposed
Design Basis Ice Mass (per basket)	1044 lbs	1163 lbs
Added Sublimation Rate	6 percent[2]	6 percent[3]
Added Instrument Error	0 percent[4]	0 percent[4]
Total TS Basket Weight	1110 lbs.	1237 lbs.
Total TS Containment Ice Mass	2,158,000	2,404,500

(1) Approved for WBN Unit 1 by NRC in Amendment 33 dated November 29, 2001.

(2) Average sublimation over 3 operating cycles is approximately 3.42 percent.

(3) Average sublimation over 6 operating cycles is approximately 3.36 percent.

(4) TS value does not account for instrument error. A margin for instrument error is added in the plant procedures for proposed TS basket weight number.

5.0. REGULATORY SAFETY ANALYSIS

5.1. No Significant Hazards Consideration

TVA is submitting a request for an amendment to the Watts Bar Nuclear Plant (WBN) Unit 1 Technical Specification (TS) which would increase the required minimum ice basket and total ice weight. TVA has revised the design basis analysis using NRC approved modeling enhancements, which show that the amount of ice required for accident mitigation must be increased due to the replacement of the Unit 1 Steam Generators.

TVA has evaluated whether or not a significant hazards consideration is involved with the proposed amendment(s) by focusing on the three standards set forth in 10 CFR 50.92, "Issuance of Amendment," as discussed below:

1. **Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?**

   Response: No

   The primary purpose of the ice bed is to provide a large heat sink to limit peak containment pressure in the event of a release of energy from a design basis loss-of-coolant (LOCA) or high energy line break (HELB) in containment. The LOCA requires the greatest amount of ice compared to other accident scenarios; therefore the increase in ice weight is based on the LOCA analysis. The amount of ice in the bed has no impact on the initiation of an accident, but rather on the mitigation of the accident.

   The containment integrity analysis shows that the proposed increased ice weight is sufficient to maintain the peak containment pressure below the containment design pressure, and that the containment heat removal systems function to rapidly reduce the containment pressure and temperature in the event of a LOCA. Therefore, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. **Does the proposed change create the possibility of a new or different kind of accident from any accident previously evaluated?**

Response: No

The ice condenser serves to limit the peak pressure inside containment following a LOCA. The revised containment pressure analysis determined that sufficient ice would be present to maintain the peak containment pressure below the containment design pressure. The increased ice weight does not create the possibility of an accident that is different than any already evaluated in the WBN Updated Final Safety (UFSAR). No new accident scenarios, failure mechanisms, or limiting single failures are introduced as a result of this proposed change. Therefore, the proposed change does not create the possibility of a new or different kind of accident from any previously evaluated.

3. **Does the proposed change involve a significant reduction in a margin of safety?**

Response: No

The containment integrity analysis for increased ice weight results in a peak containment pressure that is slightly greater than that in the previous analysis of record, but still less than design pressure. This increase in peak pressure, along with the ice weight increase, is due to an increase in RCS inventory and stored residual heat in the replacement Steam Generators that will be installed in the Unit 1 Cycle 7 Refueling Outage.

The revised technical specification ice weight surveillance limits are based on the ice weight assumed in the containment integrity analysis, with margin included for sublimation that is based on actual sublimation data from the first six refueling cycles at WBN. The analysis further demonstrates that the existing relationship between ice bed melt-out and containment spray switchover has been conservatively maintained. With the increased ice inventory, melt-out of the ice bed following a worst case large break LOCA has been determined to occur after the switchover of containment spray to the recirculation mode. Thus, the greater ice bed mass does not result in a reduction in the margin for operator action to initiate the switchover.

Therefore, the proposed change does not involve a significant reduction in a margin of safety.

Based on the above, TVA concludes that the proposed amendment presents no significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and, accordingly, a finding of "no significant hazards consideration" is justified.

5.2. Applicable Regulatory Requirements/Criteria

Regulatory requirements and criteria applicable to the design bases for the ice condensers include NRC's 10 CFR 50 Appendix A GDCs, such as GDC-1, *Quality Standards and Records*, GDC-2, *Design Bases for Protection Against Natural Phenomena*, GDC-4, *Environmental and Missile Design Basis*, GDC-5, *Sharing of Structures, Systems, and Components*, GDC-10, *Reactor Design*, GDC-13, *Instrumentation and Control*, GDC-14, *Reactor Coolant Pressure Boundary*, GDC-15, *Reactor Coolant System Design*, GDC-20, *Protection System Functions*, GDC-16, "*Containment Design*,", GDC-25, *Protection System Requirements for Reactivity Control Malfunctions*, and NRC's Standard Review Plan (SRP)- 6.2.1, *Containment Functional Design*, 15.1, *Increase in Heat Removal by the Secondary System*, and 15.6, *Decrease in Reactor Coolant Inventory*.

TVA evaluated this change against the applicable NRC regulations and criteria. The change in the TS ice bed weights will not change the ice condenser function to respond as designed. These TS changes are, therefore, considered safe and meet the applicable regulatory requirements.

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

6.0. ENVIRONMENTAL IMPACT CONSIDERATION

A review has determined that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, or would change an inspection or surveillance requirement. However, the proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9).

Therefore pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

ENCLOSURE 2

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT (WBN) UNIT 1
Docket No. 50-390

PROPOSED TECHNICAL SPECIFICATION (TS) CHANGE WBN-TS-05-09
MARKED PAGES

I. AFFECTED PAGE LIST

Technical Specifications

3.6-29

Technical Specification Bases (For Information Only)

B 3.6-28
B 3.6-37
B 3.6-65
B 3.6-70

II. MARKED PAGES

See attached.

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.6.11.2	Verify total weight of stored ice is ≥ 2,158,000 lb by: a. Weighing a representative sample of ≥ 144 ice baskets and verifying each basket contains ≥ 1110 lb of ice; and b. Calculating total weight of stored ice, at a 95% confidence level, using all ice basket weights determined in SR 3.6.11.2.a.	18 months
SR 3.6.11.3	Verify azimuthal distribution of ice at a 95% confidence level by subdividing weights, as determined by SR 3.6.11.2.a, into the following groups: a. Group 1-bays 1 through 8; b. Group 2-bays 9 through 16; and c. Group 3-bays 17 through 24. The average ice weight of the sample baskets in each group from radial rows 1, 2, 4, 6, 8, and 9 shall be ≥ 1110 lb.	18 months
SR 3.6.11.4	Verify, by visual inspection, accumulation of ice on structural members comprising flow channels through the ice bed is ≤ 15 percent blockage of the total flow area for each safety analysis section.	18 months

Replace with greater than or equal to 2,404,500

Replace with percent

Replace with greater than or equal to 1237

Replace with percent

Replace with greater than or equal to 1237

Replace with Less than or equal to 15

(continued)

B 3.6 CONTAINMENT SYSTEMS

B 3.6.4 Containment Pressure

BASES

BACKGROUND

The containment pressure is limited during normal operation to preserve the initial conditions assumed in the accident analyses for a loss of coolant accident (LOCA) or steam line break (SLB). These limits also prevent the containment pressure from exceeding the containment design negative pressure differential (-2.0 psid) with respect to the shield building annulus atmosphere in the event of inadvertent actuation of the Containment Spray System or Air Return Fans.

Containment pressure is a process variable that is monitored and controlled. The containment pressure limits are derived from the input conditions used in the containment functional analyses and the containment structure external pressure analysis. Should operation occur outside these limits coincident with a Design Basis Accident (DBA), post accident containment pressures could exceed calculated values.

APPLICABLE SAFETY ANALYSES

Containment internal pressure is an initial condition used in the DBA analyses to establish the maximum peak containment internal pressure. The limiting DBAs considered, relative to containment pressure, are the LOCA and SLB, which are analyzed using computer pressure transients. The worst case LOCA generates larger mass and energy release than the worst case SLB. Thus, the LOCA event bounds the SLB event from the containment peak pressure standpoint (Ref. 1).

Replace with
11.03

The initial pressure condition used in the containment analysis was 15.0 psia. ~~This~~ resulted in a maximum peak pressure from a LOCA of 10.64 psig. The containment analysis (Ref. 1) shows that the maximum allowable internal containment pressure, P_a (15.0 psig), bounds the calculated results from the limiting LOCA. The maximum containment pressure resulting from the worst case LOCA, does not exceed the containment design pressure, 13.5 psig.

(continued)

BASES

BACKGROUND (continued)

and water from a DBA. During the post blowdown period, the Air Return System (ARS) is automatically started. The ARS returns upper compartment air through the divider barrier to the lower compartment. This serves to equalize pressures in containment and to continue circulating heated air and steam through the ice condenser, where heat is removed by the remaining ice and by the Containment Spray System after the ice has melted.

The Containment Spray System limits the temperature and pressure that could be expected following a DBA. Protection of containment integrity limits leakage of fission product radioactivity from containment to the environment.

APPLICABLE SAFETY ANALYSES

The limiting DBAs considered relative to containment OPERABILITY are the loss of coolant accident (LOCA) and the steam line break (SLB). The DBA LOCA and SLB are analyzed using computer codes designed to predict the resultant containment pressure and temperature transients. No two DBAs are assumed to occur simultaneously or consecutively. The postulated DBAs are analyzed, in regard to containment ESF systems, assuming the loss of one ESF bus, which is the worst case single active failure, resulting in one train of the Containment Spray System, the RHR System, and the ARS being rendered inoperable (Ref. 2).

The DBA analyses show that the maximum peak containment pressure of 10.64 psig results from the LOCA analysis, and is calculated to be less than the containment design pressure. The maximum peak containment atmosphere temperature results from the SLB analysis. The calculated transient containment atmosphere temperatures are acceptable for the DBA SLB.

Replace with
11.03

(continued)

B 3.6 CONTAINMENT SYSTEMS

B 3.6.11 Ice Bed

Replace with
2,404,500

BASES

BACKGROUND

The ice bed consists of over 2,158,000 lbs of ice stored in 1944 baskets within the ice condenser. Its primary purpose is to provide a large heat sink in the event of a release of energy from a Design Basis Accident (DBA) in containment. The ice would absorb energy and limit containment peak pressure and temperature during the accident transient. Limiting the pressure and temperature reduces the release of fission product radioactivity from containment to the environment in the event of a DBA.

The ice condenser is an annular compartment enclosing approximately 300° of the perimeter of the upper containment compartment, but penetrating the operating deck so that a portion extends into the lower containment compartment. The lower portion has a series of hinged doors exposed to the atmosphere of the lower containment compartment, which, for normal plant operation, are designed to remain closed. At the top of the ice condenser is another set of doors exposed to the atmosphere of the upper compartment, which also remain closed during normal plant operation. Intermediate deck doors, located below the top deck doors, form the floor of a plenum at the upper part of the ice condenser. These doors also remain closed during normal plant operation. The upper plenum area is used to facilitate surveillance and maintenance of the ice bed.

The ice baskets contain the ice within the ice condenser. The ice bed is considered to consist of the total volume from the bottom elevation of the ice baskets to the top elevation of the ice baskets. The ice baskets position the ice within the ice bed in an arrangement to promote heat transfer from steam to ice. This arrangement enhances the ice condenser's primary function of condensing steam and absorbing heat energy released to the containment during a DBA.

In the event of a DBA, the ice condenser inlet doors (located below the operating deck) open due to the pressure rise in the lower compartment. This allows

(continued)

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.6.11.2

The weighing program is designed to obtain a representative sample of the ice baskets. The representative sample shall include 6 baskets from each of the 24 ice condenser bays and shall consist of one basket from radial rows 1, 2, 4, 6, 8, and 9. If no basket from a designated row can be obtained for weighing, a basket from the same row of an adjacent bay shall be weighed.

Replace with

Less than 1237

The rows chosen include the rows nearest the inside and outside walls of the ice condenser (rows 1 and 2, and 8 and 9, respectively), where heat transfer into the ice condenser is most likely to influence melting or sublimation. Verifying the total weight of ice ensures that there is adequate ice to absorb the required amount of energy to mitigate the DBAs.

If a basket is found to contain < 1110 lb of ice, a representative sample of 20 additional baskets from the same bay shall be weighed. The average weight of ice in these 21 baskets (the discrepant basket and the 20 additional baskets) shall be ≥ 1110 lb at a 95% confidence level. [Value does not account for instrument error.]

Weighing 20 additional baskets from the same bay in the event a Surveillance reveals that a single basket contains < 1110 lb ensures that no local zone exists that is grossly deficient in ice. Such a zone could experience early melt out during a DBA transient, creating a path for steam to pass through the ice bed without being condensed. The Frequency of 18 months was based on ice storage tests and the allowance built into the required ice mass over and above the mass assumed in the safety analyses. Operating experience has verified that, with the 18 month Frequency, the weight requirements are maintained with no significant degradation between surveillances.

Replace with

greater than or equal to 1237

(continued)

ENCLOSURE 3

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT (WBN) UNIT 1
Docket No. 50-390

PROPOSED TECHNICAL SPECIFICATION (TS) CHANGE WBN-TS-05-09
REVISED PAGES

I. AFFECTED PAGE LIST

Technical Specifications

3.6-29

Technical Specification Bases (For Information Only

B 3.6-28
B 3.6-37
B 3.6-65
B 3.6-70

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.6.11.2	Verify total weight of stored ice is greater than or equal to 2,404,500 lb by: a. Weighing a representative sample of greater than or equal to 144 ice baskets and verifying each basket contains greater than or equal to 1237 lb of ice; and b. Calculating total weight of stored ice, at a 95 percent confidence level, using all ice basket weights determined in SR 3.6.11.2.a.	18 months
SR 3.6.11.3	Verify azimuthal distribution of ice at a 95 percent confidence level by subdividing weights, as determined by SR 3.6.11.2.a, into the following groups: a. Group 1-bays 1 through 8; b. Group 2-bays 9 through 16; and c. Group 3-bays 17 through 24. The average ice weight of the sample baskets in each group from radial rows 1, 2, 4, 6, 8, and 9 shall be greater than or equal to 1237 lb.	18 months
SR 3.6.11.4	Verify, by visual inspection, accumulation of ice on structural members comprising flow channels through the ice bed is less than or equal to 15 percent blockage of the total flow area for each safety analysis section.	18 months

(continued)

B 3.6 CONTAINMENT SYSTEMS

B 3.6.4 Containment Pressure

BASES

BACKGROUND

The containment pressure is limited during normal operation to preserve the initial conditions assumed in the accident analyses for a loss of coolant accident (LOCA) or steam line break (SLB). These limits also prevent the containment pressure from exceeding the containment design negative pressure differential (-2.0 psid) with respect to the shield building annulus atmosphere in the event of inadvertent actuation of the Containment Spray System or Air Return Fans.

Containment pressure is a process variable that is monitored and controlled. The containment pressure limits are derived from the input conditions used in the containment functional analyses and the containment structure external pressure analysis. Should operation occur outside these limits coincident with a Design Basis Accident (DBA), post accident containment pressures could exceed calculated values.

APPLICABLE SAFETY ANALYSES

Containment internal pressure is an initial condition used in the DBA analyses to establish the maximum peak containment internal pressure. The limiting DBAs considered, relative to containment pressure, are the LOCA and SLB, which are analyzed using computer pressure transients. The worst case LOCA generates larger mass and energy release than the worst case SLB. Thus, the LOCA event bounds the SLB event from the containment peak pressure standpoint (Ref. 1).

