Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402

CNL-15-127

August 13, 2015

10 CFR 50.36

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

Watts Bar Nuclear Plant, Unit 2
Construction Permit No. CPPR-92
NRC Docket No. 50-391

Subject: **Revised FSAR Section 6.2.1 Containment Functional Design**

Reference: TVA letter to NRC, "Watts Bar Nuclear Plant - Unit 2 - Final Safety Analysis Report, Amendment 113," dated February 23, 2015 [ADAMS Accession No. ML15069A533]

The purpose of this letter is to revise the long term containment analysis for the design basis loss of coolant accident (LOCA) in Final Safety Analysis Report (FSAR) Section 6.2.1, "Containment Design Features." The current Watts Bar Nuclear Plant (WBN) Unit 2 FSAR analysis was provided in Amendment 113 (Reference). The analysis provided in Amendment 113 addressed Westinghouse Electric Corporation Nuclear Safety Advisory Letters and revised the initial containment compartment temperatures. The FSAR Amendment 113 containment analysis has been revised to adjust heat exchanger heat removal rates based on flow balance testing of the Essential Raw Cooling Water System and Component Cooling Water System, and to use volumetric heat capacity and density values for reactor coolant system metal mass consistent with those published by the American Society of Mechanical Engineers.

Enclosure 1 provides a summary of the revised containment analysis. Enclosure 2 provides the revised FSAR pages with the changes identified. The revised long term containment analysis will be incorporated in WBN Unit 2 FSAR Amendment 114. The revised analysis results in an increase in the required ice weight. Changes to the Technical Specification ice bed surveillance requirements associated with the increased ice weight are provided in Enclosure 3 and the changes will be incorporated into Revision 0 of the Technical Specifications and Technical Specification Bases.

Enclosure 4 provides the new regulatory commitments contained in this submittal. Please contact Gordon Arent at 423-365-2004 if there are questions regarding this submittal.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 13th day of August 2015.

Respectfully,

J. W. Shea
Vice President, Nuclear Licensing

Enclosures

1. Summary of Revised Containment Analysis
2. Revised FSAR Section 6.2.1 Pages
3. Revised Pages for TS and TS Bases 3.6.11
4. New Commitments

cc (Enclosures):

NRC Regional Administrator – Region II
NRC Senior Resident Inspector – Watts Bar Nuclear Plant, Unit 1
NRC Senior Resident Inspector – Watts Bar Nuclear Plant, Unit 2
NRC Project Manager – Watts Bar Nuclear Plant, Unit 1
NRC Project Manager – Watts Bar Nuclear Plant, Unit 2

ENCLOSURE 1
Watts Bar Nuclear Plant Unit 2

Summary of Revised Containment Analysis

1.0 SUMMARY DESCRIPTION

The containment pressure and temperature response to a design basis loss of coolant accident (LOCA) is described in Watts Bar Nuclear Plant (WBN) Unit 2 Final Safety Analysis Report (FSAR) Section 6.2.1, "Containment Design Features." The analysis that TVA submitted in Amendment 113 (Reference 1) had incorporated the impacts of Westinghouse Electric Corporation (Westinghouse) Nuclear Safety Advisory Letters (NSALs) and revised initial compartment temperatures based on a request for additional information (RAI) from the Nuclear Regulatory Commission (NRC) (Reference 2).

Two issues have been identified since that analysis was submitted to the NRC that requires a revision to the long term containment analysis in response to a LOCA. In preparation for dual unit flow balance testing of the Essential Raw Cooling Water System (ERCW) and Component Cooling Water System (CCS), some CCS flow rates were adjusted such that the heat removal rate from the Residual Heat Removal (RHR) System heat exchangers and to the CCS heat exchangers was reduced. The other issue is a Westinghouse InfoGram IG-14-1 (Reference 3) which stated that the volumetric heat capacity value used for the reactor coolant system (RCS) metal mass did not bound some of the values published by the American Society of Mechanical Engineers (ASME). These two issues have been addressed in the analysis discussed in this submittal.

The revised analysis results in a new peak containment pressure of 11.73 pounds per square inch gauge (psig) assuming a total ice weight of 2,585,000 pounds (lbs).

2.0 BACKGROUND

The ice bed consists of borated 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 LOCA or main steam line break (MSLB) in containment. The LOCA requires the greatest amount of ice compared to other accident scenarios; therefore, the ice weight is based on the LOCA analysis. The amount of ice in the bed has no affect on the initiation of an accident, but rather on the mitigation of the accident. The sodium tetraborate solution formed by meltdown of the ice absorbs and retains iodine released during the accident and prevents dilution of the borated water injected from the refueling water storage tank and accumulators. This solution also contributes to the inventory of water used for long-term heat removal from the reactor core and containment atmosphere.

The ice absorbs energy and limits the containment peak pressure and temperature during the accident. Limiting the pressure reduces the release of fission product radioactivity from containment to the environment in the event of a design basis accident. The current ice weight value is supported by the containment integrity analysis documented in the WBN Unit 2 FSAR (Reference 1), Section 6.2.1, "Containment Design Features." The Technical Specification (TS) surveillance limits on total ice weight and on ice basket weight are intended to ensure that sufficient ice is present in an appropriate distribution to perform this function. The TS surveillance limits are currently an "as-left" measurement and include margin for ice sublimation and measurement error.

Summary of Revised Containment Analysis

Westinghouse has issued three NSALs impacting the mass and energy releases to the containment after a LOCA. The impact of these NSALs was addressed for WBN Unit 2 in FSAR Amendment 112 (Reference 4). During the review of Amendment 112, the NRC raised questions about the assumptions made for the initial temperatures in the ice condenser and in other containment compartments (Reference 2). A response was provided to these RAIs in December 2014 (Reference 5) and the FSAR was updated to incorporate the revisions to the analysis of record with the submission of WBN Unit 2 FSAR Amendment 113 (Reference 1).

3.0 TECHNICAL EVALUATION

The following evaluation describes the results of the current analysis, aspects of the revised analysis, the effects of the increase in ice weight, and differences between the current FSAR Amendment 113 analysis and the revised analysis in this submittal.

Current Analytical Basis

The containment integrity analysis for WBN Unit 2 utilized LOTIC-1, a Westinghouse computer code documented in WCAP-8354-P-A (Reference 6) to calculate the peak containment pressure following a LOCA inside containment. The calculated peak pressure for WBN Unit 2 is 12.4 psig. Assumptions used in the LOTIC-1 analysis for WBN Unit 2 included an initial ice weight in the ice condenser of 2,330,000 lbs at a temperature of 27°F. This analysis addressed Westinghouse NSALs 06-6, 11-5, and 14-2 (References 7, 8, and 9). The analysis also addressed the NRC questions with respect to the initial temperatures assumed in containment compartments and the ice bed (Reference 2).

Description of Revised Analysis

The revised analysis retains the key assumptions and updates made in the current analysis and addresses two new issues. These are the use of updated material properties for the RCS metal mass in the mass and energy (M&E) calculations and changes resulting from dual unit flow balance testing of the ERCW and CCS associated with the construction of WBN Unit 2.

The M&E releases are calculated using the methodology described in WCAP-10325-P-A (Reference 10). The M&E releases for WBN Unit 2 continue to incorporate the changes associated with the three NSALs issued by Westinghouse. On November 5, 2014, Westinghouse issued InfoGram IG-14-1, “Material Properties for Loss-of-Coolant Accident Mass and Energy Release Analyses.” The InfoGram IG-14-1 stated that when the M&E release methodology was developed, values for the density and volumetric heat capacity of the RCS metal were selected from industry information, but the values did not represent the most limiting values seen in industry information. The basis for the selection of the values chosen was not documented, but given that the values were supported by industry data and the large conservatisms in the M&E model, no action was required on the part of licensees because the model provided conservative results.

ENCLOSURE 1
Watts Bar Nuclear Plant Unit 2

Summary of Revised Containment Analysis

Based on discussion in a meeting between TVA and the NRC on June 30, 2015, TVA requested Westinghouse to revise the WBN Unit 2 M&E calculations to assume a density and volumetric heat capacity for the RCS metal mass that bounds the ASME boiler and pressure vessel code Part D values. The WBN Unit 2 M&E releases were developed using a density and volumetric heat capacity of 501 lbm/ft^3 and 0.145 BTU/lbm-°F, respectively for the RCS reactor, loop piping and steam generator metal.

The containment analysis continues to use the LOTIC-1 computer code as the analysis methodology. Assumptions for heat exchanger performance were revised based on the dual unit ERCW and CCS flow balance testing. CCS flows to the CCS heat exchangers were adjusted from the single unit values and ERCW flow rates to the CCS heat exchangers were adjusted during flow balance testing. The revised input assumptions are shown as bold in Table 1. As can be seen in Table 1, the other initial condition parameters have not changed from the previous analysis submitted to the NRC.

A supplemental RHR spray system is part of the WBN design to provide additional containment heat removal for minimum safeguards cases. As described in the FSAR, if the containment pressure is above 9.4 psig and at least one hour has passed since the initiation of the LOCA, 2000 gallons per minute (gpm) of flow is to be provided to an RHR spray header located in the containment dome. During reviews of the analysis, it was identified that initiation of RHR spray in the FSAR Amendment 113 analysis occurred at 4347 seconds instead of 3600. Starting RHR spray later in time is conservative as it reduces containment heat removal and thus produces a higher peak containment pressure. The revised analysis credits RHR spray initiation at 3600 seconds as described in the FSAR.

ENCLOSURE 1
Watts Bar Nuclear Plant Unit 2

Summary of Revised Containment Analysis

TABLE 1 **Watts Bar Unit 2** **Revised Containment Analysis Inputs**		
Parameter	**Analysis of Record**	**Revised Analysis**
CCS Heat Exchanger (Hx) Heat Transfer Coefficient (UA), (MBtu/hr/°F)	5.778	**3.17***
ERCW Flow to CCS Hx, gpm	6,250	**3,500**
RHR Hx UA, (MBtu/hr/°F)	1.496	1.496*
Ice bed temperature (°F)	27.0	27.0
Ice Bay air temperature (°F)	27.0	27.0
UHS/ERCW temperature (°F)	88.0	88.0
Upper Compartment Air Temperature (°F)	110.0	110.0
Lower Compartment Air Temperature (°F)	120.0	120.0
Dead End Compartment(s) Air Temperature (°F)	120.0	120.0
Relative Humidity for non-ice compartments	10%	10%
Relative Humidity for the Ice Bay	100%	100%

*UA includes fouling factors (0.002 raw water, 0.0005 CCS water, and 0.0004 RCS hr-ft-°F/BTU) and 5% tube plugging.

Summary of Revised Containment Analysis

The revised calculated peak containment pressure is 11.73 psig, which is below the maximum allowed value and the analytical minimum allowable ice weight is 2,585,000 lbs. Table 2 provides a comparison of some key results from the new analysis to the current FSAR analysis.

TABLE 2
Watts Bar Nuclear Plant Unit 2
LOCA Containment Integrity Analysis Results

Parameter	Amendment 113	Revised
Required Ice Weight lbs	2,330,000	2,585,000
Peak Pressure @ time psig / Seconds	12.4 / 4346	11.73 / 3600
Peak Upper Compartment Temperature @ time °F / Seconds	173.0 / 4283	168.5 / 3600
Peak Lower Compartment Temperature @ time °F / Seconds	234.3 / 2	234.3 / 2
Peak Active Sump Temperature @ time of RHR swapover °F / Seconds	160.8 / 1267	159 / 1267
Delta Time between Spray Recirculation and Ice Melt Seconds	155	241
Ice Bed Melt-out Time Seconds	2874	2959

The Equipment Qualification (EQ) profile used in the WBN Unit 2 program is unchanged by this revision. The active containment sump temperature profile is slightly higher in the reanalysis compared to the sump profile in WBN U2 FSAR Amendment 113. This is the expected result since RHR and CCS Heat Exchanger performance has been reduced. The sump temperatures from the two analyses are similar until the time RHR suction is transferred from the Refueling Water Storage Tank (RWST) to the containment sump. However, the new analysis has slightly lower temperatures at the time of ECCS pump switchover. After that point, the revised analysis shows higher sump temperatures. The difference in temperature is less than five degrees and generally less than that. The maximum sump water temperature during sump recirculation is less than 160°F. The temperature profile is lower than the temperature values used for the net positive suction head determinations and there is not an adverse impact on peak sump temperature during sump recirculation. The Westinghouse summary report of the reanalysis is provided as the attachment to this Enclosure.

4.0 CONCLUSIONS

The analysis shows that WBN Unit 2 operation with an ice weight of 2.585 million lbs is acceptable. An ice mass of 2.585 million lbs results in a calculated peak containment pressure of 11.73 psig, as compared to the allowable containment pressure limit of 15 psig. The ice bed mass of 2.585 million lbs equates to an average ice basket weight of 1,330 lbs. Enclosure 2 provides the changes to the WBN Unit 2 FSAR pages associated with this reanalysis. These changes will be incorporated into WBN Unit 2 FSAR Amendment 114.

Technical Specification (TS) Surveillance Requirement (SR) 3.6.11.2 assures that there is a large enough ice mass at the start of a fuel cycle to support the analysis value at the end of the cycle accounting for sublimation and measurement errors. Similarly, TS SR 3.6.11.3 provides assurance that the ice mass is distributed in a uniform manner to support the safety analysis. Based on the analysis described in this submittal, the total ice weight specified in SR 3.6.11.2 will be 2,750,700 lbs with a per basket value of 1415 lbs specified in SR 3.6.11.2 and SR 3.6.11.3. The changes to the TS and TS Bases are provided in Enclosure 3. The new SR values, which are the sole change being made, will be included in WBN Unit 2 TS Revision 0.

The impacts on the EQ Program and the containment sump have been considered and have been determined to be acceptable. The impacts do not change any previous determinations and conclusions. The information provided in the FSAR associated with EQ or the sump has not been changed as a result of this submittal. Therefore, the potential impacts have been considered, and have been demonstrated to yield acceptable results.

Summary of Revised Containment Analysis

5.0 REFERENCES

1. TVA letter to NRC, “Watts Bar Nuclear Plant - Unit 2 - Final Safety Analysis Report, Amendment 113,” dated February 23, 2015 [ML15069A533]

2. NRC e-mail to TVA, “Watts Bar, Unit 2 - Final RAIs Regarding Review of SAR Amendment 112 for Chapter 6,” dated October 9, 2014 [ML14286A024]

3. Westinghouse Electric Corporation InfoGram IG-14-1, “Material Properties for Loss-of-Coolant Accident Mass and Energy Release Analyses,” dated November 5, 2014

4. TVA letter to NRC, “Watts Bar Nuclear Plant (WBN) - Unit 2 - Final Safety Analysis Report (FSAR), Amendment 112,” dated May 30, 2014

5. TVA letter to NRC, “Watts Bar Nuclear Plant Unit 2 - Response to Request for Additional Information Regarding NRC Review of Final Safety Analysis Report Amendment 112 for Chapter 6,” dated December 17, 2014

6. WCAP-8354-P-A, “Long Term Ice Condenser Containment Code – LOTIC Code,” dated April 1976 (Proprietary)

7. NSAL-06-6, “LOCA Mass and Energy Release Analysis,” dated June 6, 2006.

8. NSAL-11-5, “Westinghouse LOCA Mass and Energy Release Calculation Issues,” dated July 25, 2011.

9. NSAL-14-2, “Westinghouse Loss-of-Coolant Accident Mass and Energy Release Calculation Issue for Steam Generator Tube Material Properties,” dated March 31 2014.

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

ENCLOSURE 1
ATTACHMENT

Westinghouse Summary Report

Westinghouse

To: Rachel N. Bottorff
Date: July 30, 2015

cc: Bernie W. Gergos

From: Containment and Radiological Analysis
Phone: 412-374-3523
Our ref: LTR-CRA-15-83, Rev. 1

References:
1) CN-CRA-11-7, Revision 4, "Watts Bar Unit 2 (WBT) – Long Term Mass and Energy Releases and Containment Integrity – Reanalysis to Address RCS Metal Thermal Properties," July 2015.
2) WBT-D-3522, "Final Containment Analysis Summary Reports," October 2011.

Subject: **Updated Summary Report for Watts Bar Unit 2 Documenting the LOCA Analyses Supporting the Completion Project**

This revision makes the document non-proprietary. It also changes a value of 80°F to 85°F for the discussion of the sensitivity to initial conditions in the containment (Section 4.4.3.2).

Summary reports have been written to document the loss-of-coolant accident (LOCA) safety analyses performed to apply updated density and specific heat values, consistent with Part D of the ASME boiler and pressure vessel code, to the reactor coolant system (RCS) reactor, loop, and steam generator metal heat calculations (Reference 1). These report sections, which have been patterned consistent with the documentation in Reference 2, reflect mass & energy releases and containment response analyses that were included in any revised calculations for Unit 2. The following report sections are included as attachments to this letter.

Section 4.4.1 Long-Term Loss-of-Coolant Accident Mass and Energy Releases

Section 4.4.3 LOCA Containment Integrity Analysis

Please forward each of these summary reports to Mr. Frank Koontz of Tennessee Valley Authority (TVA). All report sections are Non-Proprietary Class 3 and have been noted as such in the header.

If there are any questions associated with this information, please contact the undersigned.

*Electronically approved**
Arthur C. Craig
Containment and Radiological Analysis

*Electronically approved**
Robert M. Jakub, Verifier
Containment and Radiological Analysis

*Electronically approved**
Kent W. Bonadio, Manager
Containment and Radiological Analysis

Attachment 1: Sections 4.4.1 and 4.4.3 (80 pages including cover sheet)

Attachment 1:
Sections 4.4.1 and 4.4.3

4.4.1 Long-Term Loss-of-Coolant Accident Mass and Energy Releases

4.4.1.1 Introduction

A containment integrity analysis has been performed to support the Unit 2 completion project for Watts Bar.

The 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 loss-of-coolant accident (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 containment design pressure of 15.0 psig for Watts Bar Unit 2 or the administrative acceptance criterion of 13.5 psig.

In support of the Unit 2 completion project, this analysis utilized revised input assumptions while addressing analytical conservatisms, such as auxiliary feedwater and main feedwater modeling, in the present analysis to maintain the current ice mass. The analysis was completed to provide the analytical basis for the licensing of Watts Bar Unit 2 and minimize the impact on the initial ice mass, margins in peak calculated containment pressure, and ice bed melt-out time to containment spray switchover time relative to operator action time tolerance.

The 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. The analysis uses the bounding composite of Reactor Coolant System (RCS) conditions that are calculated for the Unit 2 completion project, including a T_{avg} of 588.2°F. Additionally, the analysis issues discussed in References 13, 14, 15 and 16 have been addressed and are reflected in the results of this report.