The initial pressure condition used in the containment analysis was 15.0 psia. This resulted in a maximum peak pressure from a LOCA of 11.03 psig. The containment analysis (Ref. 1) shows that the maximum allowable internal containment pressure, P_a (15.0 psig), bounds the calculated results from the limiting LOCA. The maximum containment pressure resulting from the worst case LOCA, does not exceed the containment design pressure, 13.5 psig.

(continued)

BACKGROUND (continued)

and water from a DBA. During the post blowdown period, the Air Return System (ARS) is automatically started. The ARS returns upper compartment air through the divider barrier to the lower compartment. This serves to equalize pressures in containment and to continue circulating heated air and steam through the ice condenser, where heat is removed by the remaining ice and by the Containment Spray System after the ice has melted.

The Containment Spray System limits the temperature and pressure that could be expected following a DBA. Protection of containment integrity limits leakage of fission product radioactivity from containment to the environment.

APPLICABLE SAFETY ANALYSES

The limiting DBAs considered relative to containment OPERABILITY are the loss of coolant accident (LOCA) and the steam line break (SLB). The DBA LOCA and SLB are analyzed using computer codes designed to predict the resultant containment pressure and temperature transients. No two DBAs are assumed to occur simultaneously or consecutively. The postulated DBAs are analyzed, in regard to containment ESF systems, assuming the loss of one ESF bus, which is the worst case single active failure, resulting in one train of the Containment Spray System, the RHR System, and the ARS being rendered inoperable (Ref. 2).

The DBA analyses show that the maximum peak containment pressure of 11.03 psig results from the LOCA analysis, and is calculated to be less than the containment design pressure. The maximum peak containment atmosphere temperature results from the SLB analysis. The calculated transient containment atmosphere temperatures are acceptable for the DBA SLB.

(continued)

B 3.6 CONTAINMENT SYSTEMS

B 3.6.11 Ice Bed

BASES

BACKGROUND

The ice bed consists of over 2,404,500 lbs of ice stored in 1944 baskets within the ice condenser. Its primary purpose is to provide a large heat sink in the event of a release of energy from a Design Basis Accident (DBA) in containment. The ice would absorb energy and limit containment peak pressure and temperature during the accident transient. Limiting the pressure and temperature reduces the release of fission product radioactivity from containment to the environment in the event of a DBA.

The ice condenser is an annular compartment enclosing approximately 300° of the perimeter of the upper containment compartment, but penetrating the operating deck so that a portion extends into the lower containment compartment. The lower portion has a series of hinged doors exposed to the atmosphere of the lower containment compartment, which, for normal plant operation, are designed to remain closed. At the top of the ice condenser is another set of doors exposed to the atmosphere of the upper compartment, which also remain closed during normal plant operation. Intermediate deck doors, located below the top deck doors, form the floor of a plenum at the upper part of the ice condenser. These doors also remain closed during normal plant operation. The upper plenum area is used to facilitate surveillance and maintenance of the ice bed.

The ice baskets contain the ice within the ice condenser. The ice bed is considered to consist of the total volume from the bottom elevation of the ice baskets to the top elevation of the ice baskets. The ice baskets position the ice within the ice bed in an arrangement to promote heat transfer from steam to ice. This arrangement enhances the ice condenser's primary function of condensing steam and absorbing heat energy released to the containment during a DBA.

In the event of a DBA, the ice condenser inlet doors (located below the operating deck) open due to the pressure rise in the lower compartment. This allows

(continued)

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.6.11.2

The weighing program is designed to obtain a representative sample of the ice baskets. The representative sample shall include 6 baskets from each of the 24 ice condenser bays and shall consist of one basket from radial rows 1, 2, 4, 6, 8, and 9. If no basket from a designated row can be obtained for weighing, a basket from the same row of an adjacent bay shall be weighed.

The rows chosen include the rows nearest the inside and outside walls of the ice condenser (rows 1 and 2, and 8 and 9, respectively), where heat transfer into the ice condenser is most likely to influence melting or sublimation. Verifying the total weight of ice ensures that there is adequate ice to absorb the required amount of energy to mitigate the DBAs.

If a basket is found to contain less than 1237 lb of ice, a representative sample of 20 additional baskets from the same bay shall be weighed. The average weight of ice in these 21 baskets (the discrepant basket and the 20 additional baskets) shall be greater than or equal to 1237 lb at a 95 percent confidence level. [Value does not account for instrument error.]

Weighing 20 additional baskets from the same bay in the event a Surveillance reveals that a single basket contains less than 1237 lb ensures that no local zone exists that is grossly deficient in ice. Such a zone could experience early melt out during a DBA transient, creating a path for steam to pass through the ice bed without being condensed. The Frequency of 18 months was based on ice storage tests and the allowance built into the required ice mass over and above the mass assumed in the safety analyses. Operating experience has verified that, with the 18 month Frequency, the weight requirements are maintained with no significant degradation between surveillances.

(continued)

ENCLOSURE 4

TECHNICAL ANALYSIS

LONG-TERM LOCA MASS AND ENERGY RELEASES AND LOCA CONTAINMENT INTEGRITY ANALYSIS

1 LONG-TERM LOCA MASS AND ENERGY RELEASES

1.1 INTRODUCTION

A containment integrity analysis was performed to support the Replacement Steam Generator (RSG) Program for Watts Bar Unit 1.

A containment integrity analysis is performed during nuclear plant design to ensure that the pressure inside containment will remain below the Containment Building design pressure if a LOCA inside containment should occur during plant operation. The analysis ensures that the containment heat removal capability is sufficient to remove the maximum possible discharge of mass and energy to containment from the Nuclear Steam Supply System (NSSS) without exceeding the acceptance criteria (13.5 psig).

In support of the RSG Program, this analysis utilized revised input assumptions while addressing analytical conservatisms, such as auxiliary feedwater modeling, in the present analysis in an attempt to maintain the current ice mass. The analysis was completed to provide the analytical basis for the replacement of the steam generators at Watts Bar Unit 1 and minimize the impact on the initial ice mass, current margins in peak calculated containment pressure, and ice bed melt-out time to containment spray switchover time.

Long-term LOCA/containment integrity analysis demonstrates the ability of the containment safeguards systems to mitigate the consequences of a hypothetical large-break LOCA. The containment safeguards systems must be capable of limiting the peak containment pressure to less than the design pressure. To this end, the mass and energy releases are maximized based on high Tavg Reactor Coolant System (RCS) conditions. The analysis uses the bounding composite of RCS conditions that are calculated for the reduced Tavg and RSG Program. This temperature assumes that the plant is not operating at the reduced 2°F Tavg (586.2°F). Therefore, margin exists in this analysis input if the plant operates at a reduced average temperature.

In addition to the design basis, this analysis accounted for the effects of other plant changes of which Westinghouse is aware. These include increased valve stroke time (of +13 seconds) to open the containment spray flow control valves (Reference 1), initial condition uncertainties on RCS temperature of +7°F, and 17x17 Vantage 5 Hybrid (V5H) and Robust Fuel Assembly-2 (RFA-2) fuel upgrade (Reference 2). It should be noted that these items were included for completeness even though they may not be currently implemented at Watts Bar Unit 1.

1.2 PURPOSE OF ANALYSIS

The purpose of the analysis was to calculate the long-term LOCA mass and energy releases and the subsequent containment integrity response in order to demonstrate support for the RSG Program. This effort will address current Watts Bar Unit 1 specific plant conditions and revised models as a means of using available analytical margins to support the RSG Program and minimizing the effect on the amount of ice required in the ice condenser. The objective of performing the long-term LOCA mass and energy release and LOCA containment integrity analysis will be to minimize the effect on the initial ice mass, to maintain the current time interval (150 seconds, minimum) relationship between containment spray switchover time and ice bed melt-out time, and to provide peak pressure margin to design pressure.

A key element in minimizing the impact on initial ice mass was reducing the energy available to containment in the event of a LOCA. Areas such as core stored energy, decay heat, and available steam generator metal heat were investigated and available margins were implemented into the analysis. These margins combined with a better segmental representation of the mass and energy release transient from the computer models resulted in margins that reduced energy input into containment.

The following are the analytical bases and the results, which show that the containment design pressure is not exceeded in the event of a LOCA. The conclusions presented will demonstrate, with respect to a LOCA, that containment integrity has not been compromised. Further, since the LOCA requires the greatest amount of ice compared to other accident scenarios, the initial ice mass based on LOCA results will be acceptable for the other accident scenarios.

Rupture of any of the piping carrying pressurized high temperature reactor coolant, termed a LOCA, will result in release of steam and water into the containment. This will lead to an increase in the containment pressure and temperature. The mass and energy release rates described in this document form the basis of further computations to evaluate the structural integrity of the containment following a postulated accident in order to satisfy the Nuclear Regulatory Commission (NRC) acceptance criterion, General Design Criterion 38. Subsection 1.4 presents the long-term LOCA mass and energy release analysis for containment pressurization evaluations. Section 2 presents the LOCA containment pressure calculations.

1.3 SYSTEM CHARACTERISTICS AND MODELING ASSUMPTIONS

The mass and energy release analysis is sensitive to the assumed characteristics of various plant systems, in addition to other key modeling assumptions. Some of the most critical items are RCS initial conditions, core decay heat, safety injection flow, and metal and steam generator heat release modeling. Specific assumptions concerning each of these items are discussed below. Tables 1-1 through 1-3 present key data assumed in the analysis. The data provided in References 2 and 3 was used, in part, to develop the plant data presented in Tables 1-1 through 1-3.

For the long-term mass and energy release calculations, operating temperatures to bound the highest average coolant temperature range were used. The core rated power of 3,459 MWt adjusted for calorimetric error (+0.6 percent of power) was modeled in the analysis. The use of higher temperatures is conservative because the initial fluid energy is based on coolant temperatures, which are at the maximum levels attained in steady-state operation. Additionally, an allowance of +7.0°F is reflected in the vessel/core temperature in order to account for instrument error and deadband. The initial RCS pressure in this analysis is based on a nominal value of 2,250 psia. Also included is an allowance of +70 psi, which accounts for the measurement uncertainty on pressurizer pressure. The selection of 2,320 psia as the limiting pressure is considered to affect the blowdown phase results only, since this represents the initial pressure of the RCS. The RCS rapidly depressurizes from this value until the point at which it equilibrates with containment pressure.

The rate at which the RCS depressurizes is initially more severe at the higher RCS pressure. Additionally, the RCS has a higher fluid density at the higher pressure (assuming a constant temperature) and subsequently has a higher RCS mass available for releases. Therefore, 2,320 psia initial pressure was selected as the limiting case for the long-term LOCA mass and energy release calculations. These assumptions conservatively maximize the mass and energy in the RCS.

The selection of the fuel design features for the long-term LOCA mass and energy calculation is based on the need to conservatively maximize the core stored energy. The fuel conditions were adjusted to provide a bounding analysis for the current and the Robust Fuel Assembly-2 (RFA-2) fuel upgrade for Watts Bar Unit 1. The following items serve as the basis to ensure conservatism in the core stored energy calculation:

- A conservatively high reload core loading
- Time of maximum fuel densification, that is, highest beginning-of-life (BOL) temperatures
- Irradiated fuel assemblies assumed to have an average burnup >15,000 MWD/MTU

Margin in RCS volume of 3 percent (which is composed of 1.6-percent allowance for thermal expansion and 1.4 percent for uncertainty) is modeled.

Regarding safety injection flow, the mass and energy calculation considered the historically limiting configuration of minimum safety injection flow.

The following summarized assumptions were employed to ensure that the mass and energy releases were conservatively calculated, thereby maximizing energy release to containment:

1. Maximum expected operating temperature of the RCS (100-percent full-power conditions)

2. An allowance in temperature for instrument error and deadband assumed on the vessel/core inlet temperature (+7.0°F)

3. Margin in volume of 3 percent (which is composed of a 1.6-percent allowance for thermal expansion, and a 1.4-percent allowance for uncertainty)

4. Core rated power of 3,459 MWt

5. Allowance for calorimetric error (+0.6 percent of power)

6. Conservative coefficient of heat transfer (that is, steam generator primary/secondary heat transfer and RCS metal heat transfer)

7. Core-stored energy based on the time in life for maximum fuel densification. The assumptions used to calculate the fuel temperatures for the core-stored energy calculation account for appropriate uncertainties associated with the models in the PAD code (such as calibration of the thermal model, pellet densification model, or cladding creep model). In addition, the fuel temperatures for the core-stored energy calculation account for appropriate uncertainties associated with manufacturing tolerances (such as pellet as-built density). The total uncertainty for the fuel temperature calculation is a statistical combination of these effects and is dependent upon fuel type, power level, and burnup.

8. An allowance for RCS initial pressure uncertainty (+70 psi)

9. A maximum containment backpressure equal to design pressure

10. The steam generator metal mass was modeled to include only the portions of the steam generators that are in contact with the fluid on the secondary side. Portions of the steam generators such as the elliptical head, upper shell, and miscellaneous internals have poor heat transfer due to location. The heat stored in these areas available for release to containment will not be able to effectively transfer energy to the RCS. Therefore, the energy will be removed at a much slower rate and time period (>10,000 seconds).

11. A provision for modeling steam flow in the secondary side through the steam generator turbine stop valve was conservatively addressed only at the start of the event. A turbine stop valve isolation time equal to 0.0 seconds was used.

12. As noted in Section 2.4 of Reference 4, the option to provide more specific modeling pertaining to decay heat has been exercised to specifically reflect the Watts Bar Unit 1 core heat generation, while retaining the two sigma uncertainty to assure conservatism.

13. Steam generator tube plugging leveling (0-percent uniform)

    a. Maximizes reactor coolant volume and fluid release

    b. Maximizes heat transfer area across the steam generators tubes

    c. Reduces coolant loop resistance, which reduces the Δp upstream of the break and increases break flow

Therefore, based on the previously noted conditions and assumptions, a bounding analysis of Watts Bar Nuclear Plant Unit 1 is made for the release of mass and energy from the RCS in the event of a LOCA to support the RSG Program.

1.4 LONG-TERM LOCA MASS AND ENERGY RELEASE ANALYSIS

1.4.1 Introduction

The evaluation model used for the long-term LOCA mass and energy release calculations is the March 1979 model described in Reference 4. This evaluation model has been reviewed and approved by the NRC (References 4 and 5), and has been used in the analysis of other ice condenser plants.

This report section presents the long-term LOCA mass and energy releases that were generated in support of the Watts Bar Unit 1 RSG Program. These mass and energy releases are then subsequently used in the LOTIC-1 computer code (Reference 6) for containment integrity analysis peak pressure calculations.

1.4.2 LOCA Mass and Energy Release Phases

The containment system receives mass and energy releases following a postulated rupture in the RCS. These releases continue over a time period, which is typically divided into four phases:

1. Blowdown – the period of time from accident initiation (when the reactor is at steady-state operation) to the time that the RCS and containment reach an equilibrium state at containment design pressure.

2. Refill – the period of time when the reactor vessel lower plenum is being filled by accumulator and Emergency Core Cooling System (ECCS) water. At the end of blowdown, a large amount of water remains in the cold legs, downcomer, and lower plenum. To conservatively consider the refill period for the purpose of containment mass and energy releases, it is assumed that this water is instantaneously transferred to the lower plenum along with sufficient accumulator water to completely fill the lower plenum. This allows an uninterrupted release of mass and energy to containment. Therefore, the refill period is conservatively neglected in the mass and energy release calculation.

3. Reflood – begins when the water from the reactor vessel lower plenum enters the core and ends when the core is completely quenched.

4. Post-reflood (froth) – describes the period following the reflood transient. For the pump suction break, a two-phase mixture exits the core, passes through the hot legs, and is superheated in the steam generators prior to release to containment. After the broken loop steam generator cools, the break flow becomes two phase.

1.4.3 Computer Codes

The Reference 4 mass and energy release evaluation model is comprised of mass and energy release versions of the following codes: SATAN VI, WREFLOOD, FROTH, and EPITOME. These codes were used to calculate the long-term LOCA mass and energy releases for Watts Bar Unit 1.

The SATAN-VI code calculates blowdown (the first portion of the thermal-hydraulic transient following break initiation), including pressure, enthalpy, density, mass, energy flow rates, and energy transfer between primary and secondary systems as a function of time.

The WREFLOOD code addresses the portion of the LOCA transient where the core reflooding phase occurs after the RCS has depressurized (blowdown) due to the loss of water through the break and when water supplied by the ECCS refills the reactor vessel and provides cooling to the core. The most important feature is the steam/water mixing model (see subsection 1.7.2).

The FROTH code models the post-reflood portion of the transient. The FROTH code is used for the steam generator heat addition calculation from the broken and intact loop steam generators.

The EPITOME code continues the FROTH post-reflood portion of the transient from the time at which the secondary side equilibrates to containment design pressure to the end of the transient. It also compiles a summary of data on the entire transient, including formal instantaneous mass and energy release tables and mass and energy balance tables with data at critical times.

1.5 BREAK SIZE AND LOCATION

Generic studies have been performed with respect to the effect of postulated break size on the LOCA mass and energy releases. The double-ended guillotine break has been found to be limiting due to larger mass flow rates during the blowdown phase of the transient. During the reflood and froth phases, the break size has little effect on the releases.

Three distinct locations in the RCS loop can be postulated for pipe rupture:

1. Hot leg (between vessel and steam generator)
2. Cold leg (between pump and vessel)
3. Pump suction (between steam generator and pump)

The limiting break location analyzed for the RSG Program is the double-ended pump suction guillotine (DEPSG) (10.46 ft2). Break mass and energy releases have been calculated for the blowdown, reflood, and post-reflood phases of the LOCA for each case analyzed. The following paragraphs provide a discussion on each break location.

The hot leg double-ended guillotine has been shown in previous studies to result in the highest blowdown mass and energy release rates. Although the core flooding rate would be the highest for this break location, the amount of energy released from the steam generator secondary is minimal because the majority of the fluid that exits the core bypasses the steam generators, venting directly to containment. As a result, the reflood mass and energy releases are reduced significantly as compared to either the pump suction or cold leg break locations, where the core exit mixture must pass through the steam generators before venting through the break. For the hot leg break, generic studies have confirmed that there is no reflood peak (that is, from the end of the blowdown period the containment pressure would continually decrease). The mass and energy releases for the hot leg break have not been included in the scope of this containment integrity analysis because, for the hot leg break, only the blowdown phase of the transient is of any significance. Since there are no reflood or post-reflood phases to consider, the limiting peak pressure calculated would be the compression peak pressure and not the peak pressure following ice bed melt-out.

The cold leg break location has been found in previous studies to be much less limiting in terms of the overall containment energy releases. The cold leg blowdown is faster than that of the pump suction break, and more mass is released into the containment. However, the core heat transfer is greatly reduced, and this results in a considerably lower energy release into containment. Studies have determined that the blowdown transient for the cold leg is less limiting than that for the pump suction break. During cold leg reflood, the flooding rate is greatly reduced and the energy release rate into the containment is reduced. Therefore, the cold leg break is not included in the scope of this program.

The pump suction break combines the effects of the relatively high core flooding rate, as in the hot leg break, and the addition of the stored energy in the steam generators. As a result, the pump suction break yields the highest energy flow rates during the post-blowdown period by including all of the available energy of the RCS in calculating the releases to containment. This break has been determined to be the limiting break for the Westinghouse-design ice condenser plants.

In summary, the analysis of the limiting break location for an ice condenser containment has been performed and is shown in this report. The DEPSG break has historically been considered to be the limiting break location, by virtue of its consideration of all energy sources in the RCS. This break location provides a mechanism for the release of the available energy in the RCS, including both the broken and intact loop steam generators.

1.6 APPLICATION OF SINGLE-FAILURE CRITERIA

An analysis of the effects of the single-failure criteria has been performed on the mass and energy release rates for the DEPSG break. An inherent assumption in the generation of the mass and energy release is that offsite power is lost. This results in the actuation of the emergency diesel generators, required to power the Safety Injection System. This is not an issue for the blowdown period, which is limited by the compression peak pressure.

The limiting minimum safety injection case has been analyzed for the effects of a single failure. In the case of minimum safeguards, the single failure postulated to occur is the loss of an emergency diesel generator. This results in the loss of one pumped safety injection train, that is, ECCS pumps and heat exchangers.

1.7 MASS AND ENERGY RELEASE DATA

1.7.1 Blowdown Mass and Energy Release Data

A version of the SATAN-VI code is used for computing the blowdown transient, which is the code used for the ECCS calculation in Reference 7.

The code utilizes the control volume (element) approach with the capability for modeling a large variety of thermal fluid system configurations. The fluid properties are considered uniform and thermodynamic equilibrium is assumed in each element. A point kinetics model is used with weighted feedback effects. The major feedback effects include moderator density, moderator temperature, and Doppler broadening. A critical flow calculation for subcooled (modified Zaloudek), two-phase (Moody), or superheated break flow is incorporated into the analysis. The methodology for the use of this model is described in Reference 4.

Table 1-4 presents the calculated LOCA mass and energy releases for the blowdown phase of the DEPSG break. For the pump suction breaks, break path 1 in the mass and energy release tables refers to the mass and energy exiting from the steam generator side of the break; break path 2 refers to the mass and energy exiting from the pump side of the break.

1.7.2 Reflood Mass and Energy Release Data

The WREFLOOD code used for computing the reflood transient is a modified version of that used in the 1981 ECCS evaluation model, Reference 7.

The WREFLOOD code consists of two basic hydraulic models – one for the contents of the reactor vessel and one for the coolant loops. The two models are coupled through the interchange of the boundary conditions applied at the vessel outlet nozzles and at the top of the downcomer. Additional transient phenomena, such as pumped safety injection and accumulators, reactor coolant pump performance, and steam generator release are included as auxiliary equations that interact with the basic models as required. The WREFLOOD code permits the capability to calculate variations (during the core reflooding transient) of basic parameters such as core flooding rate, core and downcomer water levels, fluid thermodynamic conditions (pressure, enthalpy, density) throughout the primary system, and mass flow rates through the primary system. The code permits hydraulic modeling of the two flow paths available for discharging steam and entrained water from the core to the break; that is, the path through the broken loop and the path through the unbroken loops.

A complete thermal equilibrium mixing condition for the steam and emergency core cooling injection water during the reflood phase has been assumed for each loop receiving ECCS water. This is consistent with the usage and application of the Reference 4 mass and energy release evaluation model. Even though the Reference 4 model credits steam/mixing only in the intact loop and not in the broken loop, justification, applicability, and NRC approval for using the mixing model in the broken loop has been documented (Reference 8). This assumption is justified and supported by test data, and is summarized as follows.

The model assumes a complete mixing condition (that is, thermal equilibrium) for the steam/water interaction. The complete mixing process is made up of two distinct physical processes. The first is a two-phase interaction with condensation of steam by cold ECCS water. The second is a single-phase mixing of condensate and ECCS water. Since the steam release is the most important influence to the containment pressure transient, the steam condensation part of the mixing process is the only part that need be considered. (Any spillage directly heats only the sump.)

The most applicable steam/water mixing test data has been reviewed for validation of the containment integrity reflood steam/water mixing model. This data is generated in 1/3 scale tests (Reference 9), which are the largest scale data available and thus most clearly simulate the flow regimes and gravitational effects that would occur in a pressurized water reactor (PWR). These tests were designed specifically to study the steam/water interaction for PWR reflood conditions.

From the entire series of 1/3 scale tests, one group corresponds almost directly to containment integrity reflood conditions. The injection flow rates from this group cover all phases and mixing conditions calculated during the reflood transient. The data from these tests were reviewed and discussed in detail in Reference 4. For all of these tests, the data clearly indicate the occurrence of very effective mixing with rapid steam condensation. The mixing model used in the containment integrity reflood calculation is therefore wholly supported by the 1/3 scale steam/water mixing data.

Additionally, the following justification is also noted. The post-blowdown limiting break for the containment integrity peak pressure analysis is the DEPSG break. For this break, there are two flow paths available in the RCS by which mass and energy may be released to containment. One is through the outlet of the steam generator, the other is via reverse flow through the reactor coolant pump. Steam that is not condensed by ECCS injection in the intact RCS loops passes around the downcomer and through the broken loop cold leg and pump in venting to containment. This steam also encounters ECCS injection water as it passes through the broken loop cold leg, complete mixing occurs, and a portion of it is condensed. It is this portion of steam, which is condensed, for which this analysis takes credit. This assumption is justified based upon the postulated break location and the actual physical presence of the ECCS injection nozzle. A description of the test and test results is contained in References 4 and 9.

Table 1-5 presents the calculated mass and energy release for the reflood phase of the pump suction double ended rupture with minimum safety injection.

The transients of the principal parameters during reflood are given in Table 1-6.

1.7.3 Post-Reflood Mass and Energy Release Data

The FROTH code (Reference 10) is used for computing the post-reflood transient.

The FROTH code calculates the heat release rates resulting from a two-phase mixture level present in the steam generator tubes. The mass and energy releases that occur during this phase are typically superheated due to the depressurization and equilibration of the broken loop and intact loop steam generators. During this phase of the transient, the RCS has equilibrated with the containment pressure, but the steam generators contain a secondary inventory at an enthalpy that is much higher than the primary side. Therefore, a significant amount of reverse heat transfer occurs. Steam is produced in the core due to core decay heat. For a pump suction break, a two-phase fluid exits the core, flows through the hot legs, and becomes superheated as it passes through the steam generator. Once the broken loop cools, the break flow becomes two-phase. The methodology for the use of this model is described in Reference 4.

After steam generator depressurization/equilibration, the mass and energy release available to containment is generated directly from core boiloff/decay heat.

Table 1-7 presents the two-phase post-reflood (froth) mass and energy release data for the pump suction double-ended break case.

1.7.4 Decay Heat Model

On November 2, 1978 the Nuclear Power Plant Standards Committee (NUPPSCO) of the American Nuclear Society (ANS) approved ANS standard 5.1 for the determination of decay heat. This standard was used in the mass and energy release model with the following input specific for Watts Bar Unit 1. The primary assumptions that make this calculation specific for Watts Bar Unit 1 are the enrichment factor, minimum/maximum new fuel loading per cycle, and a conservative end of cycle core average burnup. A conservative lower bound for enrichment of 3 percent was used. Table 1-2 lists the decay heat curve used in the Watts Bar ice weight optimization analysis.

Significant assumptions in the generation of the decay heat curve are the following:

1. Decay heat sources considered are fission product decay and heavy element decay of U-239 and Np-239.

2. Decay heat power from the following fissioning isotopes are included: U-238, U-235, and Pu-239.

3. Fission rate is constant over the operating history of maximum power level.

4. The factor accounting for neutron capture in fission products has been taken from Equation 11, of Reference 11 (up to 10,000 seconds) and Table 10 of Reference 11 (beyond 10,000 seconds).

5. The fuel has been assumed to be at full power for 1,096 days.

6. The number of atoms of U-239 produced per second has been assumed to be equal to 70 percent of the fission rate.

7. The total recoverable energy associated with one fission has been assumed to be 200 MeV/fission.

8. Two sigma uncertainty (two times the standard deviation) has been applied to the fission product decay.

1.7.5 Steam Generator Equilibration and Depressurization

Steam generator equilibration and depressurization is the process by which secondary-side energy is removed from the steam generators in stages. The FROTH computer code calculates the heat removal from the secondary mass until the secondary temperature is saturated at the containment design pressure. After the FROTH calculations, steam generator secondary energy is removed until the steam generator reaches Tsat at the user-specified intermediate equilibration pressure, when the secondary pressure is assumed to reach the actual containment pressure. The heat removal of the broken loop steam generator and intact loop steam generators are calculated separately.

During the FROTH calculations, steam generator heat removal rates are calculated using the secondary-side temperature, primary-side temperature, and a secondary-side heat transfer coefficient determined using a modified McAdam's correlation (Reference 12). Steam generator energy is removed during the FROTH transient until the secondary-side temperature reaches saturation temperature at the containment design pressure. The constant heat removal rate used is based on the final heat removal rate calculated by FROTH. The remaining steam generator energy available to be released is determined by calculating the difference in secondary energy available at the containment design pressure and that at the (lower) user-specified equilibration pressure, assuming saturated conditions. This energy is then divided by the energy removal rate, resulting in an equilibration time.

1.8 SOURCES OF MASS AND ENERGY

The sources of mass considered in the LOCA mass and energy release analysis are given in Table 1-8. These sources are the RCS, accumulators, and pumped safety injection.

The energy inventories considered in the LOCA mass and energy release analysis are given in Table 1-9. The energy sources include:

- RCS water
- Accumulator water

- Pumped injection water
- Decay heat
- Core-stored energy
- RCS metal – primary metal (includes steam generator tubes)
- Steam generator metal (includes transition cone, shell, wrapper, and other internals)
- Steam generator secondary energy (includes fluid mass and steam mass)
- Secondary transfer of energy (feedwater into and steam out of the steam generator secondary)

It should be noted that the inconsistency in the energy balance tables from the end of reflood to the time of intact loop steam generator depressurization/equilibration ("Total Available" data versus "Total Accountable") resulted from the exclusion of the reactor upper head in the analysis following blowdown. It has been concluded that the results are more conservative when the upper head is neglected. This does not affect the instantaneous mass and energy releases or the integrated values, but causes an increase in the total accountable energy within the energy balance table.

The mass and energy inventories are presented at the following times, as appropriate:

- Time zero (initial conditions)
- End of blowdown time
- End of refill time
- End of reflood time
- Time of broken loop steam generator equilibration to pressure setpoint
- Time of intact loop steam generator equilibration to pressure setpoint

The sequence of events for the DEPSG case is shown in Table 1-10.

The energy release from the Zirc-water reaction is considered as part of the WCAP-10325-P-A methodology. Based on the way that the energy in the fuel is conservatively released to the vessel fluid, the fuel cladding temperature does not increase to the point were the Zirc-water reaction is significant. This is in contrast to the Code of Federal Regulations (CFR) 10 CFR 50.46 analyses, which are biased to calculate high fuel rod cladding temperatures and therefore a non-significant Zirc-water reaction. For the LOCA mass and energy calculation, the energy created by the Zirc-water reaction value is small and is not explicitly provided in the energy balance tables. The energy that is determined is part of the mass and energy releases and is therefore already included in the LOCA mass and energy release.

The consideration of the various energy sources in the mass and energy release analysis provides assurance that all available sources of energy have been included in this analysis. Therefore, the review guidelines presented in Standard Review Plan (SRP) Section 6.2.1.3 have been satisfied.