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 Robust Fuel Assembly-2 (RFA-2) fuel (which may incorporate tritium-producing burnable absorber rods (TPBAR)). Also, the evaluation that was provided in Reference 17 with the conclusion that a +/- 0.2 Hz variation in the diesel frequency would have a negligible impact on the LOCA mass and energy release analysis remains valid. It should be noted that these items were included for completeness even though they may not be currently implemented at Watts Bar Unit 2.

4.4.1.2 Purpose of Analysis

The purpose of the analysis is to calculate the long-term LOCA mass and energy releases while incorporating revised metal material property data that bounds the current ASME boiler and pressure vessel code values and the subsequent containment integrity response to demonstrate support for the Unit 2 completion project. This effort addressed Watts Bar Unit 2 specific plant conditions and models as a means of using available analytical margins to support the Unit 2 completion project and minimizing the effect on the amount of additional ice mass required in the ice condenser. The objective of performing the long-term LOCA mass and energy release and LOCA containment integrity analysis is to minimize the effect on the initial ice mass, to maintain a minimum 150-second time interval between containment spray switchover time and ice bed melt-out time, and to provide peak pressure margin to the design pressure.

To minimize the impact on the need for additional initial ice mass, it is important to capture the conservative, but appropriate, amount of energy available to containment in the event of a LOCA. Areas such as core stored energy, decay heat, and available secondary stored energy are investigated and targeted design analysis values are more tightly converged wherever possible. These better converged inputs, combined with the increased metal material property values and a better segmental representation of the mass and energy release transient from the computer models, resulted in an impact on the Watts Bar Unit 2 containment analyses.

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, because 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. These mass and energy release rates 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 4.4.1.4 presents the long-term LOCA mass and energy release analysis for containment pressurization evaluations. Subsection 4.4.3 presents the LOCA containment pressure calculations.

4.4.1.3 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 4.4.1-1 through 4.4.1-3 present pertinent 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 4.4.1-1 through 4.4.1-3.

For the long-term mass and energy release calculations, operating temperatures that bound the highest average coolant temperature range were used. The core rated power of 3,411 MWt adjusted for calorimetric error (+2.0 percent of power) was modeled in the analysis. The use of high 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 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, because this represents the initial pressure of the

RCS. The RCS rapidly depressurizes from this value until it reaches equilibrium 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 following factors serve as the basis to ensure conservatism in the core stored energy calculation:

- A conservatively high core loading
- Time of maximum fuel densification, that is, highest beginning-of-life (BOL) temperatures
- Maximum fluid temperature

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:

- Maximum expected operating temperature of the RCS (100-percent full-power conditions).
- An allowance in temperature for instrument error and deadband assumed on the vessel/core inlet temperature (+7.0°F).
- 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).
- Core rated power of 3,411 MWt.
- Allowance for calorimetric error (+2.0 percent of power).
- Conservative coefficient of heat transfer (that is, steam generator primary/secondary heat transfer and RCS metal heat transfer).
- Density and specific heat values of 501 lbm/ft^3 and 0.145 BTU/lbm-°F, respectively, model a volumetric heat capacity which bounds the values found in Part D of the ASME boiler pressure vessel code. These values were applied to the RCS reactor, loop and steam generator metal heat calculation and address the issue described in Reference 16.
- 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.

- An allowance for RCS initial pressure uncertainty (+70 psi).
- A maximum containment backpressure equal to design pressure.
- 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 delay time equal to 0.0 seconds was used.
- 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 2 core heat generation, while retaining the two sigma uncertainty to assure conservatism.
- Steam generator tube plugging leveling (0-percent uniform).
  - Maximizes reactor coolant volume and fluid release
  - Maximizes heat transfer area across the steam generators tubes
  - 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 2 is made for the release of mass and energy from the RCS in the event of a LOCA to support the Unit 2 completion project.

4.4.1.4 Long-Term LOCA Mass and Energy Release Analysis

4.4.1.4.1 Introduction

The evaluation model used for the long-term LOCA mass and energy release calculations is the March 1979 model described in WCAP-10325-P-A (Reference 4). A corrected version of WCAP-10325-P-A computer codes and input, which removed errors reported in NSAL-06-6, -11-5, and -14-2 (References 13, 14 and 15) and included material properties that bound Part D of the current ASME boiler and pressure vessel code to disposition the effects from IG-14-1 (Reference 16) was used for the containment LOCA M&E release analysis. The NSAL corrections are corrections to calculations in support of the approved methodology, and not a change in methodology. 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 Unit 2 completion project. These mass and energy releases are then subsequently used in the LOTIC-1 computer code (Reference 6) for containment integrity analysis peak pressure calculations.

4.4.1.4.2 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.

4.4.1.4.3 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 2.

- 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. Also, 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 4.4.1.7.2).
- 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 reaches equilibrium with 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.

4.4.1.5 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 the reactor vessel and a steam generator)
2. Cold leg (between a reactor coolant pump and the reactor vessel)
3. Pump suction (between a steam generator and a reactor coolant pump)

The limiting break location analyzed for the Unit 2 completion project is the double-ended pump suction guillotine (DEPSG) (10.46 ft^2). 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 significant. Because 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.

4.4.1.6 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, which are 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.

4.4.1.7 Mass and Energy Release Data

4.4.1.7.1 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 4.4.1-4 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.

4.4.1.7.2 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/water 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. Because 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 reactor coolant 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 4.4.1-5 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 4.4.1-6.

4.4.1.7.3 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 reached equilibrium 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 4.4.1-7 presents the two-phase post-reflood (froth) mass and energy release data for the pump suction double-ended break case.

4.4.1.7.4 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 2. The primary assumptions that make this calculation specific for Watts Bar Unit 2 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 4.4.1-2 lists the decay heat curve used in the Watts Bar Unit 2 completion project analysis.

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

- Decay heat sources considered are fission product decay and heavy element decay of U-239 and Np-239.
- Decay heat power from the following fissioning isotopes is included: U-238, U-235, and Pu-239.
- Fission rate is constant over the operating history of maximum power level.
- 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).
- The fuel has been assumed to be at full power for 1,096 days.
- The number of atoms of U-239 produced per second has been assumed to be equal to 70 percent of the fission rate.

- The total recoverable energy associated with one fission has been assumed to be 200 MeV/fission.
- Two-sigma uncertainty (two times the standard deviation) has been applied to the fission product decay.

4.4.1.7.5 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 the saturation temperature 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 McAdams' 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.

4.4.1.8 Sources of Mass and Energy

The sources of mass considered in the LOCA mass and energy release analysis are given in Table 4.4.1-8. 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 4.4.1-9. The energy sources include:

- RCS water
- Accumulator water
- Pumped safety 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)

Note 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") results from the exclusion of the reactor vessel 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 4.4.1-10.

The energy release from the Zirconium-water reaction is considered as part of the WCAP-10325-P-A (Reference 4) 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 in which the Zirconium-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 nonsignificant Zirconium-water reaction. For the LOCA mass and energy calculation, the energy created by the Zirconium-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.

4.4.1.9 References

1. TVA Letter WBT-TVA-0169, Brady Queen-Peden (TVA) to Greg A. Gisoni (Westinghouse), "Response to WeCAIR Data Request for WBS 5.2.12- Containment Integrity Analysis and LOCA Mass and Energy Releases Analyses," January 26, 2009.

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 (Nonproprietary), "Westinghouse LOCA Mass and Energy Release Model for Containment Design March 1979 Version."

5. NRC/RCPL-05-138, 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. [ADAMS Accession Number ML052660242]

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

7. WCAP-9220-P-A, Revision 1, February 1982 (Proprietary), and WCAP-9221-A, Revision 1, February 1982 (Nonproprietary), "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. [ADAMS Accession Number ML021050051]

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 (Nonproprietary) "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. McAdams, "Heat Transmission," McGraw-Hill, 3rd edition, 1954, p. 172.

13. NSAL-06-6, "LOCA Mass and Energy Release Analysis," June 6, 2006.

14. NSAL-11-5, "Westinghouse LOCA Mass and Energy Release Calculation Issues," July 25, 2011.

15. NSAL-14-2, "Westinghouse Loss-of-Coolant Accident Mass and Energy Release Calculation Issue for Steam Generator Tube Material Properties," March 31, 2014.

16. Westinghouse InfoGram IG-14-1, "Material Properties for Loss-Of-Coolant Accident Mass and Energy Release Analyses," November 5, 2014.

17. Westinghouse Letter WBT-D-4290, "WBS 5.17 Watts Bar Unit 2 Final Safety Analysis DG Freq Variation," April 22, 2013.

Table 4.4.1-1 System Parameters Initial Conditions

Parameter	Value
Core Thermal Power (MWt)	3,411
Reactor Coolant System Flow Rate, per Loop (gpm)	93,100
Vessel Outlet Temperature[(1)] (°F)	619.1
Core Inlet Temperature[(1)] (°F)	560.6
Initial Steam Generator Steam Pressure[(2)] (psia)	1,021
Steam Generator Design	Model D3-2
Steam Generator Tube Plugging (%)	0
Initial Steam Generator Secondary-Side Mass (lbm)	122,474
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)	36.13
Auxiliary Feedwater Flow (gpm/steam generator)	205

Note:
1. Analysis value includes an additional +7.0°F allowance for instrument error and deadband.
2. Analysis value includes an additional 13 psi internal steam generator pressure drop.

Table 4.4.1-2 System Parameters Decay Heat Curve	
Time (sec)	**Decay Heat (P/P_0)**
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 percent	

Table 4.4.1-3 Safety Injection Flow Minimum Safety Injection	
Injection Mode	
RCS Pressure (psia)	**Total Flow (gpm)**
15.0	4,767.77
28.2	4,594.73
55.0	4,309.98
115.0	3,456.89
175.0	2,047.63
215.0	866.15
315.0	835.40
Injection Mode (Post-Reflood Phase)	
RCS Pressure (psia)	**Total Flow (gpm)**
28.2	4,616.67
Recirculation Mode (w/o Residual Heat Removal (RHR) Spray)	
RCS Pressure (psia)	**Total Flow (gpm)**
14.7	3,093.0
Recirculation Mode (w/ RHR Spray)	
RCS Pressure (psia)	**Total Flow (gpm)**
14.7	2,269.0

Table 4.4.1-4 Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release

Time seconds	Break Path No. 1 * Mass lbm/sec	Break Path No. 1 * Energy Thousand Btu/sec	Break Path No. 2 ** Mass lbm/sec	Break Path No. 2 ** Energy Thousand Btu/sec
0.0	0.0	0.0	0.0	0.0
0.001	89712.7	50762.5	43601.9	24614.6
0.1	43100.9	24412.9	22420.4	12643.4
0.2	43877.2	25044.5	24791.5	13992.6
0.3	44879.6	25882.9	24907.2	14070.5
0.4	45812.3	26742.0	24013.0	13579.0
0.5	46294.8	27357.1	22958.7	12992.8
0.6	46137.6	27585.7	21990.2	12449.5
0.7	45218.9	27318.1	21105.9	11951.3
0.8	43979.8	26822.7	20472.3	11595.9
0.9	42697.4	26276.6	20075.2	11373.5
1.0	41445.6	25735.0	19835.3	11240.1
1.1	40189.9	25193.6	19684.3	11155.8
1.2	38936.6	24656.7	19565.1	11088.9
1.3	37663.9	24107.3	19474.0	11037.2
1.4	36421.8	23568.2	19425.9	11009.6
1.5	35245.5	23053.8	19402.1	10996.0
1.6	34025.1	22493.5	19360.8	10972.1
1.7	32869.1	21946.3	19289.5	10930.9
1.8	31738.3	21383.1	19226.6	10894.6
1.9	30693.5	20852.4	19197.3	10878.0
2.0	29718.8	20347.6	19145.9	10848.9
2.1	28735.4	19817.5	19009.6	10771.2
2.2	27600.2	19170.6	18844.4	10677.5
2.3	26038.3	18208.8	18694.1	10592.8
2.4	23968.1	16861.3	18514.3	10491.4
2.5	22079.7	15631.9	18021.7	10211.8

Table 4.4.1-4 (cont.) Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release

	Break Path No. 1 *		Break Path No. 2 **	
Time seconds	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
2.6	21284.0	15167.6	17765.2	10068.1
2.7	20766.5	14863.3	17544.5	9944.4
2.8	20115.8	14441.4	17326.2	9822.1
2.9	19610.5	14118.7	17108.1	9700.1
3.0	19036.6	13738.9	16876.8	9570.6
3.1	18692.2	13523.2	16641.3	9438.8
3.2	18159.5	13166.0	16438.5	9325.8
3.3	17553.8	12758.6	16248.4	9220.1
3.4	16909.8	12321.0	16075.1	9124.1
3.5	16294.1	11898.8	15885.0	9018.7
3.6	15736.6	11513.4	15749.2	8943.8
3.7	15269.4	11190.0	15603.6	8863.7
3.8	14887.4	10923.3	15450.3	8779.2
3.9	14567.5	10696.3	15303.6	8698.4
4.0	14299.6	10504.3	15170.1	8625.3
4.2	13862.0	10182.4	14924.6	8490.9
4.4	13535.8	9931.2	14727.0	8383.8
4.6	13223.8	9680.6	15804.1	9010.1
4.8	13139.9	9574.1	15969.9	9104.0
5.0	13154.6	9531.5	15926.9	9086.1
5.2	13205.3	9525.7	15772.1	9002.5
5.4	13231.5	9512.0	15585.9	8901.5
5.6	13187.1	9460.4	15418.5	8811.3
5.8	13102.1	9389.5	15233.6	8710.5
6.0	13007.9	9317.8	15050.9	8610.3
6.2	12989.7	9296.0	14940.8	8550.7
6.4	13118.4	9344.6	14829.6	8487.4

Table 4.4.1-4 (cont.) Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release

Time seconds	Break Path No. 1 *		Break Path No. 2 **	
	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
6.6	13981.6	9892.5	14665.9	8392.4
6.8	13430.2	9480.6	14599.5	8354.2
7.0	12034.7	9045.0	14496.5	8293.5
7.2	11036.8	8596.6	14275.1	8164.6
7.4	11192.1	8637.2	14091.0	8059.8
7.6	11504.3	8741.4	13917.9	7962.6
7.8	11770.2	8814.9	13745.0	7863.3
8.0	12098.8	8930.1	13518.2	7732.2
8.2	12525.6	9105.6	13333.6	7626.1
8.4	12920.4	9256.5	13135.7	7511.8
8.6	13175.0	9322.6	12927.4	7391.6
8.8	13323.1	9335.8	12744.7	7286.0
9.0	13301.5	9247.6	12545.5	7170.6
9.2	13029.3	9012.0	12367.4	7067.4
9.4	12588.1	8685.9	12202.2	6971.6
9.6	12062.5	8320.4	12040.0	6877.3
9.8	11438.7	7906.9	11897.4	6794.5
10.0	10867.9	7551.6	11769.8	6720.4
10.2	10443.4	7308.2	11624.7	6636.0
10.2	10441.4	7307.1	11624.0	6635.6
10.4	10057.1	7094.4	11488.9	6557.9
10.6	9690.0	6896.3	11353.4	6480.1
10.8	9367.6	6726.8	11207.4	6396.0
11.0	9070.8	6571.2	11071.0	6317.3
11.2	8792.3	6423.7	10930.6	6236.1
11.4	8536.0	6286.4	10792.4	6156.1
11.6	8298.9	6157.7	10655.2	6076.6

Table 4.4.1-4 (cont.) Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release

	Break Path No. 1 *		Break Path No. 2 **	
Time seconds	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
11.8	8078.6	6037.1	10521.3	5998.9
12.0	7874.2	5924.4	10386.8	5920.9
12.2	7682.6	5816.5	10255.7	5844.9
12.4	7499.5	5711.5	10123.8	5768.6
12.6	7317.2	5608.1	9987.3	5689.5
12.8	7132.9	5501.8	9833.4	5600.7
13.0	6948.8	5382.5	9688.4	5517.6
13.2	6783.9	5257.4	9533.7	5428.6
13.4	6641.9	5136.1	9389.5	5345.5
13.6	6511.5	5020.2	9239.8	5259.4
13.8	6386.8	4907.4	9097.9	5178.3
14.0	6270.1	4802.3	8963.9	5101.9
14.2	6162.1	4706.3	8834.6	5028.6
14.4	6059.7	4619.1	8711.8	4959.4
14.6	5959.9	4541.5	8609.0	4902.7
14.8	5860.7	4470.8	8474.2	4827.4
15.0	5764.0	4409.0	8347.0	4757.5
15.2	5686.4	4366.4	8047.2	4600.8
15.4	5655.8	4395.1	7862.3	4547.5
15.6	5539.5	4470.3	7588.2	4428.5
15.8	5271.9	4519.7	7312.2	4288.9
16.0	4917.5	4533.6	7005.7	4084.5
16.2	4516.2	4510.5	6755.0	3855.5
16.4	4088.5	4435.4	6535.5	3605.8
16.6	3670.3	4259.5	6283.1	3328.5
16.8	3343.6	4037.5	5872.8	2987.8
17.0	2989.4	3669.8	5458.3	2675.3

Table 4.4.1-4 (cont.) Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release

	Break Path No. 1 *		Break Path No. 2 **	
Time seconds	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
17.2	2705.0	3345.5	5082.0	2408.8
17.4	2469.3	3068.6	4733.4	2175.9
17.6	2272.8	2834.5	4431.7	1981.5
17.8	2110.8	2640.1	4164.2	1816.0
18.0	1985.1	2488.6	3874.5	1652.3
18.2	1864.4	2341.6	3442.7	1432.9
18.4	1719.4	2163.1	3533.0	1422.2
18.6	1570.0	1978.6	5370.2	2107.1
18.8	1423.0	1796.7	6269.1	2450.5
19.0	1293.4	1636.0	5754.3	2242.0
19.2	1198.5	1518.3	3736.0	1448.5
19.4	1116.5	1416.2	3244.1	1256.9
19.6	1036.0	1315.4	2543.7	983.0
19.8	949.2	1206.2	1686.3	644.5
20.0	858.5	1092.0	1706.9	572.8
20.2	774.1	985.7	2815.8	861.8
20.4	699.1	891.1	3916.1	1163.4
20.6	634.4	809.3	3621.2	1066.7
20.8	575.0	734.1	3138.6	921.8
21.0	524.9	670.9	2842.6	833.5
21.2	493.5	631.3	2762.5	809.1
21.4	468.0	599.1	2737.7	801.2
21.6	440.8	564.4	2707.2	792.0
21.8	408.6	523.4	2594.7	759.0
22.0	371.1	475.6	2341.0	684.4
22.2	334.2	428.7	2135.6	622.8
22.4	297.2	381.4	1922.5	557.0