1.9 REFERENCES

1. TVA Letter W-7752, J. C. Kammeyer (TVA) to Kirsh M. Rajan (Westinghouse), "TVA Proposed Change to the Stroke Time for Valve 1-FCV-72-2 (W-1-9001B)," June 23, 2004.

2. TVA Letter TVWES-0339, P. G Trudel (TVA) to Steve Radomski (Westinghouse), "DOCUMENT SUBMITTAL – LOCA MASS AND ENERGY RELEASE INPUT ASSUMPTIONS," May 24, 2004.

3. TVA Letter TVWES-0382, P. G Trudel (TVA) to Steve Radomski (Westinghouse), "INFORMATION SUBMITTAL – ANALYTICAL INPUTS FOR ICE CONDENSER ICE MASS CALCULATIONS," June 28, 2004.

4. WCAP-10325-P-A, May 1983 (Proprietary) and WCAP-10326-A (Non-Proprietary), "Westinghouse LOCA Mass and Energy Release Model for Containment Design March 1979 Version."

5. Letter from Herbert N. Berkow (NRC) to James A. Gresham (Westinghouse), Subject – Acceptance of Clarifications of Topical Report WCAP-10325-P-A, "Westinghouse LOCA Mass and Energy Release Model for Containment Design – March 1979 Version" (TAC No. MC7980), October 18, 2005.

6. WCAP-8354-P-A, April 1976 (Proprietary) and WCAP-8355-A (Non-Proprietary), "LONG TERM ICE CONDENSER CONTAINMENT CODE – LOTIC CODE."

7. WCAP-9220-P-A, Revision 1, February 1982 (Proprietary) and WCAP-9221-A, Revision 1 (Non-Proprietary), "Westinghouse ECCS Evaluation Model 1981 Version."

8. Docket No. 50-315, "Amendment No. 126, Facility Operating License No. DPR-58 (TAC No. 71062), for D.C. Cook Nuclear Plant Unit 1," June 9, 1989.

9. EPRI 294-2, "Mixing of Emergency Core Cooling Water with Steam; 1/3-Scale Test and Summary," (WCAP-8423), Final Report, June 1975.

10. WCAP-8264-P-A, Revision 1, August 1975 (Proprietary) and WCAP-8312-A, Revision 2 (Non-Proprietary) "TOPICAL REPORT WESTINGHOUSE MASS AND ENERGY RELEASE DATA FOR CONTAINMENT DESIGN."

11. ANSI/ANS-5.1-1979, "American National Standard for Decay Heat Power in Light Water Reactors," August 1979.

12. W. H. McAdam, "Heat Transmission," McGraw-Hill 3rd edition, 1954, p.172.

Table 1-1 System Parameters Initial Conditions	
Parameters	**Value**
Core Thermal Power (MWt)	3,459
Reactor Coolant System Flow Rate, per Loop (gpm)	93,100
Vessel Outlet Temperature$^{(1)}$ (°F)	619.1
Core Inlet Temperature$^{(1)}$ (°F)	557.3
Vessel Average Temperature$^{(1)(2)}$ (°F)	588.2
Initial Steam Generator Steam Pressure (psia)	1,058
Steam Generator Design	Model 68AXP
Steam Generator Tube Plugging (%)	0
Initial Steam Generator Secondary-Side Mass (lbm)	140,661.4
Accumulator	
Water Volume (ft^3)	1,020/tank plus 24.06 (average) per line
N2 Cover Gas Pressure (psig)	585
Temperature (°F)	130
Safety Injection Delay (sec) (includes time to reach pressure setpoint)	34.9
Auxiliary Feedwater Flow (gpm/steam generator)	205

Note:

1. Analysis value includes an additional +7.0°F allowance for instrument error and dead band.
2. This temperature assumes that the plant is not operating at the reduced 2°F Tavg (586.2°F). Therefore, margin exists in this analysis input if the plant operates at a reduced average temperature.

Table 1-2 System Parameters Decay Heat Curve	
Time (sec)	Decay Heat (Btu/Btu)
10.	.0506850
15.	.0477187
20.	.0456218
40.	.0406962
60.	.0378482
80.	.0358667
100.	.0343802
150.	.0318330
200.	.0301404
400.	.0264229
600.	.0242907
800.	.0227336
1,000.	.0214999
1,500.	.0192069
2,000.	.0175824
4,000.	.0140451
6,000.	.0123786
8,000.	.0113975
10,000.	.0107264
15,000.	.0100411
20,000.	.0093567
40,000.	.0079090
60,000.	.0071368
80,000.	.0066021
100,000.	.0062046
150,000.	.0054924
200,000.	.0050014
400,000.	.0038711
600,000.	.0032712
800,000.	.0028872
1,000,000.	.0026231
1,500,000.	.0022001
2,000,000.	.0019386
4,000,000.	.0013911
6,000,000.	.0011338
8,000,000.	.0009754
10,000,000.	.0008662

Key Assumptions:
End of cycle core average burnup less than 45,000 Mwd/MTU
Standard, V5H fuel and RFA-2 fuel upgrade
Core Average Enrichment greater than 3.0%

Table 1-3 Safety Injection Flow Minimum Safety Injection	
Injection Mode	
RCS Pressure (psia)	**Total Flow (gpm)**
15.0	4,788.3
55.0	4,330.4
115.0	3,477.3
175.0	2,067.7
215.0	886.0
315.0	852.8
Injection Mode (Post-Reflood Phase)	
RCS Pressure (psia)	**Total Flow (gpm)**
28.2	4,637.68
Recirculation Mode (w/o Residual Heat Removal (RHR) Spray)	
RCS Pressure (psia)	**Total Flow (gpm)**
0	3,757.5
Recirculation Mode (w/ RHR Spray)	
RCS Pressure (psia)	**Total Flow (gpm)**
0	1,855

Table 1-4 Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release				
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
.00000	.0	.0	.0	.0
.00106	92,594.2	52,001.6	42,991.6	24,084.1
.00207	43,121.7	24,157.4	42,732.8	23,937.5
.102	42,511.9	23,868.1	22,249.0	12,451.8
.201	42,970.6	24,240.3	24,421.2	13,678.2
.301	43,561.8	24,725.6	24,460.0	13,711.2
.402	44,154.4	25,248.4	23,567.2	13,222.3
.502	44,748.1	25,802.9	22,432.6	12,593.9
.602	45,161.4	26,275.6	21,477.2	12,061.8
.702	45,221.9	26,545.9	20,634.7	11,591.1
.801	44,797.9	26,517.0	20,018.7	11,247.8
.902	43,943.7	26,220.0	19,612.3	11,023.7
1.00	42,941.5	25,821.0	19,399.2	10,906.6
1.10	41,918.4	25,410.5	19,277.1	10,840.0
1.20	40,938.1	25,000.9	19,208.2	10,802.4
1.30	39,996.7	25,622.0	19,165.6	10,778.9
1.40	39,049.0	24,237.1	19,147.6	10,768.8
1.50	38,097.8	23,842.2	19,163.3	10,777.8
1.60	37,183.0	23,459.4	19,198.9	10,798.0
1.70	36,328.9	23,112.1	19,228.7	10,814.9
1.80	35,502.3	22,778.0	19,231.3	10,816.3
1.90	34,629.0	22,414.8	19,219.9	10,809.7
2.00	33,704.8	22,018.8	19,215.3	10,807.2
2.10	32,694.3	21,567.0	19,175.3	10,784.8
2.20	31,732.0	21,140.7	19,094.9	10,739.6
2.30	30,737.8	20,684.7	18,979.7	10,675.0
2.40	29,721.5	20,199.2	18,834.4	10,593.5
2.50	28,713.0	19,704.0	18,457.0	10,380.0

Table 1-4 (cont.)	Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release			
Time	**Break Path No. 1**		**Break Path No. 2**	
Second	**Mass lbm/sec**	**Energy Thousand Btu/sec**	**Mass lbm/sec**	**Energy Thousand Btu/sec**
2.60	27,530.3	19,069.6	18,157.7	10,212.9
2.70	25,632.3	17,904.1	17,968.5	10,107.9
2.80	22,975.8	16,166.4	17,763.0	9,993.2
2.90	21,670.2	15,384.3	17,534.9	9,865.9
3.00	20,840.4	14,899.1	17,324.2	9,748.8
3.10	19,750.5	14,186.1	17,135.4	9,644.3
3.20	18,914.4	13,645.0	16,941.8	9,537.2
3.30	18,161.6	13,149.5	16,767.1	9,440.9
3.40	17,463.6	12,684.8	16,611.6	9,355.6
3.50	16,848.8	12,275.1	16,456.9	9,270.7
3.60	16,296.6	11,904.7	16,310.5	9,190.6
3.70	15,828.3	11,590.8	16,181.3	9,120.3
3.80	15,435.0	11,326.7	16,056.9	9,052.7
3.90	15,087.9	11,090.4	15,929.9	8,983.6
4.00	14,777.5	10,876.1	15,811.1	8,919.2
4.20	14,291.5	10,536.0	15,603.1	8,807.2
4.40	13,909.1	10,255.6	15,388.1	8,691.3
4.60	13,630.0	10,039.1	15,177.8	8,578.1
4.80	13,419.5	9,861.2	14,968.5	8,465.6
5.00	13,286.1	9,730.4	14,780.7	8,365.1
5.20	13,206.0	9,630.0	15,234.0	8,635.4
5.40	13,192.9	9,573.1	16,175.7	9,169.6
5.60	13,260.2	9,567.4	15,893.3	9,014.5
5.80	13,369.4	9,586.6	15,783.1	8,958.5
6.00	13,518.2	9,634.2	15,574.6	8,845.0
6.20	13,693.0	9,700.2	15,377.7	8,739.3
6.40	13,869.8	9,768.9	15,207.2	8,648.2
6.60	14,006.4	9,801.3	15,083.9	8,583.4

Table 1-4 (cont.)	Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release			
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
6.80	13,654.9	9,631.7	14,989.4	8,532.8
7.00	12,528.0	9,276.8	14,733.8	8,388.1
7.20	11,292.8	8,799.7	14,670.6	8,353.2
7.40	10,976.6	8,646.9	14,488.3	8,249.0
7.60	11,137.8	8,670.0	14,288.7	8,134.7
7.80	11,462.1	8,780.0	14,154.2	8,057.2
8.00	11,881.6	8,948.8	13,970.1	7,950.8
8.20	12,404.3	9,176.4	13,777.9	7,839.9
8.40	12,964.9	9,418.5	13,598.7	7,736.6
8.60	13,488.8	9,635.8	13,412.0	7,629.0
8.80	13,894.3	9,784.0	13,236.0	7,527.5
9.00	14,110.1	9,823.2	13,064.3	7,428.3
9.20	14,080.6	9,720.5	12,897.5	7,331.8
9.40	13,805.3	9,478.1	12,747.3	7,244.7
9.60	13,392.9	9,168.5	12,605.2	7,162.2
9.80	12,919.5	8,834.7	12,468.2	7,082.6
10.0	12,304.7	8,421.5	12,352.0	7,015.0
10.2	11,622.6	7,989.2	12,261.8	6,962.2
10.4	11,145.0	7,718.1	12,146.9	6,894.7
10.6	10,807.2	7,542.0	12,010.4	6,815.6
10.8	10,418.4	7,331.8	11,916.5	6,761.9
11.0	10,078.2	7,162.6	11,792.4	6,690.2
11.2	9,788.2	7,021.7	11,660.6	6,613.9
11.4	9,496.7	6,871.4	11,551.3	6,551.0
11.6	9,235.9	6,736.3	11,428.8	6,479.9
11.8	8,994.3	6,608.3	11,307.3	6,409.5
12.0	8,771.6	6,488.5	11,196.5	6,345.3
12.2	8,568.6	6,379.0	11,077.0	6,275.9

Table 1-4 (cont.)	Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release			
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
12.4	8,380.8	6,276.7	10,963.2	6,210.1
12.6	8,205.8	6,179.0	10,849.1	6,144.2
12.8	8,035.7	6,080.9	10,718.2	6,068.6
13.0	7,865.0	5,978.9	10,582.8	5,991.1
13.2	7,697.8	5,874.0	10,452.6	5,917.0
13.4	7,539.4	5,762.6	10,318.9	5,840.9
13.6	7,398.8	5,649.8	10,187.2	5,765.9
13.8	7,269.8	5,538.2	10,056.3	5,691.4
14.0	7,166.4	5,446.0	9,925.3	5,617.2
14.2	7,062.1	5,351.1	9,802.7	5,548.0
14.4	6,966.9	5,260.8	9,683.9	5,481.2
14.6	6,881.6	5,177.4	9,573.8	5,419.6
14.8	6,769.6	5,097.5	9,444.1	5,346.8
15.0	6,721.1	5,032.3	9,377.4	5,311.0
15.2	6,639.1	4,968.8	9,263.6	5,248.2
15.4	6,554.9	4,912.5	9,170.5	5,197.9
15.6	6,462.5	4,857.5	9,082.1	5,151.2
15.8	6,365.0	4,805.6	8,981.6	5,097.8
16.0	6,261.9	4,755.1	8,891.8	5,051.4
16.2	6,156.3	4,707.0	8,799.7	5,004.5
16.4	6,047.8	4,660.4	8,704.2	4,956.7
16.6	5,939.2	4,616.2	8,608.7	4,910.1
16.8	5,830.4	4,574.0	8,512.3	4,864.6
17.0	5,722.5	4,534.3	8,340.1	4,776.3
17.2	5,626.3	4,507.2	8,152.3	4,686.2
17.4	5,562.6	4,509.3	7,923.4	4,611.6
17.6	5,537.1	4,590.6	7,615.6	4,488.8
17.8	5,390.8	4,685.3	7,352.2	4,373.7

Table 1-4 (cont.)	Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release			
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
18.0	5,070.6	4,717.7	7,002.3	4,173.6
18.2	4,613.1	4,646.8	6,653.4	3,900.6
18.4	4,149.2	4,532.6	6,396.6	3,626.0
18.6	3,720.6	4,347.9	6,203.3	3,364.8
18.8	3,382.4	4,108.9	5,918.5	3,074.4
19.0	3,047.9	3,751.0	5,560.5	2,786.8
19.2	2,781.0	3,443.1	5,235.3	2,547.3
19.4	2,551.9	3,172.2	4,921.8	2,334.1
19.6	2,348.2	2,928.6	4,630.7	2,146.4
19.8	2,171.1	2,715.1	4,366.3	1,982.5
20.0	2,032.4	2,548.2	4,081.3	1,818.7
20.2	1,901.0	2,387.8	3,596.6	1,560.7
20.4	1,786.5	2,247.8	3,250.3	1,352.3
20.6	1,649.5	2,078.4	3,582.0	1,428.4
20.8	1,502.4	1,896.7	4,306.4	1,679.7
21.0	1,370.1	1,732.5	4,746.6	1,833.7
21.2	1,255.4	1,590.1	3,697.4	1,416.8
21.4	1,161.1	1,472.8	3,092.4	1,181.9
21.6	1,081.1	1,373.0	2,722.6	1,038.3
21.8	1,000.9	1,272.4	2,177.7	828.2
22.0	912.3	1,160.6	1,514.7	559.2
22.2	819.9	1,044.1	2,000.5	628.0
22.4	731.3	932.3	3,795.8	1,116.6
22.6	647.3	825.9	4,346.2	1,264.4
22.8	579.5	740.2	3,898.6	1,133.0
23.0	520.7	665.7	2,750.6	799.4
23.2	474.2	606.8	2,673.9	777.2
23.4	444.2	569.1	2,693.9	783.1

Table 1-4 (cont.)	Double-Ended Pump Suction *Guillotine* Blowdown Mass and Energy Release			
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
23.6	425.5	545.4	2,694.3	783.4
23.8	406.7	521.6	2,690.8	782.6
24.0	382.2	490.2	2,669.2	776.7
24.2	349.0	447.8	2,600.9	757.6
24.4	316.7	406.6	2,262.9	660.4
24.6	284.4	365.4	1,885.7	551.9
24.8	253.6	325.9	1,533.4	447.7
25.0	223.4	287.3	1,309.9	376.5
25.2	195.6	251.7	1,352.8	380.7
25.4	171.8	221.1	1,413.1	394.5
25.6	153.2	197.4	1,414.4	394.5
25.8	149.1	192.1	1,338.9	374.1
26.0	140.3	180.9	1,130.2	317.0
26.2	132.7	171.1	745.6	211.0
26.4	121.5	156.7	121.1	35.0
26.6	111.9	144.5	327.6	97.7
26.8	104.3	134.7	306.1	93.1
27.0	88.0	113.7	268.2	81.2
27.2	80.2	103.6	.0	.0
27.4	74.1	95.8	23.4	7.6
27.6	49.4	64.0	14.6	5.0
27.8	52.7	68.3	61.0	21.6
28.0	43.0	55.8	.0	.0
28.2	27.7	36.0	.0	.0
28.4	6.7	8.7	.0	.0
28.6	5.8	7.6	.0	.0
28.8	.0	.0	.0	.0

Table 1-5	Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection			
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
28.81	.0	.0	.0	.0
29.3	.0	.0	.0	.0
29.5	.0	.0	.0	.0
29.6	.0	.0	.0	.0
29.7	.0	.0	.0	.0
29.8	.0	.0	.0	.0
29.81	.0	.0	.0	.0
29.9	33.2	38.6	.0	.0
30.0	13.7	16.0	.0	.0
30.2	14.6	17.0	.0	.0
30.3	19.1	22.2	.0	.0
30.4	22.9	26.6	.0	.0
30.5	26.8	31.2	.0	.0
30.6	30.7	35.7	.0	.0
30.7	34.4	40.1	.0	.0
30.8	38.1	44.3	.0	.0
30.9	41.4	48.2	.0	.0
31.0	44.1	51.3	.0	.0
31.1	46.7	54.4	.0	.0
31.2	49.2	57.3	.0	.0
31.3	51.6	60.1	.0	.0
31.4	53.9	62.8	.0	.0
31.5	56.5	65.8	.0	.0
31.6	58.9	68.6	.0	.0
31.7	61.3	71.4	.0	.0
31.8	63.6	74.1	.0	.0
31.9	65.6	76.4	.0	.0
32.9	83.6	97.4	.0	.0

Table 1-5 (cont.) **Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection**

Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
33.9	98.7	115.1	.0	.0
34.9	237.4	278.4	3,229.9	423.7
36.0	361.7	426.3	4,952.4	707.4
36.6	360.6	425.0	4,939.4	708.5
37.0	359.0	423.1	4,918.4	706.4
38.0	354.2	417.3	4,856.0	699.0
39.0	349.1	411.2	4,788.4	690.5
40.0	344.0	405.1	4,719.6	681.7
41.0	339.0	399.1	4,651.5	672.8
42.0	334.2	393.4	4,584.7	664.0
42.3	332.8	391.7	4,565.0	661.4
43.0	329.6	387.9	4,519.6	655.4
44.0	325.2	382.6	4,456.6	647.1
45.0	320.7	377.3	4,395.8	639.0
46.0	315.9	371.6	4,337.3	631.4
47.0	311.3	366.1	4,280.8	623.9
48.0	306.9	360.9	4,226.1	616.8
49.0	302.7	355.9	4,173.3	609.8
49.9	299.0	351.5	4,127.2	603.8
50.0	298.6	351.0	4,122.2	603.1
51.0	294.7	346.4	4,072.8	596.6
52.0	291.0	341.9	4,024.9	590.4
53.0	287.4	337.6	3,978.6	584.3
54.0	283.9	333.5	3,933.6	578.4
55.0	280.5	329.5	3,890.0	572.7
56.0	277.3	325.7	3,847.7	567.1
57.0	274.2	321.9	3,806.6	561.7

Table 1-5 (cont.)	Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection			
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
58.0	271.1	318.3	3,766.7	556.5
59.0	268.2	314.9	3,727.9	551.4
59.2	267.6	314.2	3,720.2	550.4
60.0	265.4	311.5	3,690.1	546.5
61.0	262.6	308.3	3,653.3	541.7
62.0	260.0	305.1	3,617.5	537.0
63.0	257.4	302.0	3,582.6	532.5
64.0	254.9	299.1	3,548.6	528.0
65.0	252.5	296.2	3,515.4	523.7
66.0	250.1	293.4	3,483.1	519.5
67.0	247.8	290.7	3,451.5	515.3
68.0	245.6	288.0	3,420.6	511.3
69.0	239.7	280.9	245.8	118.1
69.7	341.6	402.2	289.0	176.5
70.0	348.2	410.1	292.4	181.4
71.0	348.6	410.6	292.6	181.9
72.0	343.1	404.0	289.8	178.1
73.0	337.6	397.5	287.0	174.3
74.0	332.4	391.2	284.4	170.7
75.0	327.3	385.2	281.9	167.2
76.0	322.4	379.3	279.4	163.8
77.0	317.0	372.8	277.1	160.7
78.0	311.5	366.3	274.7	157.6
79.0	306.8	360.7	272.7	154.9
80.0	302.5	355.6	270.9	152.4
81.0	298.3	350.6	269.1	150.1
82.0	294.3	345.9	267.4	147.9
83.0	290.5	341.4	265.8	145.7

Table 1-5 (cont.)	Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection			
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
84.0	286.9	337.1	264.3	143.7
85.0	283.4	332.9	262.8	141.8
86.0	280.1	328.9	261.4	139.9
87.0	276.9	325.2	260.1	138.1
88.0	273.8	321.5	258.8	136.5
88.9	271.2	318.4	257.7	135.0
89.0	270.9	318.0	257.6	134.8
90.0	268.1	314.7	256.4	133.3
92.0	262.8	308.4	254.3	130.4
94.0	258.0	302.7	252.3	127.8
96.0	253.5	297.5	250.4	125.4
98.0	249.5	292.6	248.8	123.2
100.0	245.7	288.2	247.3	121.2
102.0	242.3	284.1	245.9	119.4
104.0	239.1	280.4	244.6	117.7
106.0	236.3	277.0	243.4	116.2
108.0	233.6	273.9	242.4	114.8
110.0	231.2	271.0	241.4	113.5
112.0	229.0	268.4	240.5	112.3
114.0	227.0	266.1	239.7	111.3
114.1	226.9	266.0	239.7	111.2
116.0	225.2	263.9	239.0	110.3
118.0	223.6	262.0	238.3	109.4
120.0	222.1	260.2	237.7	108.7
122.0	220.7	258.6	237.1	107.9
124.0	219.5	257.1	236.7	107.3
126.0	218.4	255.8	236.2	106.7
128.0	217.4	254.7	235.8	106.2

Table 1-5 (cont.) Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection				
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
130.0	216.5	253.6	235.5	105.7
132.0	215.7	252.7	235.1	105.3
134.0	215.0	251.9	234.8	104.9
136.0	214.4	251.2	234.6	104.6
138.0	213.9	250.5	234.4	104.3
140.0	213.4	249.9	234.2	104.0
142.0	213.0	249.5	234.0	103.8
143.4	212.7	249.2	233.9	103.7
144.0	212.6	249.0	233.8	103.6
146.0	212.3	248.7	233.7	103.4
148.0	212.1	248.4	233.6	103.3
150.0	211.9	248.1	233.5	103.2
152.0	211.7	247.9	233.4	103.0
154.0	211.5	247.7	233.3	102.9
156.0	211.4	247.6	233.3	102.9
158.0	211.7	248.0	233.4	103.0
160.0	212.2	248.6	234.0	103.2
162.0	212.9	249.3	234.8	103.5
164.0	213.6	250.2	236.0	103.9
166.0	214.4	251.1	237.5	104.3
168.0	215.1	252.0	239.0	104.7
170.0	215.9	252.9	240.6	105.1
172.0	216.6	253.7	242.3	105.4
174.0	217.2	254.4	244.0	105.7
174.7	217.3	254.6	244.6	105.8
176.0	217.6	255.0	245.7	106.0
178.0	218.0	255.4	247.3	106.2
180.0	218.3	255.8	249.0	106.4

Table 1-5 (cont.)	Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection			
Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
182.0	218.6	256.1	250.7	106.5
184.0	218.7	256.3	252.4	106.6
186.0	218.8	256.4	254.1	106.7
188.0	218.9	256.5	255.9	106.8
190.0	218.9	256.5	257.7	106.8
192.0	218.9	256.4	259.6	106.9
194.0	218.7	256.3	261.5	106.9
196.0	218.5	256.0	263.4	106.9
198.0	218.3	255.7	265.3	106.8
200.0	218.0	255.3	267.3	106.8
202.0	217.6	254.9	269.3	106.7
204.0	217.1	254.3	271.3	106.6
205.8	216.6	253.8	273.1	106.5
206.0	216.6	253.7	273.3	106.5
208.0	216.0	253.0	275.4	106.4
210.0	215.4	252.3	277.6	106.3
212.0	214.7	251.5	279.8	106.1
214.0	214.0	250.7	282.1	106.0
216.0	213.3	249.8	284.5	105.9
218.0	212.5	248.9	286.9	105.7
220.0	211.6	247.9	289.3	105.6
222.0	210.7	246.8	291.7	105.4
224.0	209.7	245.6	294.2	105.2
226.0	208.6	244.3	296.7	105.0
228.0	207.5	243.0	299.2	104.8
230.0	206.4	241.6	301.7	104.6
232.0	205.1	240.1	304.0	104.3
234.0	203.7	238.5	306.4	104.0

Table 1-5 (cont.) Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection

Time	Break Path No. 1		Break Path No. 2	
Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
236.0	202.4	236.9	308.8	103.8
238.0	200.9	235.2	311.3	103.5
238.6	200.5	234.7	312.0	103.5

Table 1-6 Double-Ended Pump Suction Guillotine Minimum Safety Injection Principal Parameters During Reflood										
Time Second	Temp °F	Flooding Rate in/sec	Carry-over Fraction	Core Height ft	Down-Comer Height ft	Flow Fraction	Total (Pounds mass per second)	Injection Accumulator (Pounds mass per second)	SI Spill (Pounds mass per second)	Enthalpy Btu/lbm
28.8	204.8	.000	.000	.00	.00	.250	.0	.0	.0	.00
29.6	201.9	22.317	.000	.65	1.46	.000	7,375.4	7,375.4	.0	99.46
29.8	200.4	24.257	.000	1.04	1.38	.000	7,322.8	7,322.8	.0	99.46
31.6	200.1	2.026	.324	1.50	6.49	.351	6,857.2	6,857.2	.0	99.46
32.9	200.5	1.970	.454	1.63	10.42	.366	6,589.8	6,589.8	.0	99.46
36.0	201.1	3.937	.618	1.94	16.12	.579	5,877.8	5,292.2	.0	96.83
36.6	201.2	3.791	.640	2.01	16.12	.578	5,787.7	5,202.1	.0	96.79
37.0	201.3	3.707	.652	2.05	16.12	.578	5,736.8	5,150.7	.0	96.76
42.3	202.9	3.144	.720	2.51	16.12	.574	5,211.0	4,616.1	.0	96.44
49.9	206.4	2.775	.746	3.00	16.12	.565	4,677.0	4,073.4	.0	96.05
59.2	211.4	2.497	.758	3.50	16.12	.553	4,202.2	3,591.7	.0	95.62
68.0	216.4	2.312	.765	3.92	16.12	.543	3,858.7	3,243.6	.0	95.25
69.0	217.0	2.408	.767	3.97	16.12	.576	617.9	.0	.0	73.03
69.7	217.4	2.974	.761	4.00	16.05	.596	591.6	.0	.0	73.03
70.0	217.6	3.018	.760	4.02	16.01	.596	588.5	.0	.0	73.03
79.0	223.2	2.642	.766	4.53	15.01	.592	600.2	.0	.0	73.03
88.9	228.0	2.348	.771	5.00	14.41	.586	607.9	.0	.0	73.03
102.0	233.2	2.111	.777	5.55	14.11	.578	613.8	.0	.0	73.03
114.1	237.0	1.983	.781	6.00	14.12	.574	616.8	.0	.0	73.02

Table 1-6 (cont.) Double-Ended Pump Suction Guillotine Minimum Safety Injection Principal Parameters During Reflood

Time Second	Temp °F	Flooding Rate in/sec	Carry-over Fraction	Core Height ft	Down-Comer Height ft	Flow Fraction	Total (Pounds mass per second)	Injection Accumulator	SI Spill	Enthalpy Btu/lbm
130.0	241.1	1.892	.786	6.56	14.39	.570	618.8	.0	.0	73.03
143.4	243.9	1.854	.789	7.00	14.73	.569	619.5	.0	.0	73.03
156.0	246.1	1.837	.792	7.41	15.10	.569	619.8	.0	.0	73.03
160.0	246.8	1.840	.793	7.53	15.22	.569	619.6	.0	.0	73.03
174.7	247.3	1.867	.793	8.00	15.59	.575	618.7	.0	.0	73.02
182.0	246.9	1.872	.793	8.24	15.73	.577	618.4	.0	.0	73.03
192.0	247.4	1.863	.793	8.56	15.87	.580	618.3	.0	.0	73.03
205.8	247.2	1.833	.792	9.00	16.00	.584	618.6	.0	.0	73.03
222.0	247.5	1.772	.793	9.51	16.08	.587	619.5	.0	.0	73.03
238.6	247.2	1.683	.793	10.00	16.11	.588	621.2	.0	.0	73.03

Table 1-7 Double-Ended Pump Suction Guillotine Minimum Safety Injection Post Reflood Mass and Energy Release				
	Break Path No. 1		Break Path No. 2	
Time Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
238.7	219.0	274.8	420.9	120.9
243.7	218.2	273.7	421.8	121.0
248.7	218.9	274.6	421.1	120.7
253.7	218.0	273.5	422.0	120.8
258.7	217.1	272.4	422.9	120.9
263.7	217.7	273.2	422.2	120.6
268.7	216.8	272.0	423.1	120.7
273.7	217.4	272.8	422.5	120.5
278.7	216.5	271.6	423.5	120.6
283.7	215.6	270.5	424.4	120.7
288.7	216.1	271.2	423.8	120.4
293.7	215.2	270.0	424.8	120.5
298.7	215.7	270.6	424.3	120.3
303.7	214.7	269.4	425.3	120.4
308.7	215.2	270.0	424.8	120.2
313.7	214.2	268.7	425.8	120.3
318.7	214.6	269.2	425.4	120.1
323.7	213.6	268.0	426.4	120.2
328.7	214.0	268.4	426.0	120.0
333.7	212.9	267.1	427.1	120.1
338.7	213.2	267.5	426.7	119.9
343.7	212.2	266.2	427.8	120.0
348.7	212.4	266.5	427.5	119.8
353.7	211.3	265.1	428.6	120.0
358.7	211.6	265.4	428.4	119.8
363.7	211.8	265.7	428.2	119.6
368.7	210.6	264.2	429.4	119.8
373.7	210.7	264.4	429.2	119.6