Table 4.4.1-4 (cont.) Double-Ended Pump Suction Guillotine Blowdown Mass and Energy Release				
	Break Path No. 1 *		Break Path No. 2 **	
Time seconds	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
22.6	260.9	335.1	1655.6	475.3
22.8	238.7	306.7	1315.6	374.4
23.0	215.9	277.5	1077.3	301.7
23.2	200.0	257.3	1097.2	300.2
23.4	185.6	238.8	1181.7	319.6
23.6	183.1	235.8	1247.5	336.2
23.8	177.6	228.6	1292.9	348.3
24.0	174.0	224.1	1318.9	355.4
24.2	168.5	217.0	1322.1	356.7
24.4	161.2	207.7	1291.9	349.2
24.6	153.2	197.4	1207.4	327.3
24.8	144.3	186.0	1033.7	281.7
25.0	139.0	179.3	698.0	192.0
25.2	125.1	161.3	68.3	19.2
25.4	112.5	145.1	0.0	0.0
25.6	93.2	120.4	0.0	0.0
25.8	85.7	110.7	0.0	0.0
26.0	72.4	93.7	47.3	16.4
26.2	60.3	78.1	156.0	57.3
26.4	48.4	62.8	102.5	38.9
26.6	38.7	50.3	99.8	37.4
26.8	19.9	25.9	0.0	0.0
27.0	0.0	0.0	0.0	0.0

* M&E releases exiting the steam generator side of the break

** M&E releases exiting the pump side of the break

Table 4.4.1-5 Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection

Time seconds	Break Path No. 1 *		Break Path No. 2 **	
	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
27.0	0.0	0.0	0.0	0.0
27.5	0.0	0.0	0.0	0.0
27.7	0.0	0.0	0.0	0.0
27.8	0.0	0.0	0.0	0.0
27.9	0.0	0.0	0.0	0.0
28.0	0.0	0.0	0.0	0.0
28.0	0.0	0.0	0.0	0.0
28.1	34.2	39.8	0.0	0.0
28.2	13.5	15.7	0.0	0.0
28.4	14.1	16.5	0.0	0.0
28.5	18.1	21.1	0.0	0.0
28.6	23.8	27.6	0.0	0.0
28.7	28.0	32.6	0.0	0.0
28.8	32.2	37.4	0.0	0.0
28.9	36.1	42.0	0.0	0.0
29.0	39.2	45.7	0.0	0.0
29.1	42.1	49.0	0.0	0.0
29.2	44.8	52.1	0.0	0.0
29.3	47.4	55.2	0.0	0.0
29.4	49.9	58.1	0.0	0.0
29.5	52.3	60.9	0.0	0.0
29.6	55.0	64.1	0.0	0.0
29.7	57.6	67.0	0.0	0.0
29.8	59.2	68.9	0.0	0.0
29.8	60.0	69.9	0.0	0.0
29.9	62.4	72.7	0.0	0.0
30.0	64.5	75.1	0.0	0.0
30.1	66.2	77.1	0.0	0.0

Table 4.4.1-5 (cont.) Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection				
	Break Path No. 1 *		Break Path No. 2 **	
Time seconds	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
31.1	84.4	98.4	0.0	0.0
32.1	99.6	116.2	0.0	0.0
33.1	191.4	223.9	2428.8	327.4
34.2	334.3	393.4	4508.5	668.4
34.9	333.4	392.4	4496.2	670.7
35.2	332.2	390.9	4479.6	669.0
36.2	327.5	385.4	4415.0	661.5
37.2	348.7	410.6	4744.9	688.1
38.2	343.7	404.7	4679.0	679.6
39.2	338.9	399.0	4613.3	671.0
40.2	334.2	393.4	4548.6	662.5
40.7	331.9	390.6	4516.9	658.3
41.2	329.7	388.0	4485.6	654.1
42.2	325.4	382.8	4424.3	645.9
43.2	321.0	377.6	4365.0	638.0
44.2	316.4	372.1	4308.0	630.5
45.2	311.9	366.7	4252.9	623.2
46.2	307.5	361.6	4199.6	616.2
47.2	303.4	356.6	4148.1	609.4
48.2	299.4	351.9	4098.2	602.8
48.7	297.5	349.6	4073.8	599.6
49.2	295.6	347.3	4049.9	596.4
50.2	291.9	342.9	4003.1	590.3
51.2	288.3	338.7	3957.7	584.3
52.2	284.9	334.6	3913.7	578.5
53.2	281.5	330.7	3871.0	572.9
54.2	278.4	326.9	3829.6	567.4

Table 4.4.1-5 (cont.) Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection

	Break Path No. 1 *		Break Path No. 2 **	
Time seconds	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
55.2	275.3	323.2	3789.3	562.1
56.2	272.3	319.6	3750.1	557.0
57.2	269.4	316.2	3712.0	552.0
58.2	266.6	312.9	3675.0	547.1
58.4	266.0	312.2	3667.7	546.2
59.2	263.9	309.7	3638.9	542.4
60.2	261.2	306.6	3603.7	537.8
61.2	258.7	303.5	3569.5	533.3
62.2	256.2	300.6	3536.0	528.9
63.2	253.8	297.7	3503.4	524.7
64.2	251.5	295.0	3471.6	520.5
65.2	249.2	292.3	3440.5	516.4
66.2	208.7	244.4	2828.2	442.4
67.2	327.6	385.3	281.0	165.8
68.2	361.9	426.5	297.8	189.9
69.1	358.7	422.6	296.2	187.9
69.2	358.1	421.9	295.9	187.5
70.2	351.6	414.2	292.8	183.2
71.2	345.5	406.9	289.8	179.0
72.2	339.9	400.1	287.0	175.1
73.2	334.5	393.8	284.3	171.4
74.2	329.4	387.6	281.7	167.9
75.2	324.1	381.3	279.1	164.3
76.2	319.0	375.2	276.8	161.1
77.2	314.2	369.5	274.7	158.4
78.2	309.7	364.1	272.8	155.8
79.2	305.4	359.0	270.9	153.4

Table 4.4.1-5 (cont.) Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection

Time seconds	Break Path No. 1 *		Break Path No. 2 **	
	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
80.2	301.3	354.1	269.2	151.1
81.2	297.3	349.4	267.5	148.9
82.2	293.6	345.0	266.0	146.8
83.2	290.0	340.7	264.5	144.8
84.2	286.6	336.7	263.0	142.9
85.2	283.4	332.8	261.7	141.1
86.2	280.3	329.1	260.4	139.4
87.2	277.3	325.6	259.2	137.8
88.2	274.5	322.3	258.0	136.2
89.9	270.0	316.9	256.1	133.7
90.2	269.2	316.0	255.8	133.3
92.2	264.4	310.2	253.8	130.7
94.2	259.9	305.0	252.0	128.3
96.2	255.9	300.2	250.3	126.1
98.2	252.1	295.8	248.8	124.1
100.2	248.7	291.7	247.4	122.2
102.2	245.5	287.9	246.1	120.5
104.2	242.6	284.4	244.9	118.9
106.2	239.9	281.2	243.8	117.5
108.2	237.4	278.3	242.8	116.2
110.2	235.1	275.6	241.9	115.0
112.2	233.1	273.2	241.0	113.9
114.2	231.2	270.9	240.3	112.9
116.2	229.5	268.9	239.6	112.0
117.1	228.8	268.1	239.3	111.6
118.2	227.9	267.1	238.9	111.1
120.2	226.5	265.4	238.3	110.4

Table 4.4.1-5 (cont.) Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection

Time seconds	Break Path No. 1 *		Break Path No. 2 **	
	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
122.2	225.2	263.9	237.8	109.7
124.2	224.0	262.5	237.3	109.1
126.2	222.9	261.2	236.9	108.5
128.2	221.9	260.0	236.5	107.9
130.2	221.0	258.9	236.1	107.5
132.2	220.2	257.9	235.8	107.0
134.2	219.4	257.0	235.5	106.6
136.2	218.7	256.2	235.2	106.2
138.2	218.1	255.4	234.9	105.9
140.2	217.5	254.8	234.7	105.6
142.2	217.0	254.2	234.4	105.3
144.2	216.5	253.6	234.2	105.0
146.2	216.1	253.1	234.1	104.8
147.8	215.8	252.8	233.9	104.6
148.2	215.8	252.7	233.9	104.6
150.2	215.4	252.3	233.8	104.4
152.2	215.1	252.0	233.6	104.2
154.2	214.8	251.6	233.5	104.0
156.2	214.5	251.3	233.4	103.9
158.2	214.3	251.0	233.3	103.7
160.2	214.1	250.7	233.1	103.6
162.2	213.9	250.5	233.0	103.5
164.2	213.7	250.2	233.0	103.3
166.2	214.1	250.8	233.3	103.5
168.2	214.5	251.2	233.8	103.7
170.2	215.0	251.8	234.6	103.9
172.2	215.5	252.5	235.7	104.2

Table 4.4.1-5 (cont.) Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection

Time seconds	Break Path No. 1 * Mass lbm/sec	Break Path No. 1 * Energy Thousand Btu/sec	Break Path No. 2 ** Mass lbm/sec	Break Path No. 2 ** Energy Thousand Btu/sec
174.2	216.1	253.2	236.9	104.5
176.2	216.7	253.9	238.3	104.8
178.2	217.3	254.5	239.7	105.1
179.4	217.6	254.9	240.6	105.2
180.2	217.8	255.1	241.2	105.3
182.2	218.2	255.6	242.7	105.5
184.2	218.6	256.1	244.2	105.7
186.2	218.9	256.4	245.7	105.9
188.2	219.1	256.7	247.3	106.0
190.2	219.3	256.9	249.0	106.2
192.2	219.5	257.1	250.6	106.3
194.2	219.6	257.2	252.4	106.4
196.2	219.6	257.2	254.1	106.4
198.2	219.5	257.2	255.8	106.4
200.2	219.4	257.0	257.6	106.4
202.2	219.2	256.8	259.4	106.4
204.2	219.0	256.5	261.3	106.4
206.2	218.7	256.1	263.1	106.3
208.2	218.3	255.7	265.0	106.2
210.2	217.9	255.2	267.0	106.1
210.8	217.8	255.1	267.6	106.1
212.2	217.5	254.7	269.0	106.1
214.2	217.0	254.2	271.1	106.0
216.2	216.5	253.6	273.3	105.9
218.2	215.9	252.9	275.5	105.8
220.2	215.3	252.1	277.7	105.6
222.2	214.6	251.3	280.0	105.5

Table 4.4.1-5 (cont.) Double-Ended Pump Suction Guillotine Reflood Mass and Energy Release – Minimum Safety Injection

Time seconds	Break Path No. 1 *		Break Path No. 2 **	
	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
224.2	213.8	250.4	282.3	105.3
226.2	213.0	249.5	284.6	105.2
228.2	212.1	248.4	286.9	105.0
230.2	211.2	247.3	289.3	104.8
232.2	210.2	246.1	291.7	104.6
234.2	209.2	244.9	294.2	104.4
236.2	208.1	243.7	296.7	104.3
238.2	206.9	242.3	299.1	104.0
240.2	205.7	240.8	301.5	103.8
242.2	204.4	239.3	304.0	103.5
243.6	203.4	238.2	305.7	103.4

* M&E releases exiting the steam generator side of the break

** M&E releases exiting the pump side of the break

Table 4.4.1-6 Double-Ended Pump Suction Guillotine Minimum Safety Injection Principal Parameters During Reflood

Time seconds	Temp °F	Flooding Rate in/sec	Carryover 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
27.0	206.5	0.000	0.000	0.00	0.00	0.250	0.0	0.0	0.0	0.00
27.8	203.7	22.205	0.000	0.65	1.44	0.000	7306.6	7306.6	0.0	99.46
28.0	202.2	24.049	0.000	1.04	1.35	0.000	7255.4	7255.4	0.0	99.46
28.4	201.7	2.345	0.100	1.30	2.13	0.235	7129.0	7129.0	0.0	99.46
28.6	201.8	2.385	0.137	1.33	2.74	0.286	7081.5	7081.5	0.0	99.46
29.8	202.6	2.033	0.323	1.50	6.33	0.352	6806.9	6806.9	0.0	99.46
31.1	203.6	1.973	0.456	1.63	10.27	0.367	6540.3	6540.3	0.0	99.46
34.2	205.7	3.711	0.619	1.93	16.12	0.567	5385.1	5385.1	0.0	99.46
34.9	206.2	3.557	0.644	2.00	16.12	0.566	5281.5	5281.5	0.0	99.46
35.2	206.4	3.499	0.653	2.03	16.12	0.566	5243.8	5243.8	0.0	99.46
36.2	207.2	3.341	0.675	2.13	16.12	0.566	5127.2	5127.2	0.0	99.46
37.2	208.0	3.426	0.691	2.23	16.12	0.574	5469.6	4881.9	0.0	96.62
40.7	211.1	3.131	0.724	2.50	16.12	0.572	5155.8	4562.6	0.0	96.42
48.7	219.0	2.745	0.753	3.00	16.12	0.562	4611.9	4010.2	0.0	96.02
58.4	227.8	2.459	0.769	3.50	16.12	0.550	4135.4	3526.9	0.0	95.58
66.2	233.6	2.039	0.781	3.85	16.12	0.513	3193.9	2573.8	0.0	94.34
67.2	234.3	2.867	0.774	3.89	16.09	0.596	596.3	0.0	0.0	73.06
68.2	235.0	3.085	0.768	3.95	15.95	0.598	580.8	0.0	0.0	73.06
69.1	235.6	3.050	0.769	4.00	15.82	0.598	581.5	0.0	0.0	73.06
79.2	241.7	2.582	0.779	4.54	14.76	0.593	598.0	0.0	0.0	73.06
89.9	246.9	2.287	0.787	5.00	14.21	0.587	605.6	0.0	0.0	73.06

Table 4.4.1-6 Double-Ended Pump Suction Guillotine Minimum Safety Injection Principal Parameters During Reflood (cont.)

Time seconds	Temp °F	Flooding Rate in/sec	Carryover Fraction	Core Height ft	Down-comer Height ft	Flow Fraction	Total	Injection Accumulator	SI Spill	Enthalpy Btu/lbm
							(pounds mass per second)			
104.2	246.2	2.073	0.790	5.55	13.98	0.580	611.2	0.0	0.0	73.06
117.1	247.0	1.962	0.793	6.00	14.04	0.576	613.8	0.0	0.0	73.06
134.2	246.5	1.891	0.793	6.57	14.34	0.573	615.6	0.0	0.0	73.06
147.8	247.5	1.859	0.795	7.00	14.67	0.572	616.3	0.0	0.0	73.06
164.2	246.8	1.843	0.795	7.52	15.12	0.571	616.8	0.0	0.0	73.06
179.4	247.5	1.863	0.795	8.00	15.52	0.575	616.1	0.0	0.0	73.06
188.2	247.0	1.869	0.794	8.28	15.68	0.578	615.8	0.0	0.0	73.06
196.2	247.5	1.864	0.795	8.54	15.81	0.580	615.7	0.0	0.0	73.06
210.8	247.1	1.838	0.794	9.00	15.97	0.584	615.9	0.0	0.0	73.06
228.2	247.3	1.778	0.794	9.54	16.07	0.588	616.7	0.0	0.0	73.06
243.6	247.5	1.700	0.795	10.00	16.11	0.590	618.1	0.0	0.0	73.06

Table 4.4.1-7 Double-Ended Pump Suction Guillotine Minimum Safety Injection Post Reflood Mass and Energy Release

Time seconds	Break Path No. 1 *		Break Path No. 2 **	
	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
243.7	213.0	268.4	424.1	119.1
248.7	212.3	267.4	424.9	119.2
253.7	211.5	266.5	425.6	119.2
258.7	212.3	267.4	424.9	119.0
263.7	211.5	266.5	425.6	119.1
268.7	210.8	265.5	426.4	119.1
273.7	211.5	266.4	425.7	118.9
278.7	210.7	265.4	426.5	118.9
283.7	209.9	264.4	427.3	119.0
288.7	210.6	265.3	426.6	118.7
293.7	209.8	264.2	427.4	118.8
298.7	210.4	265.0	426.8	118.6
303.7	209.6	264.0	427.6	118.7
308.7	208.8	263.0	428.4	118.7
313.7	209.4	263.7	427.8	118.5
318.7	208.5	262.7	428.6	118.6
323.7	207.7	261.6	429.5	118.7
328.7	208.2	262.3	428.9	118.4
333.7	207.4	261.2	429.8	118.5
338.7	207.9	261.9	429.3	118.3
343.7	207.0	260.8	430.2	118.4
348.7	206.1	259.6	431.0	118.5
353.7	206.6	260.2	430.6	118.3
358.7	205.7	259.1	431.5	118.4
363.7	206.1	259.7	431.0	118.2
368.7	205.2	258.5	432.0	118.3
373.7	205.6	259.0	431.6	118.1

Table 4.4.1-7 (cont.) Double-Ended Pump Suction Guillotine Minimum Safety Injection Post Reflood Mass and Energy Release

	Break Path No. 1 *		Break Path No. 2 **	
Time seconds	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
378.7	204.6	257.8	432.5	118.2
383.7	205.0	258.3	432.1	118.0
388.7	204.0	257.0	433.1	118.1
393.7	204.4	257.4	432.8	117.9
398.7	203.4	256.2	433.8	118.0
403.7	203.7	256.7	433.4	117.8
408.7	202.8	255.5	434.3	117.9
413.7	203.2	256.0	433.9	117.8
418.7	202.3	254.8	434.9	117.9
423.7	202.6	255.3	434.5	117.7
428.7	201.7	254.1	435.5	117.8
433.7	202.0	254.4	435.2	117.6
438.7	201.0	253.2	436.2	117.8
443.7	201.2	253.5	435.9	117.6
448.7	201.4	253.7	435.7	117.5
453.7	200.4	252.4	436.8	117.6
458.7	200.5	252.6	436.6	117.5
463.7	199.5	251.3	437.7	117.6
468.7	199.6	251.4	437.6	117.5
473.7	199.6	251.5	437.5	117.4
478.7	199.6	251.5	437.5	117.3
483.7	198.5	250.0	438.7	117.4
488.7	198.4	250.0	438.7	117.3
493.7	198.4	249.9	438.8	117.2
498.7	198.3	249.7	438.9	117.2
503.7	198.1	249.5	439.1	117.1
508.7	197.9	249.3	439.3	117.0
513.7	196.5	247.6	440.6	117.2

Table 4.4.1-7 (cont.) Double-Ended Pump Suction Guillotine Minimum Safety Injection Post Reflood Mass and Energy Release