Table 1-7 (cont.)	Double-Ended Pump Suction Guillotine Minimum Safety Injection Post Reflood Mass and Energy Release			
	Break Path No. 1		Break Path No. 2	
Time Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
378.7	210.9	264.5	429.1	119.5
383.7	209.6	263.0	430.4	119.6
388.7	209.7	263.0	430.3	119.5
393.7	209.7	263.1	430.3	119.4
398.7	208.4	261.4	431.6	119.5
403.7	208.4	261.5	431.5	119.4
408.7	208.5	261.5	431.5	119.3
413.7	208.5	261.5	431.5	119.2
418.7	207.2	259.9	432.8	119.4
423.7	207.1	259.8	432.9	119.3
428.7	207.0	259.7	433.0	119.2
433.7	206.8	259.5	433.1	119.1
438.7	206.6	259.2	433.4	119.0
443.7	206.3	258.9	433.6	119.0
448.7	206.0	258.5	433.9	118.9
453.7	205.6	258.0	434.3	118.9
458.7	205.2	257.5	434.8	118.9
463.7	204.7	256.8	435.3	118.9
468.7	204.2	256.1	435.8	118.9
473.7	204.6	256.7	435.3	118.7
478.7	203.9	255.8	436.1	118.7
483.7	203.1	254.8	436.8	118.8
488.7	203.3	255.1	436.7	118.6
493.7	203.4	255.1	436.6	118.5
498.7	202.3	253.8	437.7	118.6
503.7	202.1	253.6	437.9	118.5
508.7	201.8	253.2	438.2	118.5

Table 1-7 (cont.)	Double-Ended Pump Suction Guillotine Minimum Safety Injection Post Reflood Mass and Energy Release			
	Break Path No. 1		Break Path No. 2	
Time Second	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
513.7	201.3	252.6	438.6	118.5
518.7	201.6	253.0	438.3	118.3
523.7	200.8	251.9	439.2	118.4
528.7	200.7	251.7	439.3	118.3
533.7	200.3	251.3	439.7	118.3
538.7	199.6	250.4	440.4	118.3
543.7	199.4	250.2	440.5	118.2
548.7	199.7	250.5	440.3	118.0
553.7	198.6	249.1	441.4	118.2
558.7	198.5	249.0	441.5	118.1
563.7	198.3	248.8	441.7	118.0
568.7	197.8	248.2	442.2	118.0
573.7	197.3	247.5	442.7	118.0
578.7	197.4	247.6	442.6	117.9
583.7	196.6	246.7	443.4	117.9
588.7	196.2	246.2	443.7	117.9
593.7	80.6	101.2	559.3	142.6
824.5	80.6	101.2	559.3	142.6
824.6	77.1	96.5	562.9	138.1
828.7	77.0	96.4	562.9	138.0
1,598.7	64.9	81.2	575.1	130.4
1,600.3	64.9	81.1	583.7	131.0
1,630.3	64.5	80.7	584.0	129.9
1,631.3	64.5	80.7	579.9	145.9
1,706.3	63.7	79.7	580.7	148.4
1,708.3	63.7	79.7	451.6	135.6
2335.7	63.7	79.7	451.6	135.6

Table 1-8	Double-Ended Pump Suction Guillotine Minimum Safety Injection – Mass Balance						
		Start of Accident	**End of Blowdown**	**Bottom of Core Recovery**	**End of Reflood**	**Broken Loop SG Equilibration**	**Intact Loop SG Equilibration**
	Time (Seconds)	.00	28.80	28.80	238.64	824.64	2,335.67
	Mass (Thousands lbm)						
Initial Mass in RCS and Accumulators		799.67	799.67	799.67	799.67	799.67	799.67
Added Mass	Pumped Injection	.00	.00	.00	125.01	499.99	1,389.37
	Total Added	.00	.00	.00	125.01	499.99	1,389.37
Total Available		799.67	799.67	799.67	924.67	1,299.66	2,189.04
Distribution	Reactor Coolant	542.11	71.41	71.55	133.26	133.26	133.26
	Accumulator	257.56	178.95	178.81	.00	.00	.00
	Total Contents	799.67	250.36	250.36	133.26	133.26	133.26
Effluent	Break Flow	.00	549.29	549.29	780.79	1,155.78	2,045.03
	ECCS Spill	.00	.00	.00	.00	.00	.00
	Total Effluent	.00	549.29	549.29	780.79	1,155.78	2,045.03
Total Accountable		799.67	799.65	799.65	914.06	1,289.04	2,178.30

Table 1-9 Double-Ended Pump Suction Guillotine Minimum Safety Injection – Energy Balance

		Start of Accident	End of Blowdown	Bottom of Core Recovery	End of Reflood	Broken Loop SG Equilibration	Intact Loop SG Equilibration
Time	(Seconds)	.00	28.80	28.80	238.64	824.64	2,335.67
		Energy (Million Btu)					
Initial Energy	In RCS, Accum, & SG	948.89	948.89	948.89	948.89	948.89	948.89
Added Energy	Pumped Injection	.00	.00	.00	9.13	36.51	110.94
	Decay Heat	.00	8.58	8.58	31.86	80.91	176.84
	Heat from Secondary	.00	8.30	8.30	8.30	14.60	27.38
	Total Added	.00	16.88	16.88	49.28	132.02	315.17
Total Available		948.89	965.77	965.77	998.18	1,080.91	1,264.06
Distribution	Reactor Coolant	323.33	12.93	12.94	29.70	29.70	29.70
	Accumulator	25.62	17.80	17.78	.00	.00	.00
	Core Stored	25.97	14.72	14.72	3.98	3.66	3.48
	Primary Metal	164.76	156.14	156.14	130.89	85.22	57.43
	Secondary Metal	86.07	85.13	85.13	77.87	59.35	35.41
	Steam Generator	323.14	332.39	332.39	299.98	229.50	146.57
	Total Contents	948.89	619.11	619.11	542.41	407.41	272.58
Effluent	Break Flow	.00	346.07	346.07	443.64	661.37	966.64
	ECCS Spill	.00	.00	.00	.00	.00	.00
	Total Effluent	.00	346.07	346.07	443.64	661.37	966.64
Total Accountable		948.89	965.18	965.18	986.05	1,068.78	1,239.23

Table 1-10 Sequence of Events	
Event	**Time (Sec)**
Rupture	0.0
Accumulator Flow Starts	17.7
Assumed Initiation of ECCS	34.9
End of Blowdown	28.8
Accumulators Empty	68.87
Assumed Initiation of Spray System	234.0
End of Reflood	238.64
Low Level Alarm of Refueling Water Storage Tank	1,571.3
Beginning of Recirculation Phase of Safeguard Operation	1,631.3

2 LOCA CONTAINMENT INTEGRITY ANALYSIS

2.1 DESCRIPTION OF LOTIC-1 MODEL

Early in the ice condenser development program, it was recognized that there was a need for modeling long-term ice condenser performance. It was realized that the model would have to have capabilities comparable to those of the dry containment (COCO) model. These capabilities would permit the model to be used to address concerns of containment design and optimize the containment and safeguards systems. This has been accomplished in the development of the LOTIC code, described in Reference 1.

The model of the containment consists of five distinct control volumes: the upper compartment, the lower compartment, the portion of the ice bed from which the ice has melted, the portion of the ice bed containing unmelted ice, and the dead-ended compartment. The ice condenser control volume with unmelted and melted ice is further subdivided into six subcompartments to allow for maldistribution of break flow to the ice bed.

The conditions in these compartments are obtained as a function of time by the use of fundamental equations solved through numerical techniques. These equations are solved for three phases in time. Each phase corresponds to a distinct physical characteristic of the problem. Each of these phases has a unique set of simplifying assumptions based on test results from the ice condenser test facility. These phases are the blowdown period, the depressurization period, and the long-term period.

The most significant simplification of the problem is the assumption that the total pressure in the containment is uniform. This assumption is justified by the fact that after the initial blowdown of the RCS, the remaining mass and energy released from this system into the containment are small and very slowly changing. The resulting flow rates between the control volumes will also be relatively small. These flow rates then are unable to maintain significant pressure differences between the compartments.

In the control volumes, which are always assumed to be saturated, steam and air are assumed to be uniformly mixed and at the control volume temperature. The air is considered a perfect gas, and the thermodynamic properties of steam are taken from the American Society of Mechanical Engineers (ASME) steam table.

The condensation of steam is assumed to take place in a condensing node located, for the purpose of calculation, between the two control volumes in the ice storage compartment. The exit temperature of the air leaving this node is set equal to a specific value that is equal to the temperature of the ice filled control volume of the ice storage compartment. A lower compartment exit temperature is used if the ice bed section is melted.

2.2 CONTAINMENT PRESSURE CALCULATION

The major input assumptions used in the LOTIC analysis of the DEPSG case with the steam generators considered as an active heat source are the following:

1. Minimum safeguards are employed in all of the LOTIC calculations, that is, one of two spray pumps and one of two spray heat exchangers; one of two residual heat removal (RHR) pumps and

one of two RHR heat exchangers providing flow to the core; one of two safety injection pumps and one of two centrifugal charging pumps; one of two air return fans.

2. $2.26 * 10^6$ lbs of ice initially in the ice condenser.

3. The blowdown, reflood, and post reflood mass and energy releases described in Section 1.7 are used.

4. The blowdown period mass and energy from Table 1-4 is conservatively compressed into a 10-second period in order to melt an amount of ice consistent with the Waltz Mill ice condenser test. (Reference 2)

5. Blowdown and post-blowdown ice condenser drain temperatures of 190°F and 130°F are used. (These values are based on the long-term Waltz Mill ice condenser test data described in Reference 2.)

6. Nitrogen from the accumulators in the amount of 2,973.5 lbs is included in the calculations.

7. Hydrogen gas was added to the containment in the amount of 25,230.2 standard cubic feet (SCF) over 24 hours. Sources accounted for were radiolysis in the core and sump post-LOCA, corrosion of plant materials (aluminum, zinc, and painted surfaces found in containment), reaction of 1 percent of the Zirconium fuel rod clad in the core, and hydrogen gas assumed to be dissolved in the RCS water. (This bounds tritium-producing core designs.)

8. Essential service water temperature of 88°F is used on the spray heat exchanger and the component cooling heat exchanger.

9. The air return fan is assumed to be effective 10 minutes after the transient is initiated.

10. No maldistribution of steam flow to the ice bed is assumed. (This assumption is conservative; it contributes to early ice bed melt-out time.)

11. No ice condenser bypass is assumed. (This assumption depletes the ice in the shortest time and is, therefore, conservative.)

12. The initial conditions in the containment are a temperature of 100°F in the lower and dead-ended volumes, 80°F in the upper volume, and 15°F in the ice condenser. (Note: The 80°F temperature in the upper compartment is a reduction from the 85°F lower Technical Specification limit to account for the upper plenum volume of the ice condenser which is included in upper compartment volume for the analysis. The volume is adjusted to maximize air mass and the compression ratio.) All containment volumes are at a pressure of 0.3 psig and a 10-percent relative humidity, except the ice condenser which is at 100-percent relative humidity.

13. The minimum ECCS and containment spray flow rates versus time assumed in the peak containment pressure calculations were calculated based upon the assumption of loss of offsite power (See Table 2-1).

14. Containment structural heat sinks are assumed with conservatively low heat transfer rates (See Tables 2-2 and 2-3). Note that the dead-ended compartment structural heat sinks were conservatively neglected.

15. The containment compartment volumes were based on the following: upper compartment 645,818 ft^3; lower compartment 221,074 ft^3; and dead-ended compartment 146,600 ft^3. (Note: These volumes represent TMD volumes (Reference 3). For containment integrity analysis, the volumes are adjusted to maximize air mass and the compression ratio.)

16. The operation of one containment spray heat exchanger (Overall Conductance (UA) = 2.44 * 10^6 Btu/hr-°F) for containment cooling and the operation of one RHR heat exchanger (UA = 1.57 * 10^6 Btu/hr-°F) for core cooling are assumed. The component cooling heat exchanger UA was modeled at 7.09 * 10^6 Btu/hr-°F.

17. The air return fan returns air at a rate of 40,000 cfm from the upper to the lower compartment.

18. An active sump volume of 51,000 ft^3 is used.

19. 100.6 percent of 3,459 MWt power is used in the calculations.

20. Subcooling of emergency core cooling (ECC) water from the RHR heat exchanger is assumed.

21. Nuclear service water flow to the containment spray heat exchanger was modeled as 5,200 gpm. Also the nuclear service water flow to the component cooling heat exchanger was modeled as 7,995 gpm.

22. The decay heat curve conservatively used to calculate mass and energy releases after steam generator equilibration is the same as presented in the mass and energy release section of this report (subsection 4.4.2 of the UFSAR).

23. The minimum time at which the RHR pumps can be diverted to the RHR sprays is specified in the Watts Bar Nuclear Plant System Description for the Containment Heat Removal Spray System (Reference 4). This assumes RHR spray starts at 3,600 seconds if switchover to recirculation has already occurred and containment pressure is above 9.5 psig. Based on the preceding criteria, the RHR spray initiation was modeled at 3,781.8 seconds into the LOCA containment response transient (Reference 3).

24. The containment spray system spray flow start time for the containment volume spray was modeled at 234 seconds (Reference 5). The time for containment spray switchover to recirculation was assumed to be completed at 3,460 seconds (References 3 and 5).

25. The blowdown compression pressure was calculated to be 7.807 psig.

2.3 STRUCTURAL HEAT REMOVAL

Provision is made in the containment pressure analysis for heat storage in interior and exterior walls. Each wall is divided into a number of nodes. For each node, a conservation of energy equation expressed in finite difference form accounts for transient conduction into and out of the node and temperature rise of the node for the containment structural heat sinks used in the analysis. The heat sink and material property data from Reference 3 was used to develop Tables 2-2 and 2-3.

The heat transfer coefficient to the containment structure is based primarily on the work of Tagami (Reference 6). When applying the Tagami correlations, a conservative limit was placed on the lower compartment stagnant heat transfer coefficients. They were limited to a steam-air ratio of 1.4 according to the Tagami correlation. The imposition of this limitation is to restrict the use of the Tagami correlation within the test range of steam-air ratios where the correlation was derived.

With these assumptions, the heat removal capability of the containment is sufficient to absorb the energy releases and still keep the maximum calculated pressure below the design pressure.

2.4 ANALYSIS RESULTS

The results of the analysis show that the maximum calculated containment pressure is 11.03 psig, for the DEPSG minimum safeguards break case, assuming an ice bed mass of 2.26 x 10^6 lbm. This pressure is less than the design pressure of 13.5 psig and, therefore, shows the acceptability of the reduced ice mass. The pressure peak occurred at approximately 6,449.9 seconds, with ice bed melt-out at approximately 3,628.5 seconds. It is noted that the apparent containment pressure margin between 11.03 psig and the design pressure of 13.5 psig cannot be used to further reduce the ice mass. The ice bed mass is limited by the spray switchover time of 3,460 seconds and the margin between spray switchover and ice bed melt-out of at least 150 seconds.

The following plots show the containment integrity transient, as calculated by the LOTIC-1 code:

Figure 2-1, Containment Pressure Transient
Figure 2-2, Upper Compartment Temperature Transient
Figure 2-3, Lower Compartment Temperature Transient
Figure 2-4, Active and Inactive Sump Temperature Transient
Figure 2-5, Ice Melt Transient
Figure 2-6, Comparison of Containment Pressure Versus Ice Melt Transients

Tables 2-4 and 2-5 give energy accountings at various points in the transient.

Tables 2-6 through 2-8 provide data points for Figures 2-1 through 2-6.

2.5 RELEVANT ACCEPTANCE CRITERIA

The LOCA mass and energy analysis has been performed in accordance with the criteria shown in SRP subsection 6.2.1.3. In this analysis, the relevant requirements of General Design Criterion (GDC) 50 and the Code of Federal Regulations (CFR) 10 CFR Part 50 Appendix K have been included by confirmation that the calculated pressure is less than the design pressure, and because all available sources of energy have been included. These sources include reactor power, decay heat, core stored energy, energy stored in the reactor vessel and internals, metal-water reaction energy, and stored energy in the secondary system.

The containment integrity peak pressure analysis has been performed in accordance with the criteria shown in the SRP subsection 6.2.1.1.b, for ice condenser containments. Conformance to GDCs 16, 38, and 50 is demonstrated by showing that the containment design pressure is not exceeded at any time in the transient. This analysis also demonstrates that the containment heat removal systems function to rapidly reduce the containment pressure and temperature in the event of a LOCA.

2.6 CONCLUSIONS

Based upon the information presented in this report, it may be concluded that operation with an ice weight of 2.26 million pounds for the Watts Bar Unit 1 is acceptable. Operation with an ice mass of 2.26 million pounds results in a calculated peak containment pressure of 11.03 psig, as compared to the design pressure of 13.5 psig. Further, the ice bed mass of 2.26×10^6 lbm equates to an average of 1,162.55 lbm per basket. This average value recognizes that all baskets may not have the same initial weight nor have the same sublimation rate. To ensure that a sufficient quantity of ice exists in each basket to survive the blowdown phase of a LOCA, a minimum amount of ice per basket to survive the blowdown would be approximately 346.3 lbm, based on Table 2-4. To ensure that an adequate distribution of ice exists in the ice condenser to prevent early burn-through of a localized area, 346.3 lbm of ice should be the minimum weight of ice per basket at any time while also ensuring that the average weight per basket remains above 1,162.55 lbm.

Therefore, the most limiting case has been considered, and has been demonstrated to yield acceptable results.

2.7 REFERENCES

1. WCAP-8354-P-A, April 1976 (Proprietary) and WCAP-8355-A (Non-Proprietary) "Long Term Ice Condenser Containment Code – LOTIC Code" April 1976.

2. WCAP-8110, Supplement 6, (Non-Proprietary), "TEST PLANS AND RESULTS FOR THE ICE CONDENSER SYSTEM, ICE CONDENSER FULL-SCALE SECTION TEST AT THE WALTZ MILL FACILITY," May 1974.

3. TVA Letter TVWES-0339, P. G. Trudel (TVA) to Steve Radomski (Westinghouse), "DOCUMENT SUBMITTAL – LOCA MASS AND ENERGY RELEASE INPUT ASSUMPTIONS," May 24, 2004.

4. WATTS BAR NUCLEAR PLANT SYSTEM DESCRIPTION, NO. N3-72-4001, R15, (CONTAINMENT HEAT REMOVAL SPRAY SYSTEM), January 9, 2004.

5. TVA Letter W-7752, J. C. Kammeyer (TVA) to Kirsh M. Rajan (Westinghouse), "TVA Proposed Change to the Stroke Time for Valve 1-FCV-72-2 (W-1-9001B)," June 23, 2004.

6. Tagami, Takasi, "Interim Report on Safety Assessments and Facilities Establishment Project in Japan for Period Ending June, 1965 (No. 1)."

Table 2-1	ECCS Switchover Pump Flow vs. Time (Loss of Offsite Power At Event Initiation)				
Time After Safeguards Initiation (Sec)	**ECCS Flow To Core (RWST) (gpm)**	**Spray (Flow) (gpm)**	**RHR Spray (Flow) (gpm)**	**ECCS Flow To Core (Sump) (gpm)**	**Comments**
0	0	0	0	0	"S" – Signal
11.9	0	0	0	0	
12.0	358.9	0	0	0	CCP Start
16.9	358.9	0	0	0	
17.0	942.3	0	0	0	SI Pump Start
21.9	942.3	0	0	0	
22.0	4,699.8(1)	0	0	0	RHR Pump Start
233.9	4,699.8	0	0	0	
234.0	4,699.8	4,000	0	0	Containment Spray (CS) Start
1,631.2	4,699.8	4,000	0	0	
1,631.3	4,699.8	4,000	0	3,757.5	RHR Switchover to Sump
1,707.9	4,699.8	4,000	0	3,757.5	
1,708.3	0	4,000	0	3,757.5	CCP/SI Pump Switchover
3,339.9	0	4,000	0	3,757.5	
3,340.0	0	0	0	3,757.5	CS Pump Stopped
3459.9	0	0	0	3,757.5	
3,460.0	0	4,000 (Sump)	0	3,757.5	CS Pump Switchover
3,781.7	0	4,000 (Sump)	0	3,757.5	
3,781.8	0	4,000 (Sump)	1,475	1,855	RHR Alignment for Auxiliary CS
End of Transient	0	4,000 (Sump)	1,475	1,855	

Note:

1. 4,699.8 gpm total flow refueling water storage tank (RWST)
   358.9 gpm – 1 centrifugal charging pump (CCP)
   583.4 gpm – 1 safety injection (SI) pump
   3,757.5 gpm – 1 RHR pump

Table 2-2 Structural Heat Sink Table			
Upper Compartment	**Area (Ft^2)**	**Thickness (Ft)**	**Material**
1. Operating Deck			
Slab 1	4,880.	1.066	Concrete
Slab 2	18,280.	0.0055 1.4	Paint Concrete
Slab 3	760.	0.0055 1.5	Paint Concrete
Slab 4	3,840.	0.0208 1.5	Stainless Steel Concrete
2. Shell and Misc.			
Slab 5	56,331.	0.001 0.079	Paint Steel
Lower Compartment			
1. Operating Deck, Crane Wall, and Interior Concrete			
Slab 6	31,963.	1.43	Concrete
2. Operating Deck			
Slab 7	2,830.	0.0055 1.1	Paint Concrete
Slab 8	760	0.0055 1.75	Paint Concrete
3. Interior Concrete and Stainless Steel			
Slab 9	2,270.	0.0208 2.0	Stainless Steel Concrete
4. Floor(1)			
Slab 10	15,921.	0.0055 1.6	Paint Concrete
5. Misc. Steel			
Slab 11	28,500.	0.001 0.0656	Paint Steel
Note: 1. In contact with sump.			

Table 2-2 (cont.) Structural Heat Sink Table			
Ice Condenser	**Area (Ft^2)**	**Thickness (Ft)**	**Material**
1. Ice Baskets			
Slab 12	149,600.	0.00663	Steel
2. Lattice Frames			
Slab 13	75,865.	0.0217	Steel
3. Lower Support Structure			
Slab 14	28,670.	0.0587	Steel
4. Ice Condenser Floor			
Slab 15	3,336.	0.0055 0.333	Paint Concrete
5. Containment Wall Panels & Containment Shell			
Slab 16	19,100.	1.0 0.0625	Steel & Insulation Steel Shell
6. Crane Wall Panels and Crane Wall			
Slab 17	13,055.	1.0 1.0	Steel & Insulation Concrete

Table 2-3 Material Properties Table		
Material	Thermal Conductivity Btu/hr-ft-°F	Volumetric Heat Capacity Btu/ft^3-°F
Paint on Steel	0.21	19.9
Paint on Concrete	0.083	39.9
Concrete	0.8	31.9
Stainless Steel	9.4	53.68
Carbon Steel	26.0	53.9
Insulation on Steel	0.15	2.75

Table 2-4 Energy Accounting		
	Approx. End of Blowdown (t =10.0 sec.)	Approx. End of Reflood (t = 238.6 sec.)
	(in Millions of Btus)	
Ice Heat Removal(1)	208.53	262.26
Structural Heat Sinks(1)	18.06	61.72
RHR Heat Exchanger Heat Removal(1)	0	0
Spray Heat Exchanger Heat Removal(1)	0	0
Energy Content of Sump	190.54	244.78
Ice Melted (Pounds) (10^6)	0.6732	0.8884
Note: 1. Integrated energies		

Table 2-5 Energy Accounting		
	Approx. Time of Ice Melt Out (t =3,630.5 sec.)	Approx. Time Peak Pressure (t = 6,450 sec.)
	(In Millions of Btus)	
Ice Heat Removal(1)	604.8	604.8
Structural Heat Sinks(1)	80.7	119.9
RHR Heat Exchanger Heat Removal(1)	29.4	63.2
Spray Heat Exchanger Heat Removal(1)	3.03	53.6
Energy Content of Sump	666.4	670.5
Ice Melted (Pounds) (10^6)	2.26	2.26

Note:

1. Integrated energies

Table 2-6 Containment Pressure and Ice Melt Mass		
Time (Sec)	Pressure (psig)	Melted Ice (lbm)
2.00	7.81	134,641.40
11.96	7.85	673,207.20
21.93	7.61	673,208.80
38.93	7.51	675,234.90
55.93	7.47	684,557.80
72.93	7.45	703,161.10
88.47	7.06	723,247.10
104.64	6.99	744,452.80
121.64	6.69	764,322.80
137.64	6.66	781,999.80
154.64	6.71	800,308.60
171.64	6.87	818,487.20
188.64	6.99	836,864.80
221.64	6.81	871,396.10
236.94	6.81	886,504.40
250.15	7.15	900,793.50
267.15	7.34	919,205.50
284.15	7.47	937,511.70
317.15	7.59	972,802.60
351.15	7.64	1,008,824.00
568.15	7.67	1,230,843.00
585.15	7.67	1,247,631.00
629.27	6.88	1,271,758.00
662.27	6.60	1,288,170.00
696.27	6.42	1,305,232.00
729.27	6.30	1,321,816.00
762.27	6.24	1,338,376.00
895.48	6.09	1,401,703.00
1,614.48	6.01	1,687,151.00
1,695.88	6.19	1,719,558.00

Table 2-6 (cont.) Containment Pressure and Ice Melt Mass		
Time (Sec)	Pressure (psig)	Melted Ice (lbm)
1,711.49	6.30	1,726,266.00
1,811.49	6.38	1,772,778.00
2,341.77	6.43	2,018,914.00
2,383.52	6.17	2,027,552.00
2,429.52	5.99	2,037,223.00
2,513.02	5.84	2,054,773.00
2,680.02	5.76	2,089,257.00
3,340.27	5.83	2,216,779.00
3,407.02	6.55	2,228,651.00
3,457.27	7.16	2,237,158.00
3,469.77	6.96	2,239,183.00
3,478.27	6.86	2,240,520.00
3,494.77	6.79	2,243,043.00
3,528.27	6.88	2,247,915.00
3,566.02	7.09	2,253,005.00
3,624.27	7.76	2,259,694.00
3,637.02	8.24	2,260,000.00
3,641.02	8.23	2,260,000.00
3,645.27	8.24	2,260,000.00
3,653.52	8.28	2,260,000.00
3,670.27	8.46	2,260,000.00
3,720.52	9.04	2,260,000.00
3,787.27	9.40	2,260,000.00
3,791.52	9.34	2,260,000.00
3,804.02	9.26	2,260,000.00
3,816.52	9.25	2,260,000.00
3,933.52	9.63	2,260,000.00
4,035.02	9.87	2,260,000.00
4,269.02	10.24	2,260,000.00
4,704.02	10.63	2,260,000.00

Table 2-6 (cont.) Containment Pressure and Ice Melt Mass		
Time (Sec)	**Pressure (psig)**	**Melted Ice (lbm)**
5,067.54	10.82	2,260,000.00
5,611.13	10.99	2,260,000.00
6,213.23	10.97	2,260,000.00
6,449.88	11.03	2,260,000.00
6,585.51	11.02	2,260,000.00
7,647.72	10.88	2,260,000.00
9,988.86	10.67	2,260,000.00
15,020.17	10.44	2,260,000.00
20,094.56	9.99	2,260,000.00
25,015.06	9.63	2,260,000.00
34,948.41	9.01	2,260,000.00
45,122.62	8.53	2,260,000.00
55,240.82	8.19	2,260,000.00
64,900.86	7.94	2,260,000.00
75,463.80	7.76	2,260,000.00
85,343.89	7.57	2,260,000.00
95,308.09	7.40	2,260,000.00
105,541.70	7.27	2,260,000.00
115,550.80	7.15	2,260,000.00
125,142.20	7.06	2,260,000.00
135,702.00	6.93	2,260,000.00
145,031.80	6.85	2,260,000.00
155,026.40	6.74	2,260,000.00
165,222.00	6.67	2,260,000.00
175,001.80	6.59	2,260,000.00
180,593.50	6.55	2,260,000.00
185,566.80	6.52	2,260,000.00
194,925.10	6.45	2,260,000.00
199,964.10	6.42	2,260,000.00

Table 2-7 Containment Upper and Lower Compartment Temperatures		
Time (Sec)	Upper Compartment Temperature (°F)	Lower Compartment Temperature (°F)
2.00	94.09	234.30
10.00	94.09	234.31
11.96	93.25	234.50
21.93	89.06	233.80
38.93	87.57	236.30
55.93	87.18	233.50
72.93	87.23	233.40
88.47	87.56	230.89
104.64	88.17	227.68
121.64	88.76	223.32
137.64	89.30	222.51
188.64	90.74	226.20
221.64	91.47	223.28
236.94	93.08	222.40
250.15	97.46	224.38
267.15	100.34	225.25
284.15	101.85	225.93
317.15	103.05	226.78
568.15	103.66	227.14
585.15	103.67	227.09
612.27	105.07	217.50
646.27	106.82	210.73
696.27	107.26	204.81
729.27	107.31	202.58
878.48	107.38	197.78
1,614.48	107.67	191.23
1,695.88	107.71	194.72
1,711.49	107.71	197.08

Table 2-7 (cont.) Containment Upper and Lower Compartment Temperatures		
Time (Sec)	Upper Compartment Temperature (°F)	Lower Compartment Temperature (°F)
1,795.49	107.75	198.18
2,337.52	107.92	197.75
2,371.02	107.93	192.36
2,400.27	107.93	188.84
2,467.02	107.94	183.68
2,529.77	107.95	181.04
2,592.27	107.97	179.53
2,843.02	108.04	177.36
3,340.27	108.55	175.65
3,398.77	119.62	177.20
3,457.27	129.79	180.14
3,461.52	129.35	180.33
3,469.77	126.29	180.44
3,478.27	124.51	180.55
3,486.52	123.62	180.64
3,499.02	123.22	180.79
3,528.27	124.38	181.19
3,561.77	127.02	181.83
3,624.27	134.65	183.57
3,637.02	136.30	183.44
3,641.02	136.00	183.57
3,645.27	135.94	183.72
3,653.52	136.33	184.03
3,682.77	139.78	185.27
3,720.52	143.81	186.99
3,791.52	145.29	189.53
3,808.27	143.97	189.74
3,820.77	143.91	189.90
3,987.77	147.96	192.08