	Break Path No. 1 *		Break Path No. 2 **	
Time seconds	Mass lbm/sec	Energy Thousand Btu/sec	Mass lbm/sec	Energy Thousand Btu/sec
518.7	196.3	247.2	440.9	117.2
523.7	197.0	248.2	440.2	116.9
528.7	196.6	247.7	440.5	116.9
533.7	196.2	247.1	441.0	116.9
538.7	195.7	246.5	441.5	116.9
543.7	195.1	245.8	442.1	116.9
548.7	194.5	245.0	442.7	117.0
553.7	194.8	245.4	442.4	116.8
558.7	194.0	244.4	443.2	116.9
563.7	194.1	244.5	443.0	116.7
568.7	194.1	244.6	443.0	116.6
573.7	193.1	243.3	444.1	116.8
578.7	192.9	243.0	444.3	116.7
583.7	192.6	242.6	444.6	116.7
588.7	192.1	242.0	445.1	116.7
593.7	192.3	242.3	444.8	116.5
598.7	191.5	241.3	445.6	116.6
603.7	191.4	241.1	445.7	116.5
608.7	191.1	240.7	446.1	116.5
613.7	190.5	240.0	446.7	116.5
618.7	190.4	239.9	446.8	116.4
623.7	189.9	239.3	447.2	116.4
628.7	189.8	239.1	447.4	116.4
633.7	189.8	239.1	447.4	116.3
638.7	189.1	238.2	448.0	116.3
643.7	188.9	238.0	448.2	116.2
648.7	188.8	237.9	448.3	116.2
653.7	188.3	237.2	448.8	116.2

Table 4.4.1-7 (cont.) Double-Ended Pump Suction Guillotine Minimum Safety Injection Post Reflood Mass and Energy Release

Time seconds	Break Path No. 1 * Mass lbm/sec	Break Path No. 1 * Energy Thousand Btu/sec	Break Path No. 2 ** Mass lbm/sec	Break Path No. 2 ** Energy Thousand Btu/sec
658.7	187.6	236.4	449.5	116.2
663.7	187.5	236.2	449.6	116.1
1096.9	187.5	236.2	449.6	116.1
1097.0	72.9	91.5	564.3	138.2
1098.7	72.9	91.5	564.3	138.2
1203.7	71.3	89.4	565.9	135.9
1207.3	71.2	89.4	565.8	135.8
1262.3	70.4	88.3	566.7	134.5
1267.3	70.3	88.2	571.3	152.7
1342.3	69.2	86.8	572.4	150.9
1344.3	69.1	86.8	354.8	128.9
2568.96	69.1	86.8	354.8	128.9

* M&E releases exiting the steam generator side of the break

** M&E releases exiting the pump side of the break

Table 4.4.1-8 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)	0.00	27.00	27.00	243.64	1097.04	2568.96
	Mass (Thousands lbm)						
Initial Mass in RCS and Accumulators		750.32	750.32	750.32	750.32	750.32	750.32
Added Mass	Pumped Injection	0.00	0.00	0.00	126.79	670.50	1347.51
	Total Added	0.00	0.00	0.00	126.79	670.50	1347.51
Total Available		750.32	750.32	750.32	877.11	1420.82	2097.83
Distribution	Reactor Coolant	492.76	74.45	74.60	136.14	136.14	136.14
	Accumulator	257.56	176.99	176.83	0.00	0.00	0.00
	Total Contents	750.32	251.44	251.44	136.14	136.14	136.14
Effluent	Break Flow	0.00	498.87	498.87	730.36	1274.08	1950.88
	ECCS Spill	0.00	0.00	0.00	0.00	0.00	0.00
	Total Effluent	0.00	498.87	498.87	730.36	1274.08	1950.88
Total Accountable		750.32	750.30	750.30	866.50	1410.21	2087.02

Table 4.4.1-9 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)	0.00	27.00	27.00	243.64	1097.04	2568.96
		Energy (Million Btu)					
Initial Energy	In RCS, Accum, & SG	984.47	984.47	984.47	984.47	984.47	984.47
Added Energy	Pumped Injection	0.00	0.00	0.00	9.26	48.99	114.34
	Decay Heat	0.00	7.74	7.74	31.76	99.91	189.17
	Heat from Secondary	0.00	12.23	12.23	12.23	21.45	31.41
	Total Added	0.00	19.97	19.97	53.25	170.34	334.91
Total Available		984.47	1004.44	1004.44	1037.72	1154.81	1319.38
Distribution	Reactor Coolant	296.93	13.54	13.55	29.66	29.66	29.66
	Accumulator	25.62	17.60	17.59	0.00	0.00	0.00
	Core Stored	25.61	14.16	14.16	3.98	3.65	3.46
	Primary Metal	214.29	205.63	205.63	185.27	108.49	77.54
	Secondary Metal	136.88	136.16	136.16	125.62	90.43	55.90
	Steam Generator	285.15	301.32	301.32	273.92	198.94	131.47
	Total Contents	984.47	688.40	688.40	618.45	431.17	298.03
Effluent	Break Flow	0.00	315.46	315.46	416.07	720.43	1045.25
	ECCS Spill	0.00	0.00	0.00	0.00	0.00	0.00
	Total Effluent	0.00	315.46	315.46	416.07	720.43	1045.25
Total Accountable		984.47	1003.86	1003.86	1034.52	1151.61	1343.28

Table 4.4.1-10 Sequence of Events

Event	Time (sec)
Rupture	0.0
Accumulator Flow Starts	15.6
Assumed Initiation of ECCS	36.1
End of Blowdown	27.0
Accumulators Empty	66.2
Assumed Initiation of Spray System	234.0
End of Reflood	243.6
Low Level Alarm of Refueling Water Storage Tank	1,207.3
Beginning of Recirculation Phase of Safeguards Operation	1,267.3

4.4.3 LOCA Containment Integrity Analysis

4.4.3.1 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 need 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 containment model 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: blowdown period, depressurization period, and long-term period. 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.

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 among 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 tables.

The condensation of steam is assumed to take place in a condensing node located, for the purpose of the 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.

4.4.3.2 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.

- 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; and one-of-two air return fans – where the performance of each considered a +/- 0.2 Hz variation in the frequency of the diesel generator (Reference 9).

- 2.585 x 10^6 lbs of ice initially in the ice condenser.
- The blowdown, reflood, and post reflood mass and energy releases described in Section 4.4.1.7 are used.
- The blowdown period mass and energy from Table 4.4.1-4 is conservatively compressed into a 10-second period consistent with the Waltz Mill ice condenser test (Reference 2). During this period, steam and air flow through the ice condenser and an ice mass melt is calculated.
- 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.)
- Nitrogen from the accumulators in the amount of 2,955.7 lbs is included in the calculations.
- Hydrogen gas is added to the containment in the amount of 25,230.2 standard cubic feet (SCF) over 24 hours. Sources accounted for are 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 cladding in the core, and hydrogen gas is assumed to be dissolved in the RCS water. (This bounds tritium-producing core designs, i.e., Unit 1 WCAP-15699, Revision 1.)
- Essential service water temperature of 88°F is used on the spray heat exchanger and the component cooling heat exchanger.
- The air return fan is assumed to be effective 10 minutes after the transient is initiated.
- No maldistribution of steam flow to the ice bed is assumed. (This assumption is conservative; it contributes to early ice bed melt-out time.)
- No ice condenser bypass is assumed. (This assumption depletes the ice in the shortest time and is, therefore, conservative.)
- The initial conditions in the containment are a temperature of 120°F in the lower and dead-ended volumes, 110°F in the upper volume, and 27°F in the ice condenser. 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. These values were shown to be conservative for peak pressure calculations based on sensitivities which used 85°F in the upper volume, 100°F in the lower and dead-ended volumes and 15°F for the ice bed.
- The pump flow rates versus time presented in Table 4.4.3-1 are used in support of the refueling water storage tank (RWST) draindown time sequence for switchover from the injection mode to recirculation. These flow rates reflect ECCS and containment spray pump runout flow rates.) A loss of offsite power at the event initiation is assumed.
- Containment structural heat sinks are assumed with conservatively low heat transfer rates (see Tables 4.4.3-2 and 4.4.3-3). Note that the dead-ended compartment structural heat sinks were conservatively neglected.

- 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 the Transient Mass Distribution (TMD) computer model volumes (Reference 3). For containment integrity analysis, the volumes are adjusted to maximize air mass and the compression ratio.)
- The operation of one containment spray heat exchanger (Overall Conductance (UA) = $2.440 \, x \, 10^6$ Btu/hr-°F) for containment cooling and the operation of one RHR heat exchanger (UA = $1.496 \, x \, 10^6$ Btu/hr-°F) for core cooling are assumed. The component cooling heat exchanger UA was modeled at $3.17 \, x \, 10^6$ Btu/hr-°F (References 3, 7 and 8). The UA for the spray heat exchanger represents an assumed tube plugging of 10%, while the RHR heat exchanger and component cooling UA's reflect dual operation of the Watts Bar Unit 1 and Unit 2 plants.
- The air return fan returns air at a rate of 40,000 cfm from the upper to the lower compartment.
- An active sump volume of 51,000 ft^3 is used.
- 102 percent of 3,411 MWt power is used in the calculations.
- Subcooling of emergency core cooling (ECC) water from the RHR heat exchanger is assumed.
- Essential raw cooling water flow to the containment spray heat exchanger is modeled as 5,200 gpm. Also, the essential raw cooling water flow to the component cooling heat exchanger is modeled as 3,500 gpm which represents dual operation of the Watts Bar Unit 1 and Unit 2 plants (References 3 and 8).
- 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 4.4.1.7.4).
- 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 (Reference 3). Based on the preceding criteria, the RHR spray initiation was modeled at 3,600 seconds into the LOCA containment response transient. An RHR spray flow rate of 1,475 gpm (analytical value) is modeled.
- The containment spray system spray flow start time for the containment volume spray is modeled at 234 seconds (Reference 5). The time for containment spray switchover to recirculation is assumed to be completed at 2,718.7 seconds (see Table 4.4.3-1). A containment spray pump flow rate of 4,000 gpm is modeled to be available in both the injection and recirculation modes to the upper compartment spray header.
- The blowdown compression pressure is calculated to be 7.807 psig.

4.4.3.3 Structural Heat Removal

A 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 increase of the node for the containment structural heat sinks used in the analysis. The heat sink and material property data from Reference 3 is used to develop Tables 4.4.3-2 and 4.4.3-3. The ice condenser structural model and material properties reflect a generic Westinghouse ice condenser compartment design.

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 is placed on the lower compartment stagnant heat transfer coefficients. They are 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 in which 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.

4.4.3.4 Analysis Results

The results of the analysis show that the maximum calculated containment pressure is 11.73 psig, for the DEPSG minimum safeguards break case, assuming an ice bed mass of $2.585 \, x \, 10^6$ lbm. This pressure is less than the design pressure of 15.0 psig as well as the administrative limit of 13.5 psig and, therefore, shows the acceptability for Unit 2. The pressure peak occurs at approximately 3,600 seconds (approximately 60 minutes), with ice bed melt-out at approximately 2,959 seconds (approximately 49+ minutes). It is noted that the apparent containment pressure margin between 11.73 psig and the design pressure cannot be used to further reduce the ice mass. The ice bed mass is limited by the spray switchover time of 2,718.7 seconds (approximately 45 minutes) and the margin between spray switchover and ice bed melt-out of at least 150 seconds (2.5 minutes).

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

- Figure 4.4.3-1, Containment Pressure Transient
- Figure 4.4.3-2, Upper Compartment Temperature Transient
- Figure 4.4.3-3, Lower Compartment Temperature Transient
- Figure 4.4.3-4, Active and Inactive Sump Temperature Transient
- Figure 4.4.3-5, Ice Melt Transient
- Figure 4.4.3-6, Comparison of Containment Pressure versus Ice Melt Transients

Tables 4.4.3-4 and 4.4.3-5 provide energy accountings at various points in the transient.

Table 4.4.3-6 provides data points for Figures 4.4.3-1 through 4.4.3-6 out to 30 days to address the effect on environmental qualification.

4.4.3.5 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 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, core stored energy, decay heat, 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.

4.4.3.6 Conclusions

Based upon the information presented in this report, it may be concluded that operation with an ice weight of 2.585 million pounds for Watts Bar Unit 2 is acceptable. Operation with an ice mass of 2.585 million pounds results in a calculated peak containment pressure of 11.73 psig, as compared to the design pressure of 15.0 psig or the administrative limit of 13.5 psig. Further, the ice bed mass of $2.585x10^6$ lbm equates to an average of 1,330 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 325 lbm, based on Table 4.4.3-4 [631,900 lbm / 1944 baskets]. To ensure that an adequate distribution of ice exists in the ice condenser to prevent early burn-through of a localized area, 325 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 1,330 lbm.

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

4.4.3.7 References

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

2. WCAP-8110, Supplement 6, (Nonproprietary), "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 Assumption," May 24, 2004.

4. Watts Bar Nuclear Plant System Description, No. N3-72-4001, R19, (Containment Heat Removal Spray System).

5. TVA Letter W-7752, J. C. Kammeyer (TVA) to Krish 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)."

7. TVA Letter Number WBT-TVA-0881, Larry Bond (TVA) to Greg Gisoni (Westinghouse), "Analysis Input Request for Heat Exchanger UAs – for RHR Cooldown," December 17, 2009.

8. TVA Letter WBT-TVA-2832 R1, Roni Wilson (TVA) to Bob Schillat (Westinghouse), "Containment Analysis Parameters R1," April 9, 2015.

9. Westinghouse Letter WBT-D-4290, "WBS 5.17 Watts Bar Unit 2 Final Safety Analysis DG Freq Variation," April 22, 2013.

Table 4.4.3-1 RWST Draindown Time Sequence for Switchover Injection to Recirculation Mode

	Steps	Time After Initiation of SI Signal (sec)	CCP Flow (gpm)	HHSI Pump Flow (gpm)	RHR Pump Flow (gpm)	CSS Pump Flow (gpm)	RHR Spray Flow (gpm)	Sump Flow (gpm)	RWST Flow (gpm)	RWST Volume (gal)	Max SI Injected Flow (gpm)
	Runout Flowrates Assumed		560	675	5,500	4950	2000				
1	Safety Injection Signal Initiated	0	0	0	0	0	0	0	0	370,000	0
2	CCP Starts and Reaches Rated Flow	12	560	0	0	0	0	0	560	370,000	560
3	HHSI Pump Starts and Reaches Rated Flow	17	560	675	0	0	0	0	1,235	366,953	1,235
4	RHR Pump Starts and Reaches Rated Flow	22	560	675	5,500	0	0	0	6,735	369,850	6,735
5	CSS Pump Starts and Reaches Rated Flow	234	560	675	5,500	4,950	0	0	11,685	346,053	6,735
6	RWST Low Level Alarm, Automatic Realignment of RHR	1,207.27	560	675	5,500	4,950	0	0	11,685	156,510	6,735
7	Sump Valves Open, RWST-to-RHR Valves Close	1,267.27	560	675	2,750	4,950	0	2,750	6,185	144,825	3,985
8	HHSI & CCP Suction Valves from RHR Discharge Open	1,344.27	560	675	2,750	4,950	0	2,750	4,950	136,888	2,750
9	Low-Low RWST Level Alarm	2,588.66	560	675	2,750	4,950	0	2,750	4,950	34,225	2,750
10	Shut Off CSS Pump	2,598.66	560	675	2,750	0	0	2,750	0	33,400	2,750
11	Restart CSS Pump	2,718.66	560	675	2,750	0	0	2,750	0	33,400	2,750
12	Start RHR Spray	3,600	560	675	2,750	4,950	2,000	2,750	0	33,400	2,750
13	End of Transient										

Table 4.4.3-2 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 Carbon 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 Carbon Steel

Note:
1. In contact with sump.

Table 4.4.3-2 Structural Heat Sink Table (cont.)

Ice Condenser	Area (ft^2)	Thickness (ft)	Material
1. Ice Baskets			
Slab 12	149,600.	0.00663	Carbon Steel
2. Lattice Frames			
Slab 13	75,865.	0.0217	Carbon Steel
3. Lower Support Structure			
Slab 14	28,670.	0.0587	Carbon Steel
4. Ice Condenser Floor			
Slab 15	3,336.	0.0055 0.33	Paint Concrete
5. Containment Wall Panels & Containment Shell			
Slab 16	19,100.	1.0 0.0625	Steel & Insulation Composite Panel Carbon Steel Shell
6. Crane Wall Panels and Crane Wall			
Slab 17	13,055.	1.0 1.0	Steel & Insulation Composite Panel Concrete

Table 4.4.3-3 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 (containment)	0.8	31.9
Concrete (ice condenser)	0.8	28.8
Stainless Steel	9.4	53.68
Carbon Steel (containment)	26.0	53.9
Carbon Steel (ice condenser)	26.0	56.4
Steel & Insulation Composite Panel on Steel (ice condenser)	0.15	2.75
Steel & Insulation Composite Panel on Concrete (ice condenser)	0.2	3.663

Table 4.4.3-4 Energy Accounting		
	Approximate End of Blowdown (t =10.0 sec.)	**Approximate End of Reflood (t = 243.64 sec.)**
	(in Millions of Btus)	
Ice Heat Removal(1)	192.0	246.37
Structural Heat Sinks(1)	16.804	54.978
RHR Heat Exchanger Heat Removal(1)	0	0
Spray Heat Exchanger Heat Removal(1)	0	0
Energy Content of Sump(2)	176.05	231.28
Ice Melted (pounds) (10^6)	0.6319	0.855

Note:

1. Integrated energies
2. Sum of active and inactive sump

Table 4.4.3-5 Energy Accounting		
	Approximate Time of Ice Melt Out (t = 2958.95 sec.)	**Approximate Time of Peak Pressure (t = 3599.95 sec.)**
	(in Millions of Btus)	
Ice Heat Removal(1)	668.15	668.15
Structural Heat Sinks(1)	70.56	85.39
RHR Heat Exchanger Heat Removal(1)	18.4	24.79
Spray Heat Exchanger Heat Removal(1)	4.77	17.27
Energy Content of Sump(2)	633.03	631.28
Ice Melted (pounds) (10^6)	2.585	2.585

Note:

1. Integrated energies
2. Sum of active and inactive sump

Table 4.4.3-6 Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
2.0	7.8	234.3	110.0	190.0	0.0	126378.7
62.5	7.6	233.8	110.0	187.9	0.0	644170.6
96.12	7.51	231.77	110.4	185.6	0.0	686597.7
127.8	6.9	223.2	111.1	183.9	0.0	726576.6
193.8	7.2	226.7	112.1	181.0	0.0	801575.8
258.9	6.8	224.2	108.5	178.2	0.0	872877.9
324.9	6.8	225.5	106.2	175.1	0.0	944459.2
390.9	6.8	225.8	106.0	172.5	0.0	1014790.0
456.9	6.8	225.8	106.0	170.4	0.0	1083947.0
522.9	6.8	225.7	106.0	168.5	0.0	1151918.0
588.9	6.8	225.4	106.0	167.0	0.0	1218579.0
654.9	6.2	214.8	109.2	165.6	0.0	1284651.0
720.9	6.1	211.5	109.5	164.4	0.0	1350514.0
786.9	6.0	210.8	109.6	163.3	0.0	1416190.0
852.9	6.0	210.7	109.6	162.4	0.0	1481679.0
918.9	6.1	210.7	109.6	161.5	0.0	1547035.0
984.9	6.1	210.7	109.6	160.7	160.9	1612301.0
1050.9	6.1	210.8	109.6	160.0	160.5	1677504.0
1116.0	5.9	207.3	109.6	159.4	160.2	1731396.0
1182.0	5.6	200.3	109.6	159.3	160.0	1760890.0
1248.0	5.4	197.0	109.6	159.1	159.8	1789788.0
1312.7	5.5	198.9	109.6	159.0	159.7	1820793.0
1377.0	5.6	201.1	109.6	158.6	159.6	1855141.0
1443.0	5.7	201.5	109.6	158.0	159.5	1892926.0
1509.0	5.7	201.6	109.6	157.5	159.4	1930668.0
1575.0	5.7	201.7	109.6	157.0	159.2	1968381.0
1641.0	5.7	201.7	109.6	156.5	159.0	2006074.0
1707.0	5.7	201.7	109.6	156.0	158.8	2043751.0
1773.0	5.7	201.7	109.6	155.5	158.7	2081416.0
1839.0	5.7	201.8	109.6	155.1	158.5	2119071.0
1905.0	5.8	201.8	109.6	154.6	158.3	2156720.0
1971.0	5.8	201.8	109.6	154.2	158.1	2194364.0
2009.3	5.8	201.8	109.6	154.0	157.9	2216180.0
2025.8	5.8	201.8	109.6	153.9	157.9	2225590.0
2042.3	5.8	201.8	109.6	153.8	157.8	2235000.0
2058.8	5.8	201.8	109.6	153.7	157.8	2244410.0
2075.3	5.8	201.8	109.6	153.6	157.7	2253820.0
2091.8	5.8	201.8	109.6	153.5	157.7	2263231.0
2108.3	5.8	201.8	109.6	153.4	157.6	2272641.0
2124.8	5.8	201.8	109.6	153.3	157.6	2282051.0
2141.3	5.8	201.8	109.6	153.2	157.5	2291461.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
2157.8	5.8	201.8	109.6	153.1	157.5	2300872.0
2174.3	5.8	201.8	109.6	153.0	157.4	2310282.0
2190.8	5.8	201.8	109.6	152.9	157.4	2319692.0
2207.3	5.8	201.8	109.6	152.8	157.3	2329103.0
2223.8	5.8	201.8	109.6	152.7	157.3	2338514.0
2240.3	5.8	201.8	109.6	152.6	157.2	2347924.0
2256.8	5.8	201.8	109.6	152.5	157.2	2357335.0
2273.3	5.8	201.8	109.6	152.4	157.1	2366746.0
2289.8	5.8	201.8	109.6	152.4	157.1	2376157.0
2306.3	5.8	201.8	109.6	152.3	157.0	2385568.0
2322.8	5.8	201.8	109.6	152.2	157.0	2394980.0
2339.3	5.8	201.8	109.6	152.1	156.9	2404391.0
2355.8	5.8	201.8	109.6	152.0	156.9	2413803.0
2372.3	5.8	201.8	109.6	151.9	156.8	2423215.0
2388.8	5.8	201.8	109.6	151.8	156.8	2432627.0
2405.3	5.8	201.8	109.6	151.8	156.7	2442039.0
2421.8	5.9	201.8	109.6	151.7	156.7	2451452.0
2438.3	5.9	201.8	109.6	151.6	156.6	2460864.0
2454.8	5.9	201.8	109.6	151.5	156.6	2470278.0
2471.3	5.9	201.8	109.6	151.4	156.5	2479690.0
2487.8	5.9	201.8	109.6	151.3	156.5	2489104.0
2504.3	5.9	201.8	109.6	151.3	156.4	2498518.0
2520.8	5.9	201.8	109.6	151.2	156.4	2507931.0
2537.3	5.9	201.8	109.6	151.1	156.3	2517345.0
2553.8	5.9	201.8	109.6	151.0	156.3	2526760.0
2570.3	5.6	194.5	109.7	150.9	156.3	2533909.0
2586.8	5.5	192.1	110.3	150.7	156.2	2537431.0
2603.3	5.5	190.2	112.7	150.5	156.2	2540912.0
2619.8	5.8	189.1	118.3	150.4	156.2	2544367.0
2636.3	6.0	188.5	123.3	150.3	156.2	2547797.0
2652.8	6.3	188.3	127.7	150.3	156.2	2551191.0
2669.3	6.5	188.5	131.7	150.2	156.2	2554540.0
2685.8	6.8	188.9	135.5	150.1	156.1	2557834.0
2702.3	7.1	189.4	139.1	150.0	156.1	2561064.0
2718.8	7.3	190.2	142.4	150.0	156.1	2564224.0
2735.3	6.7	189.7	134.1	149.9	156.1	2567225.0
2751.8	6.6	189.4	131.9	149.7	156.1	2570059.0
2768.3	6.6	189.3	132.2	149.6	156.1	2572769.0
2784.8	6.7	189.3	133.4	149.5	156.1	2575361.0
2801.3	6.8	189.3	135.0	149.4	156.1	2577796.0
2817.8	7.1	189.4	136.8	149.3	156.1	2579877.0
2834.3	7.3	189.5	138.4	149.2	156.1	2581505.0
2850.8	7.5	189.6	139.8	149.1	156.1	2582604.0

Table 4.4.3-6 (cont.)	Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass					
Time Seconds	**Pressure Psig**	**Lower Compartment Temperature °F**	**Upper Compartment Temperature °F**	**Active Sump Temperature °F**	**Inactive Sump Temperature °F**	**Melted Ice Pounds**
2867.3	7.7	189.9	140.9	149.0	156.1	2583320.0
2883.8	7.9	190.2	141.7	148.9	156.1	2583812.0
2900.3	8.0	190.5	142.5	148.9	156.1	2584180.0
2916.8	8.1	190.9	143.4	148.8	156.1	2584466.0
2933.3	8.3	191.3	144.4	148.7	156.1	2584701.0
2949.8	8.4	191.7	145.5	148.7	156.1	2584900.0
2966.3	8.7	192.4	148.4	148.6	156.1	2584971.0
2982.8	9.0	193.2	151.5	148.6	156.1	2584971.0
2999.3	9.3	193.9	153.4	148.5	156.1	2584971.0
3015.8	9.5	194.6	154.8	148.5	156.1	2584971.0
3032.3	9.6	195.3	155.9	148.5	156.1	2584971.0
3048.8	9.7	195.9	156.7	148.5	156.1	2584971.0
3065.3	9.8	196.5	157.4	148.4	156.1	2584971.0
3081.8	9.9	197.0	158.0	148.4	156.1	2584971.0
3098.3	10.0	197.5	158.6	148.4	156.1	2584971.0
3114.8	10.1	198.0	159.1	148.4	156.1	2584971.0
3131.3	10.2	198.4	159.7	148.4	156.1	2584971.0
3147.8	10.3	198.9	160.2	148.4	156.1	2584971.0
3164.3	10.4	199.2	160.6	148.4	156.1	2584971.0
3180.8	10.5	199.6	161.1	148.3	156.1	2584971.0
3197.3	10.5	199.9	161.5	148.3	156.1	2584971.0
3213.8	10.6	200.3	161.9	148.3	156.1	2584971.0
3230.3	10.7	200.6	162.4	148.3	156.1	2584971.0
3246.8	10.7	200.9	162.7	148.3	156.1	2584971.0
3263.3	10.8	201.1	163.1	148.3	156.1	2584971.0
3279.8	10.9	201.4	163.5	148.3	156.1	2584971.0
3296.3	10.9	201.6	163.9	148.3	156.1	2584971.0
3312.8	11.0	201.9	164.2	148.3	156.1	2584971.0
3329.3	11.0	202.1	164.5	148.3	156.1	2584971.0
3345.8	11.1	202.3	164.8	148.3	156.1	2584971.0
3362.3	11.1	202.5	165.2	148.3	156.1	2584971.0
3378.8	11.2	202.7	165.4	148.3	156.1	2584971.0
3395.3	11.2	202.9	165.7	148.3	156.1	2584971.0
3411.8	11.3	203.1	166.0	148.3	156.1	2584971.0
3428.3	11.3	203.2	166.3	148.3	156.1	2584971.0
3444.8	11.4	203.4	166.5	148.4	156.1	2584971.0
3461.3	11.4	203.5	166.8	148.4	156.1	2584971.0
3477.8	11.5	203.7	167.0	148.4	156.1	2584971.0
3494.3	11.5	203.8	167.3	148.4	156.1	2584971.0
3510.8	11.5	204.0	167.5	148.4	156.1	2584971.0
3527.3	11.6	204.1	167.7	148.4	156.1	2584971.0
3543.8	11.6	204.2	167.9	148.4	156.1	2584971.0
3560.3	11.7	204.3	168.1	148.4	156.1	2584971.0

Table 4.4.3-6 (cont.)	Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass					
Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
3576.8	11.7	204.4	168.3	148.4	156.1	2584971.0
3593.3	11.7	204.5	168.5	148.5	156.1	2584971.0
3599.76	11.728	204.6	168.5	148.5	156.1	2584971.0
3609.8	11.3	204.2	164.8	148.5	156.1	2584971.0
3626.3	11.0	203.7	162.3	148.6	156.1	2584971.0
3642.8	10.9	203.4	161.8	148.6	156.1	2584971.0
3659.3	10.9	203.2	161.8	148.6	156.1	2584971.0
3675.8	10.9	203.0	162.0	148.7	156.1	2584971.0
3692.3	10.9	202.9	162.2	148.7	156.1	2584971.0
3708.8	10.9	202.7	162.4	148.8	156.1	2584971.0
3725.3	10.9	202.6	162.5	148.8	156.1	2584971.0
3741.8	10.9	202.5	162.6	148.9	156.1	2584971.0
3758.3	10.9	202.4	162.7	148.9	156.1	2584971.0
3774.8	10.9	202.4	162.8	149.0	156.1	2584971.0
3791.3	10.9	202.3	162.8	149.0	156.1	2584971.0
3807.8	10.9	202.2	162.9	149.1	156.1	2584971.0
3824.3	10.9	202.2	162.9	149.1	156.1	2584971.0
3840.8	10.9	202.1	163.0	149.2	156.1	2584971.0
3857.3	10.9	202.1	163.0	149.2	156.1	2584971.0
3873.8	10.9	202.0	163.1	149.2	156.1	2584971.0
3890.3	10.9	202.0	163.1	149.3	156.1	2584971.0
3906.8	10.9	201.9	163.1	149.3	156.1	2584971.0
3923.3	10.9	201.9	163.1	149.4	156.1	2584971.0
3939.8	10.9	201.8	163.1	149.4	156.1	2584971.0
3956.3	10.9	201.8	163.2	149.5	156.1	2584971.0
3972.8	10.9	201.8	163.2	149.5	156.1	2584971.0
3989.3	10.9	201.7	163.2	149.6	156.1	2584971.0
4023.0	10.9	201.7	163.2	149.7	156.1	2584971.0
4089.0	10.9	201.6	163.4	149.8	156.1	2584971.0
4155.0	10.9	201.5	163.5	150.0	156.1	2584971.0
4221.0	10.9	201.5	163.6	150.2	156.1	2584971.0
4287.0	10.9	201.4	163.7	150.4	156.1	2584971.0
4353.0	10.9	201.4	163.8	150.6	156.1	2584971.0
4419.0	11.0	201.4	163.9	150.7	156.1	2584971.0
4485.0	11.0	201.4	163.9	150.9	156.1	2584971.0
4551.0	11.0	201.3	164.0	151.1	156.1	2584971.0
4617.0	11.0	201.3	164.0	151.2	156.1	2584971.0
4683.0	11.0	201.2	164.1	151.4	156.1	2584971.0
4749.0	11.0	201.2	164.1	151.6	156.1	2584971.0
4815.0	11.0	201.2	164.2	151.7	156.1	2584971.0
4881.0	11.0	201.1	164.2	151.9	156.1	2584971.0
4947.0	11.0	201.1	164.2	152.0	156.1	2584971.0
5216.8	11.0	200.6	164.7	152.6	156.1	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
6403.6	10.8	198.1	164.4	154.9	156.1	2584971.0
7543.4	10.7	197.6	163.6	156.3	156.1	2584971.0
8751.4	10.5	196.0	162.3	157.1	156.1	2584971.0
10024.7	10.3	194.7	161.7	157.5	156.1	2584971.0
11326.2	10.3	194.3	161.0	157.5	156.1	2584971.0
12666.3	10.2	194.0	160.6	157.4	156.1	2584971.0
14049.5	10.1	193.3	159.9	157.1	156.1	2584971.0
15472.1	10.0	192.5	159.1	156.7	156.1	2584971.0
16926.8	9.8	191.1	158.2	156.1	156.1	2584971.0
18417.1	9.7	190.0	157.0	155.5	156.1	2584971.0
19961.2	9.5	189.1	155.8	154.7	156.1	2584971.0
21523.9	9.3	188.5	154.8	153.8	156.1	2584971.0
23069.6	9.2	187.7	154.1	153.0	156.1	2584971.0
24653.3	9.1	187.0	153.4	152.2	156.1	2584971.0
26291.6	9.0	186.3	152.6	151.4	156.1	2584971.0
27934.1	8.9	185.5	152.1	150.6	156.1	2584971.0
29634.3	8.8	184.7	151.5	149.8	156.1	2584971.0
31309.6	8.7	183.9	150.7	149.1	156.1	2584971.0
33018.5	8.6	183.3	149.9	148.3	156.1	2584971.0
34734.9	8.4	182.8	149.0	147.5	156.1	2584971.0
36477.5	8.3	182.1	148.2	146.7	156.1	2584971.0
38250.9	8.2	181.3	147.4	145.9	156.1	2584971.0
40038.2	8.1	180.5	146.5	145.1	156.1	2584971.0
41861.7	8.0	179.9	145.6	144.3	156.1	2584971.0
43678.5	7.9	179.4	144.8	143.6	156.1	2584971.0
45505.4	7.8	178.4	144.3	142.9	156.1	2584971.0
47392.7	7.8	178.2	144.1	142.3	156.1	2584971.0
49214.1	7.7	177.7	143.7	141.7	156.1	2584971.0
51167.1	7.6	177.5	142.7	141.2	156.1	2584971.0
52974.4	7.6	176.7	142.3	140.6	156.1	2584971.0
54998.4	7.5	175.5	142.1	140.1	156.0	2584971.0
56893.5	7.5	176.2	141.5	139.6	156.0	2584971.0
58908.2	7.3	175.0	140.7	139.1	156.0	2584971.0
60832.7	7.3	174.6	140.2	138.6	156.0	2584971.0
62824.9	7.3	174.2	140.2	138.1	156.0	2584971.0
64820.0	7.2	173.7	139.7	137.7	156.0	2584971.0
66861.7	7.1	173.0	139.0	137.3	156.0	2584971.0
68879.9	7.1	173.0	138.9	136.9	156.0	2584971.0
70951.6	7.0	172.6	138.3	136.5	156.0	2584971.0
72981.8	7.0	172.2	137.8	136.1	156.0	2584971.0
75034.9	7.0	171.9	137.8	135.7	155.9	2584971.0
77170.0	6.9	171.2	137.1	135.3	155.9	2584971.0
79315.9	6.8	170.2	136.7	135.0	155.9	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
81507.6	6.8	170.3	136.7	134.6	155.9	2584971.0
83679.8	6.8	169.9	136.0	134.2	155.9	2584971.0
85837.5	6.7	169.1	135.7	133.9	155.9	2584971.0
88068.4	6.7	169.2	135.7	133.6	155.9	2584971.0
90283.4	6.6	168.9	135.0	133.3	155.8	2584971.0
92492.0	6.6	168.0	134.8	133.0	155.8	2584971.0
94775.4	6.6	168.1	134.8	132.7	155.8	2584971.0
97051.5	6.5	167.8	134.1	132.3	155.8	2584971.0
99320.9	6.5	167.0	133.8	132.0	155.8	2584971.0
101654.5	6.5	167.2	133.8	131.7	155.8	2584971.0
103963.9	6.4	167.0	133.3	131.4	155.8	2584971.0
106280.3	6.4	166.3	133.0	131.2	155.7	2584971.0
108661.0	6.4	166.4	133.1	130.9	155.7	2584971.0
110957.5	6.4	166.4	132.6	130.7	155.7	2584971.0
113193.8	6.3	166.0	132.2	130.4	155.7	2584971.0
115460.1	6.3	165.9	132.3	130.2	155.7	2584971.0
117838.6	6.2	165.1	131.9	130.0	155.7	2584971.0
120096.3	6.3	165.4	131.9	129.8	155.6	2584971.0
122423.3	6.2	164.7	131.6	129.5	155.6	2584971.0
124691.9	6.2	165.0	131.1	129.3	155.6	2584971.0
127006.8	6.2	163.9	131.3	129.1	155.6	2584971.0
129391.9	6.1	163.9	131.0	128.9	155.6	2584971.0
131781.1	6.1	164.0	130.5	128.7	155.5	2584971.0
134236.2	6.1	163.4	130.2	128.4	155.5	2584971.0
136719.4	6.0	163.0	130.2	128.2	155.5	2584971.0
139137.0	6.0	162.5	130.0	128.0	155.5	2584971.0
141585.2	6.0	162.3	129.8	127.7	155.5	2584971.0
144063.4	5.9	162.1	129.5	127.5	155.5	2584971.0
146515.1	5.9	161.9	129.3	127.2	155.4	2584971.0
148979.2	5.9	161.8	129.0	127.0	155.4	2584971.0
151473.7	5.9	161.6	128.8	126.8	155.4	2584971.0
153906.8	5.9	161.5	128.5	126.6	155.4	2584971.0
156416.5	5.8	161.1	128.2	126.4	155.4	2584971.0
158918.4	5.8	161.1	127.9	126.2	155.3	2584971.0
161406.0	5.8	160.7	127.7	126.0	155.3	2584971.0
163940.9	5.7	160.2	127.6	125.8	155.3	2584971.0
166445.7	5.7	160.0	127.3	125.6	155.3	2584971.0
168973.0	5.7	159.6	127.3	125.4	155.3	2584971.0
171557.9	5.7	159.4	127.3	125.3	155.2	2584971.0
174086.5	5.7	159.2	127.1	125.1	155.2	2584971.0
176663.2	5.7	159.1	126.9	124.9	155.2	2584971.0
179272.7	5.6	158.9	126.8	124.7	155.2	2584971.0
181844.2	5.6	158.8	126.6	124.6	155.2	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
184464.5	5.6	158.7	126.4	124.4	155.1	2584971.0
187097.8	5.6	158.5	126.2	124.2	155.1	2584971.0
189736.8	5.6	158.2	126.0	124.0	155.1	2584971.0
192379.9	5.5	158.0	125.8	123.9	155.1	2584971.0
195035.4	5.5	157.8	125.6	123.7	155.0	2584971.0
197700.8	5.5	157.5	125.4	123.5	155.0	2584971.0
200374.9	5.5	157.3	125.3	123.3	155.0	2584971.0
203009.9	5.5	157.2	125.1	123.2	155.0	2584971.0
205678.0	5.4	157.2	124.9	123.0	155.0	2584971.0
208335.3	5.4	157.0	124.7	122.9	154.9	2584971.0
211039.1	5.4	156.9	124.5	122.7	154.9	2584971.0
213672.2	5.4	156.6	124.3	122.6	154.9	2584971.0
216341.4	5.4	156.1	124.3	122.5	154.9	2584971.0
219005.1	5.4	156.0	124.1	122.4	154.9	2584971.0
221677.1	5.4	155.8	124.2	122.3	154.8	2584971.0
224401.2	5.3	155.6	124.1	122.2	154.8	2584971.0
227084.1	5.3	155.5	124.1	122.1	154.8	2584971.0
229802.9	5.3	155.4	124.0	122.0	154.8	2584971.0
232481.7	5.3	155.5	123.8	121.9	154.7	2584971.0
235212.4	5.3	155.4	123.7	121.8	154.7	2584971.0
237900.9	5.3	155.4	123.6	121.7	154.7	2584971.0
240654.2	5.3	155.2	123.4	121.6	154.7	2584971.0
243379.4	5.3	155.0	123.2	121.4	154.7	2584971.0
246131.5	5.2	155.0	123.0	121.3	154.6	2584971.0
248890.3	5.2	154.7	122.9	121.2	154.6	2584971.0
251616.6	5.2	154.5	122.8	121.1	154.6	2584971.0
254386.6	5.2	154.4	122.6	121.0	154.6	2584971.0
257137.5	5.2	154.0	122.6	120.9	154.5	2584971.0
259904.0	5.2	153.8	122.5	120.8	154.5	2584971.0
262675.4	5.2	153.6	122.3	120.7	154.5	2584971.0
265466.7	5.1	153.5	122.2	120.6	154.5	2584971.0
268256.9	5.1	153.2	122.2	120.5	154.5	2584971.0
271061.3	5.1	153.0	122.1	120.4	154.4	2584971.0
273845.2	5.1	153.0	122.0	120.3	154.4	2584971.0
276664.4	5.1	152.8	121.9	120.2	154.4	2584971.0
279496.9	5.1	152.7	121.9	120.0	154.4	2584971.0
282325.5	5.1	152.5	121.8	119.9	154.3	2584971.0
285148.1	5.1	152.3	121.7	119.8	154.3	2584971.0
287983.2	5.1	152.1	121.6	119.7	154.3	2584971.0
290827.1	5.0	152.0	121.5	119.6	154.3	2584971.0
293681.6	5.0	151.9	121.3	119.5	154.2	2584971.0
296543.5	5.0	151.8	121.2	119.4	154.2	2584971.0
299404.1	5.0	151.7	121.1	119.3	154.2	2584971.0