Table 2-7 (cont.) Containment Upper and Lower Compartment Temperatures		
Time (Sec)	Upper Compartment Temperature (°F)	Lower Compartment Temperature (°F)
4,152.02	150.31	193.51
4,470.02	153.11	195.09
5,067.54	155.91	196.33
5,323.21	156.59	195.72
5,611.13	157.53	196.30
5,905.73	157.24	195.69
6,213.23	157.36	195.68
7,305.62	157.98	194.24
10,724.45	156.02	192.20
11,476.43	155.93	191.89
11,857.68	155.35	191.90
12,987.53	155.37	190.57
15,422.80	154.43	189.54
15,827.12	153.83	189.63
22,304.26	150.65	185.31
27,757.86	148.01	182.73
36,455.86	144.52	178.81
36,969.68	143.89	179.36
45,659.56	140.80	176.65
46,651.50	140.91	176.39
47,161.19	140.47	175.72
62,245.21	137.19	171.91
88,921.41	132.88	166.96
153,731.90	126.31	159.56
198,531.30	123.52	155.47
199,964.10	123.43	155.35

Table 2-8 Containment Active and Inactive Sump Temperatures		
Time (Sec)	Active Sump Temperature (°F)	Inactive Sump Temperature (°F)
2.00	189.99	.00
10.00	189.98	.00
11.96	189.98	.00
38.93	189.46	.00
55.93	188.18	.00
88.47	185.94	.00
104.64	185.03	.00
137.64	183.53	.00
154.64	182.84	.00
204.64	180.97	.00
221.64	180.42	.00
236.94	179.88	.00
267.15	178.28	.00
301.15	176.68	.00
334.15	175.28	.00
367.15	174.01	.00
401.15	172.80	.00
434.15	171.73	.00
484.15	170.25	.00
551.15	168.52	.00
585.15	167.74	.00
746.27	166.25	.00
862.48	165.40	.00
995.48	164.66	.00
1,012.48	164.57	164.57
1,129.48	164.04	164.30
1,246.38	163.57	164.05
1,463.48	162.85	163.64
1,630.25	162.43	163.38

Table 2-8 (cont.) Containment Active and Inactive Sump Temperatures		
Time (Sec)	**Active Sump Temperature (°F)**	**Inactive Sump Temperature (°F)**
1,711.49	162.16	163.29
1,945.49	160.65	162.94
2,220.74	159.10	162.39
2,341.77	158.42	162.14
2,575.77	154.84	161.62
2,692.77	153.16	161.28
2,813.77	151.49	160.88
2,930.77	149.94	160.47
3,169.02	146.97	159.56
3,286.02	145.60	159.09
3,344.52	144.96	158.86
3,465.52	144.37	158.74
3,607.77	143.29	158.63
3,641.02	143.11	158.62
3,745.52	142.69	158.62
3,799.77	142.57	158.62
3,958.77	142.41	158.62
4,269.02	142.43	158.62
4,670.02	142.76	158.62
4,988.02	143.14	158.62
6,585.51	145.31	158.62
7,305.62	146.10	158.62
7,647.72	146.41	158.62
8,336.71	146.89	158.62
8,634.34	147.05	158.62
9,627.79	147.41	158.62
10,724.45	147.57	158.62
11,857.68	147.56	158.62
12,987.53	147.50	158.62

Table 2-8 (cont.) Containment Active and Inactive Sump Temperatures

Time (Sec)	Active Sump Temperature (°F)	Inactive Sump Temperature (°F)
14,608.82	147.28	158.62
15,827.12	146.98	158.62
17,068.62	146.60	158.62
18,347.66	146.14	158.62
24,557.00	143.38	158.62
28,223.20	141.91	158.62
41,512.41	136.77	158.62
44,590.39	135.77	158.62
47,161.19	135.04	158.62
53,049.70	133.62	158.62
58,491.89	132.39	158.62
62,782.80	131.48	158.60
67,086.16	130.70	158.57
76,024.59	129.29	158.51
80,615.41	128.61	158.48
84,730.97	128.06	158.45
93,596.79	126.97	158.39
102,453.70	125.98	158.32
111,766.30	125.14	158.25
147,002.80	122.26	157.96
155,720.80	121.60	157.88
164,518.10	121.06	157.81
199,964.10	118.99	157.50

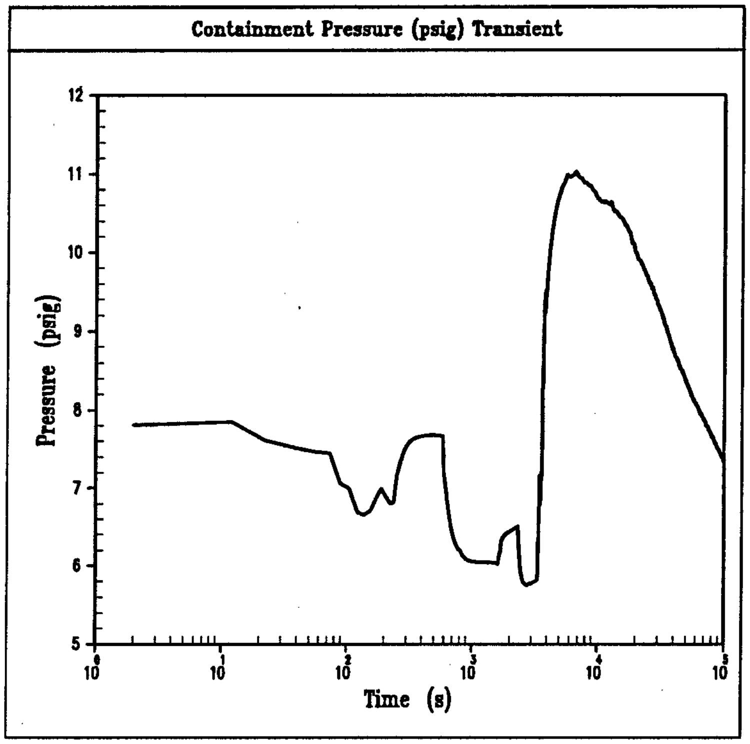

Figure 2-1 Containment Pressure (psig) Transient

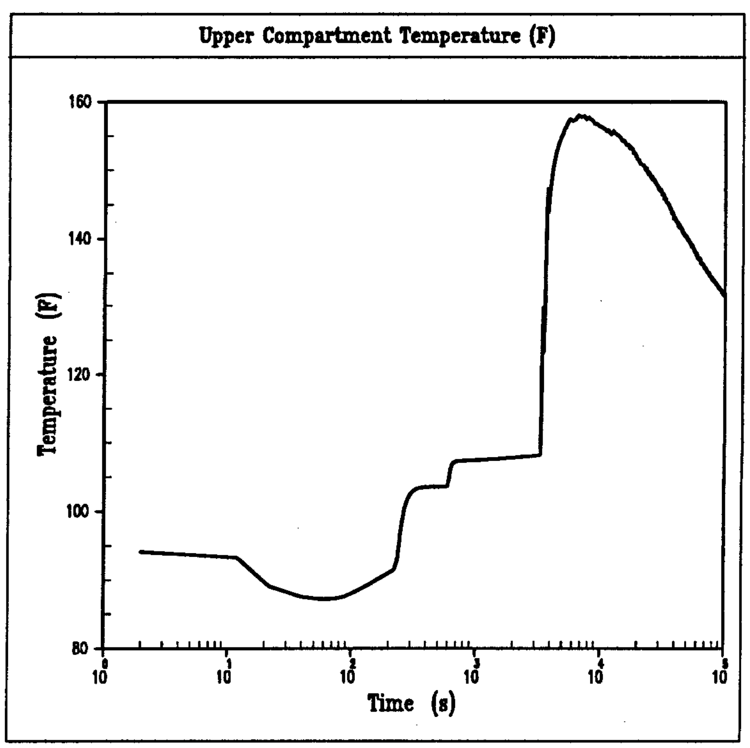

Figure 2-2 Upper Compartment Temperature Transient (°F)

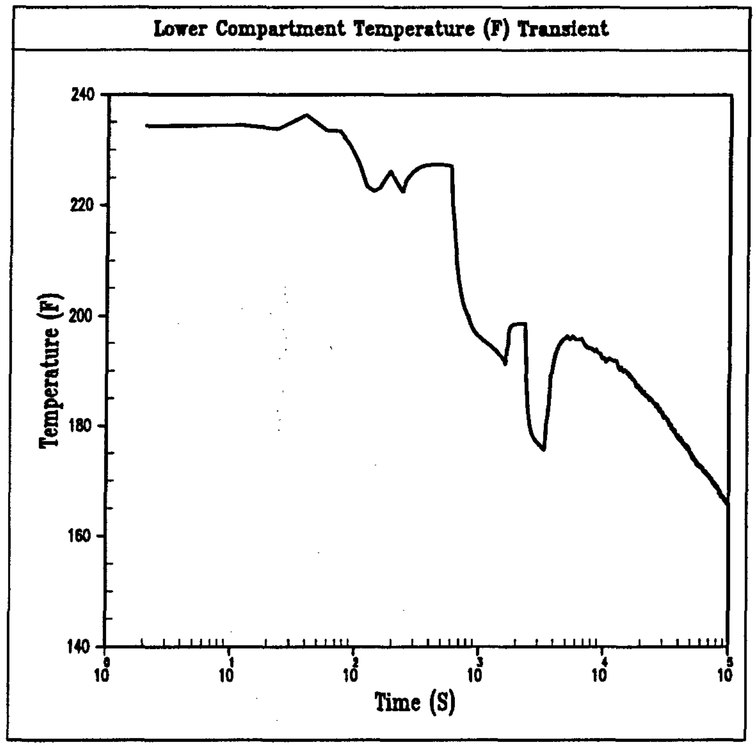

Figure 2-3 Lower Compartment Temperature Transient (°F)

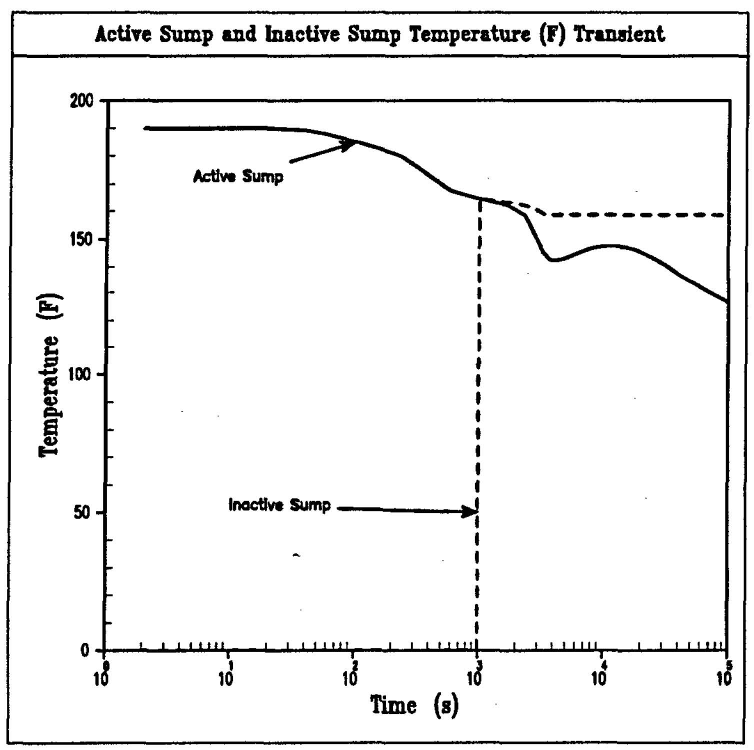

Figure 2-4 Active Sump and Inactive Sump Temperature Transient (°F)

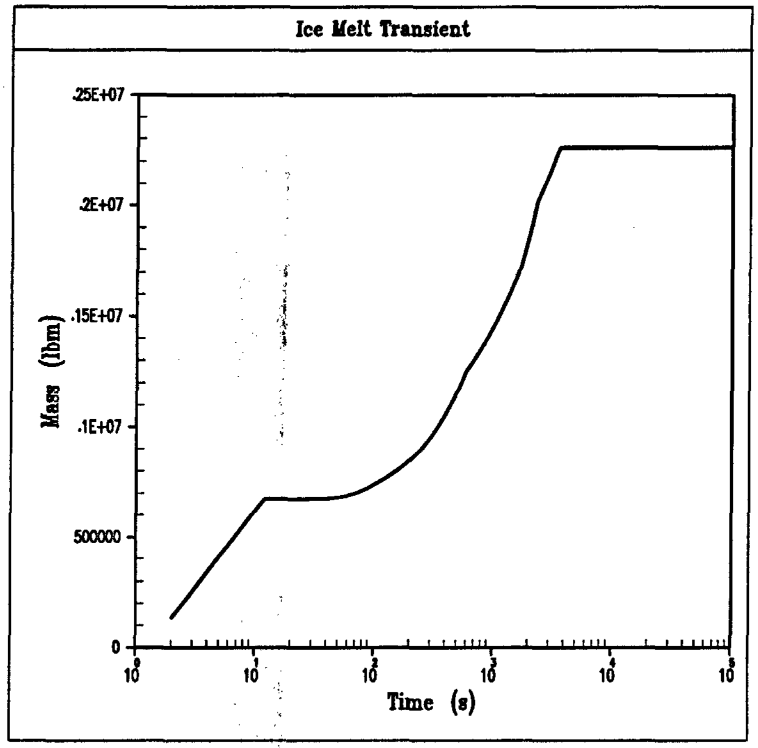

Figure 2-5 Ice Melt Transient

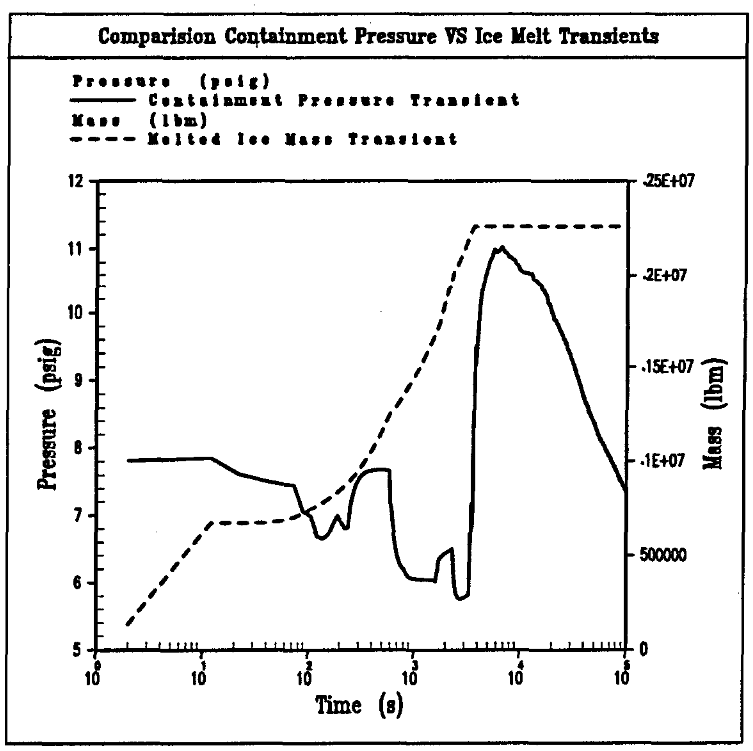

Figure 2-6 Comparison of Containment Pressure Versus Ice Melt Transients