Table 4.4.3-6 (cont.)	Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass					
Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
302262.7	5.0	151.6	121.0	119.2	154.2	2584971.0
305129.8	5.0	151.5	120.9	119.0	154.2	2584971.0
308016.0	5.0	151.5	120.7	118.9	154.1	2584971.0
310907.9	5.0	151.3	120.6	118.8	154.1	2584971.0
313793.2	4.9	151.2	120.5	118.7	154.1	2584971.0
316682.2	4.9	151.1	120.4	118.6	154.1	2584971.0
319601.4	4.9	151.0	120.2	118.5	154.0	2584971.0
322518.5	4.9	150.7	120.0	118.4	154.0	2584971.0
325434.2	4.9	150.5	119.9	118.3	154.0	2584971.0
328366.6	4.9	150.5	119.7	118.1	154.0	2584971.0
331316.1	4.9	150.3	119.6	118.0	153.9	2584971.0
334241.9	4.9	150.0	119.4	117.9	153.9	2584971.0
337186.6	4.8	149.8	119.3	117.8	153.9	2584971.0
340145.4	4.8	149.5	119.2	117.7	153.9	2584971.0
343091.5	4.8	149.3	119.1	117.6	153.8	2584971.0
346054.9	4.8	149.0	118.9	117.5	153.8	2584971.0
349032.7	4.8	148.8	118.9	117.3	153.8	2584971.0
351997.6	4.8	148.6	118.8	117.2	153.8	2584971.0
354997.1	4.8	148.5	118.8	117.1	153.7	2584971.0
357996.2	4.8	148.3	118.7	117.0	153.7	2584971.0
360987.6	4.7	148.1	118.6	116.9	153.7	2584971.0
364000.6	4.7	148.0	118.5	116.8	153.7	2584971.0
367002.8	4.7	148.0	118.3	116.6	153.6	2584971.0
370015.0	4.7	147.9	118.2	116.5	153.6	2584971.0
373049.3	4.7	147.7	118.1	116.4	153.6	2584971.0
376069.5	4.7	147.7	117.9	116.3	153.6	2584971.0
379115.2	4.7	147.6	117.8	116.2	153.6	2584971.0
382162.0	4.6	147.3	117.6	116.1	153.5	2584971.0
385227.8	4.6	147.2	117.4	115.9	153.5	2584971.0
388286.4	4.6	146.9	117.2	115.8	153.5	2584971.0
391356.5	4.6	146.7	117.1	115.7	153.5	2584971.0
394425.3	4.6	146.4	117.0	115.6	153.4	2584971.0
397508.1	4.6	146.1	116.8	115.5	153.4	2584971.0
400591.6	4.6	145.8	116.8	115.3	153.4	2584971.0
403675.2	4.6	145.7	116.8	115.2	153.4	2584971.0
406746.2	4.6	145.7	116.8	115.1	153.3	2584971.0
409805.2	4.6	145.8	116.7	115.1	153.3	2584971.0
412866.4	4.5	145.9	116.5	115.0	153.3	2584971.0
415947.8	4.5	145.7	116.4	114.9	153.3	2584971.0
419008.9	4.5	145.4	116.3	114.8	153.2	2584971.0
422073.8	4.5	145.1	116.3	114.8	153.2	2584971.0
425162.0	4.5	145.0	116.3	114.7	153.2	2584971.0
428236.3	4.5	145.2	116.3	114.6	153.2	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
431312.9	4.5	145.3	116.2	114.6	153.1	2584971.0
434412.1	4.5	145.2	116.0	114.5	153.1	2584971.0
437510.7	4.5	145.0	115.8	114.4	153.1	2584971.0
440603.1	4.5	144.6	115.8	114.4	153.1	2584971.0
443705.9	4.5	144.4	115.9	114.3	153.0	2584971.0
446803.4	4.5	144.5	115.9	114.2	153.0	2584971.0
449897.2	4.5	144.6	115.8	114.2	153.0	2584971.0
453006.0	4.5	144.6	115.6	114.1	153.0	2584971.0
456122.4	4.4	144.4	115.4	114.0	152.9	2584971.0
459234.2	4.4	144.1	115.4	114.0	152.9	2584971.0
462356.0	4.4	143.9	115.4	113.9	152.9	2584971.0
465497.4	4.4	143.8	115.4	113.8	152.9	2584971.0
468617.2	4.4	143.9	115.4	113.8	152.8	2584971.0
471739.0	4.4	144.0	115.2	113.7	152.8	2584971.0
474875.3	4.4	143.8	115.0	113.6	152.8	2584971.0
478006.9	4.4	143.5	115.0	113.6	152.8	2584971.0
481144.2	4.4	143.3	115.0	113.5	152.7	2584971.0
484305.4	4.4	143.2	115.0	113.4	152.7	2584971.0
487455.8	4.4	143.3	114.9	113.4	152.7	2584971.0
490604.9	4.4	143.4	114.8	113.3	152.7	2584971.0
493765.4	4.4	143.2	114.7	113.2	152.6	2584971.0
496916.3	4.4	142.9	114.6	113.2	152.6	2584971.0
500073.8	4.3	142.7	114.6	113.1	152.6	2584971.0
503251.1	4.3	142.6	114.6	113.1	152.6	2584971.0
506422.8	4.3	142.7	114.5	113.0	152.6	2584971.0
509601.3	4.3	142.8	114.4	112.9	152.5	2584971.0
512790.2	4.3	142.6	114.3	112.9	152.5	2584971.0
515965.6	4.3	142.3	114.1	112.8	152.5	2584971.0
519143.4	4.3	142.0	114.1	112.7	152.5	2584971.0
522340.5	4.3	141.9	114.2	112.7	152.4	2584971.0
525535.8	4.3	142.1	114.1	112.6	152.4	2584971.0
528740.5	4.3	142.2	114.0	112.5	152.4	2584971.0
531951.6	4.3	142.0	113.8	112.5	152.4	2584971.0
535151.6	4.3	141.7	113.7	112.4	152.3	2584971.0
538355.4	4.3	141.4	113.7	112.3	152.3	2584971.0
541578.2	4.3	141.3	113.7	112.3	152.3	2584971.0
544804.6	4.3	141.4	113.7	112.2	152.3	2584971.0
548032.4	4.2	141.5	113.6	112.1	152.2	2584971.0
551259.2	4.2	141.3	113.4	112.1	152.2	2584971.0
554484.8	4.2	141.0	113.3	112.0	152.2	2584971.0
557721.1	4.2	140.8	113.3	111.9	152.2	2584971.0
560978.8	4.2	140.7	113.3	111.9	152.1	2584971.0
564223.9	4.2	140.8	113.3	111.8	152.1	2584971.0

Table 4.4.3-6 (cont.)	Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass					
Time Seconds	**Pressure Psig**	**Lower Compartment Temperature °F**	**Upper Compartment Temperature °F**	**Active Sump Temperature °F**	**Inactive Sump Temperature °F**	**Melted Ice Pounds**
567469.8	4.2	140.8	113.1	111.7	152.1	2584971.0
570723.9	4.2	140.7	113.0	111.6	152.1	2584971.0
573990.5	4.2	140.3	112.8	111.6	152.0	2584971.0
577259.4	4.2	140.1	112.9	111.5	152.0	2584971.0
580527.4	4.2	140.1	112.9	111.4	152.0	2584971.0
583801.6	4.2	140.2	112.8	111.4	152.0	2584971.0
587088.5	4.2	140.2	112.7	111.3	151.9	2584971.0
590372.9	4.2	139.9	112.5	111.2	151.9	2584971.0
593666.3	4.1	139.6	112.5	111.2	151.9	2584971.0
596963.4	4.1	139.5	112.5	111.1	151.9	2584971.0
600263.4	4.1	139.6	112.5	111.0	151.8	2584971.0
603556.6	4.1	139.7	112.3	111.0	151.8	2584971.0
606842.1	4.1	139.4	112.2	110.9	151.8	2584971.0
610125.2	4.1	139.1	112.2	110.9	151.8	2584971.0
613403.6	4.1	139.2	112.3	110.8	151.7	2584971.0
616693.0	4.1	139.4	112.2	110.8	151.7	2584971.0
619990.6	4.1	139.1	112.0	110.7	151.7	2584971.0
623290.6	4.1	138.8	112.0	110.7	151.7	2584971.0
626590.6	4.1	138.9	112.1	110.6	151.7	2584971.0
629890.6	4.1	139.1	112.0	110.6	151.6	2584971.0
633188.5	4.1	138.8	111.8	110.5	151.6	2584971.0
636487.2	4.1	138.5	111.9	110.5	151.6	2584971.0
639787.1	4.1	138.7	111.9	110.4	151.6	2584971.0
643087.1	4.1	138.7	111.7	110.4	151.5	2584971.0
646387.1	4.1	138.5	111.7	110.4	151.5	2584971.0
649687.1	4.1	138.4	111.7	110.3	151.5	2584971.0
652987.1	4.1	138.4	111.6	110.3	151.5	2584971.0
656287.1	4.1	138.3	111.6	110.2	151.4	2584971.0
659587.1	4.1	138.2	111.5	110.2	151.4	2584971.0
662887.1	4.0	138.2	111.5	110.2	151.4	2584971.0
666187.1	4.0	138.1	111.4	110.1	151.4	2584971.0
669487.1	4.0	138.0	111.4	110.1	151.3	2584971.0
672787.1	4.0	137.9	111.4	110.0	151.3	2584971.0
676087.1	4.0	137.9	111.3	110.0	151.3	2584971.0
679387.1	4.0	137.8	111.3	109.9	151.3	2584971.0
682687.1	4.0	137.7	111.2	109.9	151.2	2584971.0
685987.1	4.0	137.6	111.2	109.9	151.2	2584971.0
689287.1	4.0	137.6	111.1	109.8	151.2	2584971.0
692587.1	4.0	137.5	111.1	109.8	151.2	2584971.0
695887.1	4.0	137.4	111.0	109.7	151.1	2584971.0
699187.1	4.0	137.3	111.0	109.7	151.1	2584971.0
702487.1	4.0	137.3	110.9	109.6	151.1	2584971.0
705787.1	4.0	137.2	110.9	109.6	151.1	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
709087.1	4.0	137.1	110.8	109.5	151.1	2584971.0
712387.1	4.0	137.1	110.8	109.5	151.0	2584971.0
715687.1	4.0	137.0	110.7	109.5	151.0	2584971.0
718987.1	4.0	136.9	110.7	109.4	151.0	2584971.0
722287.1	4.0	136.8	110.7	109.4	151.0	2584971.0
725587.1	4.0	136.8	110.6	109.3	150.9	2584971.0
728887.1	4.0	136.7	110.6	109.3	150.9	2584971.0
732187.1	4.0	136.6	110.5	109.2	150.9	2584971.0
735487.1	4.0	136.5	110.5	109.2	150.9	2584971.0
738787.1	3.9	136.5	110.4	109.1	150.8	2584971.0
742087.1	3.9	136.4	110.4	109.1	150.8	2584971.0
745387.1	3.9	136.3	110.3	109.1	150.8	2584971.0
748687.1	3.9	136.2	110.3	109.0	150.8	2584971.0
751987.1	3.9	136.2	110.2	109.0	150.7	2584971.0
755287.1	3.9	136.1	110.2	108.9	150.7	2584971.0
758587.1	3.9	136.0	110.1	108.9	150.7	2584971.0
761887.1	3.9	135.9	110.1	108.8	150.7	2584971.0
765187.1	3.9	135.9	110.0	108.8	150.7	2584971.0
768487.1	3.9	135.8	110.0	108.7	150.6	2584971.0
771787.1	3.9	135.7	110.0	108.7	150.6	2584971.0
775087.1	3.9	135.6	109.9	108.7	150.6	2584971.0
778387.1	3.9	135.6	109.9	108.6	150.6	2584971.0
781687.1	3.9	135.5	109.8	108.6	150.5	2584971.0
784987.1	3.9	135.4	109.8	108.5	150.5	2584971.0
788287.1	3.9	135.3	109.7	108.5	150.5	2584971.0
791587.1	3.9	135.3	109.7	108.4	150.5	2584971.0
794887.1	3.9	135.2	109.6	108.4	150.4	2584971.0
798187.1	3.9	135.1	109.6	108.3	150.4	2584971.0
801487.1	3.9	135.0	109.5	108.3	150.4	2584971.0
804787.1	3.9	135.0	109.5	108.3	150.4	2584971.0
808087.1	3.9	134.9	109.5	108.2	150.4	2584971.0
811387.1	3.9	134.9	109.4	108.2	150.3	2584971.0
814687.1	3.9	134.8	109.4	108.2	150.3	2584971.0
817987.1	3.9	134.8	109.4	108.1	150.3	2584971.0
821287.1	3.8	134.7	109.3	108.1	150.3	2584971.0
824587.1	3.8	134.7	109.3	108.1	150.2	2584971.0
827887.1	3.8	134.6	109.3	108.0	150.2	2584971.0
831187.1	3.8	134.6	109.2	108.0	150.2	2584971.0
834487.1	3.8	134.5	109.2	108.0	150.2	2584971.0
837787.1	3.8	134.4	109.2	107.9	150.2	2584971.0
841087.1	3.8	134.4	109.1	107.9	150.1	2584971.0
844387.1	3.8	134.3	109.1	107.9	150.1	2584971.0
847687.1	3.8	134.3	109.1	107.8	150.1	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
850987.1	3.8	134.2	109.0	107.8	150.1	2584971.0
854287.1	3.8	134.2	109.0	107.8	150.0	2584971.0
857587.1	3.8	134.1	109.0	107.8	150.0	2584971.0
860887.1	3.8	134.1	108.9	107.7	150.0	2584971.0
864187.1	3.8	134.0	108.9	107.7	150.0	2584971.0
867487.1	3.8	134.0	108.9	107.7	150.0	2584971.0
870787.1	3.8	133.9	108.8	107.6	149.9	2584971.0
874087.1	3.8	133.9	108.8	107.6	149.9	2584971.0
877387.1	3.8	133.8	108.8	107.6	149.9	2584971.0
880687.1	3.8	133.8	108.7	107.5	149.9	2584971.0
883987.1	3.8	133.7	108.7	107.5	149.8	2584971.0
887287.1	3.8	133.7	108.7	107.5	149.8	2584971.0
890587.1	3.8	133.6	108.6	107.4	149.8	2584971.0
893887.1	3.8	133.5	108.6	107.4	149.8	2584971.0
897187.1	3.8	133.5	108.6	107.4	149.8	2584971.0
900487.1	3.8	133.4	108.6	107.4	149.7	2584971.0
903787.1	3.8	133.4	108.5	107.3	149.7	2584971.0
907087.1	3.8	133.3	108.5	107.3	149.7	2584971.0
910387.1	3.8	133.3	108.5	107.3	149.7	2584971.0
913687.1	3.8	133.2	108.4	107.2	149.7	2584971.0
916987.1	3.8	133.2	108.4	107.2	149.6	2584971.0
920287.1	3.8	133.1	108.4	107.2	149.6	2584971.0
923587.1	3.8	133.1	108.3	107.1	149.6	2584971.0
926887.1	3.8	133.0	108.3	107.1	149.6	2584971.0
930187.1	3.8	133.0	108.3	107.1	149.5	2584971.0
933487.1	3.8	132.9	108.2	107.1	149.5	2584971.0
936787.1	3.7	132.9	108.2	107.0	149.5	2584971.0
940087.1	3.7	132.8	108.2	107.0	149.5	2584971.0
943387.1	3.7	132.7	108.1	107.0	149.5	2584971.0
946687.1	3.7	132.7	108.1	106.9	149.4	2584971.0
949987.1	3.7	132.6	108.1	106.9	149.4	2584971.0
953287.1	3.7	132.6	108.0	106.9	149.4	2584971.0
956587.1	3.7	132.5	108.0	106.8	149.4	2584971.0
959887.1	3.7	132.5	108.0	106.8	149.4	2584971.0
963187.1	3.7	132.4	107.9	106.8	149.3	2584971.0
966487.1	3.7	132.4	107.9	106.7	149.3	2584971.0
969787.1	3.7	132.3	107.9	106.7	149.3	2584971.0
973087.1	3.7	132.3	107.8	106.7	149.3	2584971.0
976387.1	3.7	132.2	107.8	106.7	149.2	2584971.0
979687.1	3.7	132.2	107.8	106.6	149.2	2584971.0
982987.1	3.7	132.1	107.7	106.6	149.2	2584971.0
986287.1	3.7	132.0	107.7	106.6	149.2	2584971.0
989587.1	3.7	132.0	107.7	106.5	149.2	2584971.0

Table 4.4.3-6 (cont.)	Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass					
Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
992887.1	3.7	131.9	107.7	106.5	149.1	2584971.0
996187.1	3.7	131.9	107.6	106.5	149.1	2584971.0
999487.1	3.7	131.8	107.6	106.4	149.1	2584971.0
1002787.0	3.7	131.8	107.6	106.4	149.1	2584971.0
1006087.0	3.7	131.8	107.5	106.4	149.1	2584971.0
1009387.0	3.7	131.7	107.5	106.4	149.0	2584971.0
1012687.0	3.7	131.7	107.5	106.3	149.0	2584971.0
1015987.0	3.7	131.6	107.5	106.3	149.0	2584971.0
1019287.0	3.7	131.6	107.4	106.3	149.0	2584971.0
1022587.0	3.7	131.6	107.4	106.3	149.0	2584971.0
1025887.0	3.7	131.5	107.4	106.3	148.9	2584971.0
1029187.0	3.7	131.5	107.4	106.2	148.9	2584971.0
1032487.0	3.7	131.5	107.4	106.2	148.9	2584971.0
1035787.0	3.7	131.4	107.3	106.2	148.9	2584971.0
1039087.0	3.7	131.4	107.3	106.2	148.9	2584971.0
1042387.0	3.7	131.4	107.3	106.2	148.8	2584971.0
1045687.0	3.7	131.3	107.3	106.1	148.8	2584971.0
1048987.0	3.7	131.3	107.3	106.1	148.8	2584971.0
1052287.0	3.7	131.3	107.2	106.1	148.8	2584971.0
1055587.0	3.7	131.2	107.2	106.1	148.8	2584971.0
1058887.0	3.7	131.2	107.2	106.1	148.7	2584971.0
1062187.0	3.7	131.2	107.2	106.0	148.7	2584971.0
1065487.0	3.7	131.1	107.2	106.0	148.7	2584971.0
1068787.0	3.7	131.1	107.1	106.0	148.7	2584971.0
1072087.0	3.7	131.0	107.1	106.0	148.7	2584971.0
1075387.0	3.7	131.0	107.1	106.0	148.6	2584971.0
1078687.0	3.7	131.0	107.1	105.9	148.6	2584971.0
1081987.0	3.7	130.9	107.0	105.9	148.6	2584971.0
1085287.0	3.6	130.9	107.0	105.9	148.6	2584971.0
1088587.0	3.6	130.9	107.0	105.9	148.6	2584971.0
1091887.0	3.6	130.8	107.0	105.9	148.5	2584971.0
1095187.0	3.6	130.8	107.0	105.8	148.5	2584971.0
1098487.0	3.6	130.8	106.9	105.8	148.5	2584971.0
1101787.0	3.6	130.7	106.9	105.8	148.5	2584971.0
1105087.0	3.6	130.7	106.9	105.8	148.5	2584971.0
1108387.0	3.6	130.7	106.9	105.8	148.4	2584971.0
1111687.0	3.6	130.6	106.9	105.7	148.4	2584971.0
1114987.0	3.6	130.6	106.8	105.7	148.4	2584971.0
1118287.0	3.6	130.5	106.8	105.7	148.4	2584971.0
1121587.0	3.6	130.5	106.8	105.7	148.4	2584971.0
1124887.0	3.6	130.5	106.8	105.7	148.3	2584971.0
1128187.0	3.6	130.4	106.8	105.6	148.3	2584971.0
1131487.0	3.6	130.4	106.7	105.6	148.3	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
1134787.0	3.6	130.4	106.7	105.6	148.3	2584971.0
1138087.0	3.6	130.3	106.7	105.6	148.3	2584971.0
1141387.0	3.6	130.3	106.7	105.6	148.2	2584971.0
1144687.0	3.6	130.3	106.7	105.5	148.2	2584971.0
1147987.0	3.6	130.2	106.6	105.5	148.2	2584971.0
1151287.0	3.6	130.2	106.6	105.5	148.2	2584971.0
1154587.0	3.6	130.2	106.6	105.5	148.2	2584971.0
1157887.0	3.6	130.1	106.6	105.5	148.1	2584971.0
1161187.0	3.6	130.1	106.6	105.5	148.1	2584971.0
1164487.0	3.6	130.1	106.5	105.4	148.1	2584971.0
1167787.0	3.6	130.0	106.5	105.4	148.1	2584971.0
1171087.0	3.6	130.0	106.5	105.4	148.1	2584971.0
1174387.0	3.6	129.9	106.5	105.4	148.0	2584971.0
1177687.0	3.6	129.9	106.4	105.4	148.0	2584971.0
1180987.0	3.6	129.9	106.4	105.3	148.0	2584971.0
1184287.0	3.6	129.8	106.4	105.3	148.0	2584971.0
1187587.0	3.6	129.8	106.4	105.3	148.0	2584971.0
1190887.0	3.6	129.8	106.4	105.3	148.0	2584971.0
1194187.0	3.6	129.7	106.3	105.3	147.9	2584971.0
1197487.0	3.6	129.7	106.3	105.2	147.9	2584971.0
1200787.0	3.6	129.7	106.3	105.2	147.9	2584971.0
1204087.0	3.6	129.6	106.3	105.2	147.9	2584971.0
1207387.0	3.6	129.6	106.3	105.2	147.9	2584971.0
1210687.0	3.6	129.6	106.2	105.2	147.8	2584971.0
1213987.0	3.6	129.5	106.2	105.1	147.8	2584971.0
1217287.0	3.6	129.5	106.2	105.1	147.8	2584971.0
1220587.0	3.6	129.4	106.2	105.1	147.8	2584971.0
1223887.0	3.6	129.4	106.2	105.1	147.8	2584971.0
1227187.0	3.6	129.4	106.1	105.1	147.7	2584971.0
1230487.0	3.6	129.3	106.1	105.0	147.7	2584971.0
1233787.0	3.6	129.3	106.1	105.0	147.7	2584971.0
1237087.0	3.6	129.3	106.1	105.0	147.7	2584971.0
1240387.0	3.6	129.2	106.1	105.0	147.7	2584971.0
1243687.0	3.6	129.2	106.0	105.0	147.6	2584971.0
1246987.0	3.6	129.2	106.0	104.9	147.6	2584971.0
1250287.0	3.6	129.1	106.0	104.9	147.6	2584971.0
1253587.0	3.6	129.1	106.0	104.9	147.6	2584971.0
1256887.0	3.6	129.1	106.0	104.9	147.6	2584971.0
1260187.0	3.6	129.0	105.9	104.9	147.6	2584971.0
1263487.0	3.6	129.0	105.9	104.8	147.5	2584971.0
1266787.0	3.6	128.9	105.9	104.8	147.5	2584971.0
1270087.0	3.6	128.9	105.9	104.8	147.5	2584971.0
1273387.0	3.6	128.9	105.8	104.8	147.5	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
1276687.0	3.6	128.8	105.8	104.8	147.5	2584971.0
1279987.0	3.5	128.8	105.8	104.7	147.4	2584971.0
1283287.0	3.5	128.8	105.8	104.7	147.4	2584971.0
1286587.0	3.5	128.7	105.8	104.7	147.4	2584971.0
1289887.0	3.5	128.7	105.7	104.7	147.4	2584971.0
1293187.0	3.5	128.7	105.7	104.7	147.4	2584971.0
1296487.0	3.5	128.6	105.7	104.7	147.4	2584971.0
1299787.0	3.5	128.6	105.7	104.6	147.3	2584971.0
1303087.0	3.5	128.5	105.7	104.6	147.3	2584971.0
1306387.0	3.5	128.5	105.6	104.6	147.3	2584971.0
1309687.0	3.5	128.5	105.6	104.6	147.3	2584971.0
1312987.0	3.5	128.4	105.6	104.6	147.3	2584971.0
1316287.0	3.5	128.4	105.6	104.5	147.2	2584971.0
1319587.0	3.5	128.4	105.6	104.5	147.2	2584971.0
1322887.0	3.5	128.3	105.5	104.5	147.2	2584971.0
1326187.0	3.5	128.3	105.5	104.5	147.2	2584971.0
1329487.0	3.5	128.3	105.5	104.5	147.2	2584971.0
1332787.0	3.5	128.2	105.5	104.4	147.2	2584971.0
1336087.0	3.5	128.2	105.5	104.4	147.1	2584971.0
1339387.0	3.5	128.2	105.4	104.4	147.1	2584971.0
1342687.0	3.5	128.1	105.4	104.4	147.1	2584971.0
1345987.0	3.5	128.1	105.4	104.4	147.1	2584971.0
1349287.0	3.5	128.0	105.4	104.3	147.1	2584971.0
1352587.0	3.5	128.0	105.4	104.3	147.0	2584971.0
1355887.0	3.5	128.0	105.3	104.3	147.0	2584971.0
1359187.0	3.5	127.9	105.3	104.3	147.0	2584971.0
1362487.0	3.5	127.9	105.3	104.3	147.0	2584971.0
1365787.0	3.5	127.9	105.3	104.2	147.0	2584971.0
1369087.0	3.5	127.8	105.3	104.2	147.0	2584971.0
1372387.0	3.5	127.8	105.2	104.2	146.9	2584971.0
1375687.0	3.5	127.8	105.2	104.2	146.9	2584971.0
1378987.0	3.5	127.7	105.2	104.2	146.9	2584971.0
1382287.0	3.5	127.7	105.2	104.1	146.9	2584971.0
1385587.0	3.5	127.6	105.1	104.1	146.9	2584971.0
1388887.0	3.5	127.6	105.1	104.1	146.8	2584971.0
1392187.0	3.5	127.6	105.1	104.1	146.8	2584971.0
1395487.0	3.5	127.5	105.1	104.1	146.8	2584971.0
1398787.0	3.5	127.5	105.1	104.0	146.8	2584971.0
1402087.0	3.5	127.5	105.0	104.0	146.8	2584971.0
1405387.0	3.5	127.4	105.0	104.0	146.8	2584971.0
1408687.0	3.5	127.4	105.0	104.0	146.7	2584971.0
1411987.0	3.5	127.3	105.0	104.0	146.7	2584971.0
1415287.0	3.5	127.3	105.0	104.0	146.7	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
1418587.0	3.5	127.3	104.9	103.9	146.7	2584971.0
1421887.0	3.5	127.2	104.9	103.9	146.7	2584971.0
1425187.0	3.5	127.2	104.9	103.9	146.7	2584971.0
1428487.0	3.5	127.2	104.9	103.9	146.6	2584971.0
1431787.0	3.5	127.1	104.9	103.9	146.6	2584971.0
1435087.0	3.5	127.1	104.8	103.8	146.6	2584971.0
1438387.0	3.5	127.1	104.8	103.8	146.6	2584971.0
1441687.0	3.5	127.0	104.8	103.8	146.6	2584971.0
1444987.0	3.5	127.0	104.8	103.8	146.5	2584971.0
1448287.0	3.5	126.9	104.8	103.8	146.5	2584971.0
1451587.0	3.5	126.9	104.7	103.7	146.5	2584971.0
1454887.0	3.5	126.9	104.7	103.7	146.5	2584971.0
1458187.0	3.5	126.8	104.7	103.7	146.5	2584971.0
1461487.0	3.5	126.8	104.7	103.7	146.5	2584971.0
1464787.0	3.5	126.8	104.7	103.7	146.4	2584971.0
1468087.0	3.5	126.7	104.6	103.6	146.4	2584971.0
1471387.0	3.5	126.7	104.6	103.6	146.4	2584971.0
1474687.0	3.4	126.7	104.6	103.6	146.4	2584971.0
1477987.0	3.4	126.6	104.6	103.6	146.4	2584971.0
1481287.0	3.4	126.6	104.6	103.6	146.4	2584971.0
1484587.0	3.4	126.5	104.5	103.5	146.3	2584971.0
1487887.0	3.4	126.5	104.5	103.5	146.3	2584971.0
1491187.0	3.4	126.5	104.5	103.5	146.3	2584971.0
1494487.0	3.4	126.4	104.5	103.5	146.3	2584971.0
1497787.0	3.4	126.4	104.4	103.5	146.3	2584971.0
1501087.0	3.4	126.4	104.4	103.4	146.3	2584971.0
1504387.0	3.4	126.3	104.4	103.4	146.2	2584971.0
1507687.0	3.4	126.3	104.4	103.4	146.2	2584971.0
1510987.0	3.4	126.3	104.4	103.4	146.2	2584971.0
1514287.0	3.4	126.3	104.4	103.4	146.2	2584971.0
1517587.0	3.4	126.2	104.4	103.4	146.2	2584971.0
1520887.0	3.4	126.2	104.3	103.4	146.2	2584971.0
1524187.0	3.4	126.2	104.3	103.3	146.1	2584971.0
1527487.0	3.4	126.2	104.3	103.3	146.1	2584971.0
1530787.0	3.4	126.1	104.3	103.3	146.1	2584971.0
1534087.0	3.4	126.1	104.3	103.3	146.1	2584971.0
1537387.0	3.4	126.1	104.3	103.3	146.1	2584971.0
1540687.0	3.4	126.1	104.3	103.3	146.1	2584971.0
1543987.0	3.4	126.1	104.3	103.3	146.0	2584971.0
1547287.0	3.4	126.0	104.2	103.3	146.0	2584971.0
1550587.0	3.4	126.0	104.2	103.2	146.0	2584971.0
1553887.0	3.4	126.0	104.2	103.2	146.0	2584971.0
1557187.0	3.4	126.0	104.2	103.2	146.0	2584971.0

Table 4.4.3-6 (cont.)	Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass					
Time Seconds	**Pressure Psig**	**Lower Compartment Temperature °F**	**Upper Compartment Temperature °F**	**Active Sump Temperature °F**	**Inactive Sump Temperature °F**	**Melted Ice Pounds**
1560487.0	3.4	125.9	104.2	103.2	146.0	2584971.0
1563787.0	3.4	125.9	104.2	103.2	145.9	2584971.0
1567087.0	3.4	125.9	104.2	103.2	145.9	2584971.0
1570387.0	3.4	125.9	104.1	103.2	145.9	2584971.0
1573687.0	3.4	125.8	104.1	103.2	145.9	2584971.0
1576987.0	3.4	125.8	104.1	103.2	145.9	2584971.0
1580287.0	3.4	125.8	104.1	103.1	145.9	2584971.0
1583587.0	3.4	125.8	104.1	103.1	145.8	2584971.0
1586887.0	3.4	125.8	104.1	103.1	145.8	2584971.0
1590187.0	3.4	125.7	104.1	103.1	145.8	2584971.0
1593487.0	3.4	125.7	104.1	103.1	145.8	2584971.0
1596787.0	3.4	125.7	104.0	103.1	145.8	2584971.0
1600087.0	3.4	125.7	104.0	103.1	145.8	2584971.0
1603387.0	3.4	125.6	104.0	103.1	145.7	2584971.0
1606687.0	3.4	125.6	104.0	103.0	145.7	2584971.0
1609987.0	3.4	125.6	104.0	103.0	145.7	2584971.0
1613287.0	3.4	125.6	104.0	103.0	145.7	2584971.0
1616587.0	3.4	125.5	104.0	103.0	145.7	2584971.0
1619887.0	3.4	125.5	104.0	103.0	145.7	2584971.0
1623187.0	3.4	125.5	103.9	103.0	145.6	2584971.0
1626487.0	3.4	125.5	103.9	103.0	145.6	2584971.0
1629787.0	3.4	125.5	103.9	103.0	145.6	2584971.0
1633087.0	3.4	125.4	103.9	102.9	145.6	2584971.0
1636387.0	3.4	125.4	103.9	102.9	145.6	2584971.0
1639687.0	3.4	125.4	103.9	102.9	145.6	2584971.0
1642987.0	3.4	125.4	103.9	102.9	145.5	2584971.0
1646287.0	3.4	125.3	103.9	102.9	145.5	2584971.0
1649587.0	3.4	125.3	103.8	102.9	145.5	2584971.0
1652887.0	3.4	125.3	103.8	102.9	145.5	2584971.0
1656187.0	3.4	125.3	103.8	102.9	145.5	2584971.0
1659487.0	3.4	125.2	103.8	102.8	145.5	2584971.0
1662787.0	3.4	125.2	103.8	102.8	145.4	2584971.0
1666087.0	3.4	125.2	103.8	102.8	145.4	2584971.0
1669387.0	3.4	125.2	103.8	102.8	145.4	2584971.0
1672687.0	3.4	125.1	103.8	102.8	145.4	2584971.0
1675987.0	3.4	125.1	103.7	102.8	145.4	2584971.0
1679287.0	3.4	125.1	103.7	102.8	145.4	2584971.0
1682587.0	3.4	125.1	103.7	102.8	145.4	2584971.0
1685887.0	3.4	125.1	103.7	102.8	145.3	2584971.0
1689187.0	3.4	125.0	103.7	102.7	145.3	2584971.0
1692487.0	3.4	125.0	103.7	102.7	145.3	2584971.0
1695787.0	3.4	125.0	103.7	102.7	145.3	2584971.0
1699087.0	3.4	125.0	103.6	102.7	145.3	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
1702387.0	3.4	124.9	103.6	102.7	145.3	2584971.0
1705687.0	3.4	124.9	103.6	102.7	145.2	2584971.0
1708987.0	3.4	124.9	103.6	102.7	145.2	2584971.0
1712287.0	3.4	124.9	103.6	102.7	145.2	2584971.0
1715587.0	3.4	124.8	103.6	102.6	145.2	2584971.0
1718887.0	3.4	124.8	103.6	102.6	145.2	2584971.0
1722187.0	3.4	124.8	103.6	102.6	145.2	2584971.0
1725487.0	3.4	124.8	103.5	102.6	145.1	2584971.0
1728787.0	3.4	124.8	103.5	102.6	145.1	2584971.0
1732087.0	3.4	124.7	103.5	102.6	145.1	2584971.0
1735387.0	3.4	124.7	103.5	102.6	145.1	2584971.0
1738687.0	3.4	124.7	103.5	102.6	145.1	2584971.0
1741987.0	3.4	124.7	103.5	102.5	145.1	2584971.0
1745287.0	3.4	124.6	103.5	102.5	145.1	2584971.0
1748587.0	3.4	124.6	103.5	102.5	145.0	2584971.0
1751887.0	3.4	124.6	103.4	102.5	145.0	2584971.0
1755187.0	3.4	124.6	103.4	102.5	145.0	2584971.0
1758487.0	3.4	124.5	103.4	102.5	145.0	2584971.0
1761787.0	3.4	124.5	103.4	102.5	145.0	2584971.0
1765087.0	3.4	124.5	103.4	102.5	145.0	2584971.0
1768387.0	3.4	124.5	103.4	102.5	144.9	2584971.0
1771687.0	3.4	124.4	103.4	102.4	144.9	2584971.0
1774987.0	3.4	124.4	103.4	102.4	144.9	2584971.0
1778287.0	3.4	124.4	103.3	102.4	144.9	2584971.0
1781587.0	3.4	124.4	103.3	102.4	144.9	2584971.0
1784887.0	3.4	124.4	103.3	102.4	144.9	2584971.0
1788187.0	3.4	124.3	103.3	102.4	144.9	2584971.0
1791487.0	3.4	124.3	103.3	102.4	144.8	2584971.0
1794787.0	3.3	124.3	103.3	102.4	144.8	2584971.0
1798087.0	3.3	124.3	103.3	102.3	144.8	2584971.0
1801387.0	3.3	124.2	103.3	102.3	144.8	2584971.0
1804687.0	3.3	124.2	103.2	102.3	144.8	2584971.0
1807987.0	3.3	124.2	103.2	102.3	144.8	2584971.0
1811287.0	3.3	124.2	103.2	102.3	144.7	2584971.0
1814587.0	3.3	124.1	103.2	102.3	144.7	2584971.0
1817887.0	3.3	124.1	103.2	102.3	144.7	2584971.0
1821187.0	3.3	124.1	103.2	102.3	144.7	2584971.0
1824487.0	3.3	124.1	103.2	102.2	144.7	2584971.0
1827787.0	3.3	124.0	103.2	102.2	144.7	2584971.0
1831087.0	3.3	124.0	103.1	102.2	144.7	2584971.0
1834387.0	3.3	124.0	103.1	102.2	144.6	2584971.0
1837687.0	3.3	124.0	103.1	102.2	144.6	2584971.0
1840987.0	3.3	124.0	103.1	102.2	144.6	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
1844287.0	3.3	123.9	103.1	102.2	144.6	2584971.0
1847587.0	3.3	123.9	103.1	102.2	144.6	2584971.0
1850887.0	3.3	123.9	103.1	102.1	144.6	2584971.0
1854187.0	3.3	123.9	103.0	102.1	144.5	2584971.0
1857487.0	3.3	123.8	103.0	102.1	144.5	2584971.0
1860787.0	3.3	123.8	103.0	102.1	144.5	2584971.0
1864087.0	3.3	123.8	103.0	102.1	144.5	2584971.0
1867387.0	3.3	123.8	103.0	102.1	144.5	2584971.0
1870687.0	3.3	123.7	103.0	102.1	144.5	2584971.0
1873987.0	3.3	123.7	103.0	102.1	144.5	2584971.0
1877287.0	3.3	123.7	103.0	102.1	144.4	2584971.0
1880587.0	3.3	123.7	102.9	102.0	144.4	2584971.0
1883887.0	3.3	123.6	102.9	102.0	144.4	2584971.0
1887187.0	3.3	123.6	102.9	102.0	144.4	2584971.0
1890487.0	3.3	123.6	102.9	102.0	144.4	2584971.0
1893787.0	3.3	123.6	102.9	102.0	144.4	2584971.0
1897087.0	3.3	123.6	102.9	102.0	144.4	2584971.0
1900387.0	3.3	123.5	102.9	102.0	144.3	2584971.0
1903687.0	3.3	123.5	102.9	102.0	144.3	2584971.0
1906987.0	3.3	123.5	102.8	101.9	144.3	2584971.0
1910287.0	3.3	123.5	102.8	101.9	144.3	2584971.0
1913587.0	3.3	123.4	102.8	101.9	144.3	2584971.0
1916887.0	3.3	123.4	102.8	101.9	144.3	2584971.0
1920187.0	3.3	123.4	102.8	101.9	144.3	2584971.0
1923487.0	3.3	123.4	102.8	101.9	144.2	2584971.0
1926787.0	3.3	123.3	102.8	101.9	144.2	2584971.0
1930087.0	3.3	123.3	102.8	101.9	144.2	2584971.0
1933387.0	3.3	123.3	102.7	101.8	144.2	2584971.0
1936687.0	3.3	123.3	102.7	101.8	144.2	2584971.0
1939987.0	3.3	123.2	102.7	101.8	144.2	2584971.0
1943287.0	3.3	123.2	102.7	101.8	144.1	2584971.0
1946587.0	3.3	123.2	102.7	101.8	144.1	2584971.0
1949887.0	3.3	123.2	102.7	101.8	144.1	2584971.0
1953187.0	3.3	123.1	102.7	101.8	144.1	2584971.0
1956487.0	3.3	123.1	102.7	101.8	144.1	2584971.0
1959787.0	3.3	123.1	102.6	101.8	144.1	2584971.0
1963087.0	3.3	123.1	102.6	101.7	144.1	2584971.0
1966387.0	3.3	123.1	102.6	101.7	144.0	2584971.0
1969687.0	3.3	123.0	102.6	101.7	144.0	2584971.0
1972987.0	3.3	123.0	102.6	101.7	144.0	2584971.0
1976287.0	3.3	123.0	102.6	101.7	144.0	2584971.0
1979587.0	3.3	123.0	102.6	101.7	144.0	2584971.0
1982887.0	3.3	122.9	102.6	101.7	144.0	2584971.0

Table 4.4.3-6 (cont.)	Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass					
Time Seconds	**Pressure Psig**	**Lower Compartment Temperature °F**	**Upper Compartment Temperature °F**	**Active Sump Temperature °F**	**Inactive Sump Temperature °F**	**Melted Ice Pounds**
1986187.0	3.3	122.9	102.5	101.7	144.0	2584971.0
1989487.0	3.3	122.9	102.5	101.6	143.9	2584971.0
1992787.0	3.3	122.9	102.5	101.6	143.9	2584971.0
1996087.0	3.3	122.8	102.5	101.6	143.9	2584971.0
1999387.0	3.3	122.8	102.5	101.6	143.9	2584971.0
2002687.0	3.3	122.8	102.5	101.6	143.9	2584971.0
2005987.0	3.3	122.8	102.5	101.6	143.9	2584971.0
2009287.0	3.3	122.8	102.5	101.6	143.9	2584971.0
2012587.0	3.3	122.8	102.5	101.6	143.8	2584971.0
2015887.0	3.3	122.7	102.4	101.6	143.8	2584971.0
2019187.0	3.3	122.7	102.4	101.6	143.8	2584971.0
2022487.0	3.3	122.7	102.4	101.6	143.8	2584971.0
2025787.0	3.3	122.7	102.4	101.5	143.8	2584971.0
2029087.0	3.3	122.7	102.4	101.5	143.8	2584971.0
2032387.0	3.3	122.7	102.4	101.5	143.8	2584971.0
2035687.0	3.3	122.7	102.4	101.5	143.7	2584971.0
2038987.0	3.3	122.7	102.4	101.5	143.7	2584971.0
2042287.0	3.3	122.6	102.4	101.5	143.7	2584971.0
2045587.0	3.3	122.6	102.4	101.5	143.7	2584971.0
2048887.0	3.3	122.6	102.4	101.5	143.7	2584971.0
2052187.0	3.3	122.6	102.4	101.5	143.7	2584971.0
2055487.0	3.3	122.6	102.4	101.5	143.7	2584971.0
2058787.0	3.3	122.6	102.4	101.5	143.6	2584971.0
2062087.0	3.3	122.6	102.3	101.5	143.6	2584971.0
2065387.0	3.3	122.6	102.3	101.5	143.6	2584971.0
2068687.0	3.3	122.5	102.3	101.5	143.6	2584971.0
2071987.0	3.3	122.5	102.3	101.5	143.6	2584971.0
2075287.0	3.3	122.5	102.3	101.4	143.6	2584971.0
2078587.0	3.3	122.5	102.3	101.4	143.6	2584971.0
2081887.0	3.3	122.5	102.3	101.4	143.5	2584971.0
2085187.0	3.3	122.5	102.3	101.4	143.5	2584971.0
2088487.0	3.3	122.5	102.3	101.4	143.5	2584971.0
2091787.0	3.3	122.5	102.3	101.4	143.5	2584971.0
2095087.0	3.3	122.4	102.3	101.4	143.5	2584971.0
2098387.0	3.3	122.4	102.3	101.4	143.5	2584971.0
2101687.0	3.3	122.4	102.3	101.4	143.5	2584971.0
2104987.0	3.3	122.4	102.3	101.4	143.4	2584971.0
2108287.0	3.3	122.4	102.3	101.4	143.4	2584971.0
2111587.0	3.3	122.4	102.2	101.4	143.4	2584971.0
2114887.0	3.3	122.4	102.2	101.4	143.4	2584971.0
2118187.0	3.3	122.4	102.2	101.4	143.4	2584971.0
2121487.0	3.3	122.3	102.2	101.4	143.4	2584971.0
2124787.0	3.3	122.3	102.2	101.4	143.4	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
2128087.0	3.3	122.3	102.2	101.3	143.4	2584971.0
2131387.0	3.3	122.3	102.2	101.3	143.3	2584971.0
2134687.0	3.3	122.3	102.2	101.3	143.3	2584971.0
2137987.0	3.3	122.3	102.2	101.3	143.3	2584971.0
2141287.0	3.3	122.3	102.2	101.3	143.3	2584971.0
2144587.0	3.3	122.2	102.2	101.3	143.3	2584971.0
2147887.0	3.3	122.2	102.2	101.3	143.3	2584971.0
2151187.0	3.3	122.2	102.2	101.3	143.3	2584971.0
2154487.0	3.3	122.2	102.2	101.3	143.2	2584971.0
2157787.0	3.3	122.2	102.2	101.3	143.2	2584971.0
2161087.0	3.3	122.2	102.1	101.3	143.2	2584971.0
2164387.0	3.3	122.2	102.1	101.3	143.2	2584971.0
2167687.0	3.3	122.2	102.1	101.3	143.2	2584971.0
2170987.0	3.3	122.1	102.1	101.3	143.2	2584971.0
2174287.0	3.3	122.1	102.1	101.3	143.2	2584971.0
2177587.0	3.3	122.1	102.1	101.2	143.1	2584971.0
2180887.0	3.3	122.1	102.1	101.2	143.1	2584971.0
2184187.0	3.3	122.1	102.1	101.2	143.1	2584971.0
2187487.0	3.3	122.1	102.1	101.2	143.1	2584971.0
2190787.0	3.3	122.1	102.1	101.2	143.1	2584971.0
2194087.0	3.3	122.1	102.1	101.2	143.1	2584971.0
2197387.0	3.3	122.0	102.1	101.2	143.1	2584971.0
2200687.0	3.3	122.0	102.1	101.2	143.0	2584971.0
2203987.0	3.3	122.0	102.1	101.2	143.0	2584971.0
2207287.0	3.3	122.0	102.1	101.2	143.0	2584971.0
2210587.0	3.3	122.0	102.0	101.2	143.0	2584971.0
2213887.0	3.3	122.0	102.0	101.2	143.0	2584971.0
2217187.0	3.3	122.0	102.0	101.2	143.0	2584971.0
2220487.0	3.3	122.0	102.0	101.2	143.0	2584971.0
2223787.0	3.3	121.9	102.0	101.2	143.0	2584971.0
2227087.0	3.3	121.9	102.0	101.2	142.9	2584971.0
2230387.0	3.3	121.9	102.0	101.1	142.9	2584971.0
2233687.0	3.3	121.9	102.0	101.1	142.9	2584971.0
2236987.0	3.3	121.9	102.0	101.1	142.9	2584971.0
2240287.0	3.3	121.9	102.0	101.1	142.9	2584971.0
2243587.0	3.3	121.9	102.0	101.1	142.9	2584971.0
2246887.0	3.3	121.9	102.0	101.1	142.9	2584971.0
2250187.0	3.3	121.8	102.0	101.1	142.8	2584971.0
2253487.0	3.3	121.8	102.0	101.1	142.8	2584971.0
2256787.0	3.3	121.8	102.0	101.1	142.8	2584971.0
2260087.0	3.3	121.8	101.9	101.1	142.8	2584971.0
2263387.0	3.3	121.8	101.9	101.1	142.8	2584971.0
2266687.0	3.3	121.8	101.9	101.1	142.8	2584971.0

Table 4.4.3-6 (cont.) Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass

Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
2269987.0	3.3	121.8	101.9	101.1	142.8	2584971.0
2273287.0	3.3	121.8	101.9	101.1	142.8	2584971.0
2276587.0	3.3	121.7	101.9	101.1	142.7	2584971.0
2279887.0	3.3	121.7	101.9	101.1	142.7	2584971.0
2283187.0	3.3	121.7	101.9	101.0	142.7	2584971.0
2286487.0	3.3	121.7	101.9	101.0	142.7	2584971.0
2289787.0	3.3	121.7	101.9	101.0	142.7	2584971.0
2293087.0	3.3	121.7	101.9	101.0	142.7	2584971.0
2296387.0	3.3	121.7	101.9	101.0	142.7	2584971.0
2299687.0	3.3	121.7	101.9	101.0	142.6	2584971.0
2302987.0	3.3	121.6	101.9	101.0	142.6	2584971.0
2306287.0	3.3	121.6	101.9	101.0	142.6	2584971.0
2309587.0	3.3	121.6	101.8	101.0	142.6	2584971.0
2312887.0	3.3	121.6	101.8	101.0	142.6	2584971.0
2316187.0	3.3	121.6	101.8	101.0	142.6	2584971.0
2319487.0	3.3	121.6	101.8	101.0	142.6	2584971.0
2322787.0	3.3	121.6	101.8	101.0	142.6	2584971.0
2326087.0	3.3	121.6	101.8	101.0	142.5	2584971.0
2329387.0	3.3	121.5	101.8	101.0	142.5	2584971.0
2332687.0	3.3	121.5	101.8	101.0	142.5	2584971.0
2335987.0	3.3	121.5	101.8	100.9	142.5	2584971.0
2339287.0	3.2	121.5	101.8	100.9	142.5	2584971.0
2342587.0	3.2	121.5	101.8	100.9	142.5	2584971.0
2345887.0	3.2	121.5	101.8	100.9	142.5	2584971.0
2349187.0	3.2	121.5	101.8	100.9	142.4	2584971.0
2352487.0	3.2	121.4	101.8	100.9	142.4	2584971.0
2355787.0	3.2	121.4	101.8	100.9	142.4	2584971.0
2359087.0	3.2	121.4	101.7	100.9	142.4	2584971.0
2362387.0	3.2	121.4	101.7	100.9	142.4	2584971.0
2365687.0	3.2	121.4	101.7	100.9	142.4	2584971.0
2368987.0	3.2	121.4	101.7	100.9	142.4	2584971.0
2372287.0	3.2	121.4	101.7	100.9	142.4	2584971.0
2375587.0	3.2	121.4	101.7	100.9	142.3	2584971.0
2378887.0	3.2	121.3	101.7	100.9	142.3	2584971.0
2382187.0	3.2	121.3	101.7	100.9	142.3	2584971.0
2385487.0	3.2	121.3	101.7	100.9	142.3	2584971.0
2388787.0	3.2	121.3	101.7	100.8	142.3	2584971.0
2392087.0	3.2	121.3	101.7	100.8	142.3	2584971.0
2395387.0	3.2	121.3	101.7	100.8	142.3	2584971.0
2398687.0	3.2	121.3	101.7	100.8	142.3	2584971.0
2401987.0	3.2	121.3	101.7	100.8	142.2	2584971.0
2405287.0	3.2	121.2	101.7	100.8	142.2	2584971.0
2408587.0	3.2	121.2	101.6	100.8	142.2	2584971.0

Table 4.4.3-6 (cont.)	Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass					
Time Seconds	Pressure Psig	Lower Compartment Temperature °F	Upper Compartment Temperature °F	Active Sump Temperature °F	Inactive Sump Temperature °F	Melted Ice Pounds
2411887.0	3.2	121.2	101.6	100.8	142.2	2584971.0
2415187.0	3.2	121.2	101.6	100.8	142.2	2584971.0
2418487.0	3.2	121.2	101.6	100.8	142.2	2584971.0
2421787.0	3.2	121.2	101.6	100.8	142.2	2584971.0
2425087.0	3.2	121.2	101.6	100.8	142.2	2584971.0
2428387.0	3.2	121.2	101.6	100.8	142.1	2584971.0
2431687.0	3.2	121.1	101.6	100.8	142.1	2584971.0
2434987.0	3.2	121.1	101.6	100.8	142.1	2584971.0
2438287.0	3.2	121.1	101.6	100.7	142.1	2584971.0
2441587.0	3.2	121.1	101.6	100.7	142.1	2584971.0
2444887.0	3.2	121.1	101.6	100.7	142.1	2584971.0
2448187.0	3.2	121.1	101.6	100.7	142.1	2584971.0
2451487.0	3.2	121.1	101.6	100.7	142.0	2584971.0
2454787.0	3.2	121.1	101.6	100.7	142.0	2584971.0
2458087.0	3.2	121.0	101.5	100.7	142.0	2584971.0
2461387.0	3.2	121.0	101.5	100.7	142.0	2584971.0
2464687.0	3.2	121.0	101.5	100.7	142.0	2584971.0
2467987.0	3.2	121.0	101.5	100.7	142.0	2584971.0
2471287.0	3.2	121.0	101.5	100.7	142.0	2584971.0
2474587.0	3.2	121.0	101.5	100.7	142.0	2584971.0
2477887.0	3.2	121.0	101.5	100.7	141.9	2584971.0
2481187.0	3.2	121.0	101.5	100.7	141.9	2584971.0
2484487.0	3.2	120.9	101.5	100.7	141.9	2584971.0
2487787.0	3.2	120.9	101.5	100.7	141.9	2584971.0
2491087.0	3.2	120.9	101.5	100.6	141.9	2584971.0
2494387.0	3.2	120.9	101.5	100.6	141.9	2584971.0
2497687.0	3.2	120.9	101.5	100.6	141.9	2584971.0
2500987.0	3.2	120.9	101.5	100.6	141.9	2584971.0
2504287.0	3.2	120.9	101.5	100.6	141.8	2584971.0
2507587.0	3.2	120.8	101.4	100.6	141.8	2584971.0
2510887.0	3.2	120.8	101.4	100.6	141.8	2584971.0
2514187.0	3.2	120.8	101.4	100.6	141.8	2584971.0
2517487.0	3.2	120.8	101.4	100.6	141.8	2584971.0
2520787.0	3.2	120.8	101.4	100.6	141.8	2584971.0
2524087.0	3.2	120.8	101.4	100.6	141.8	2584971.0
2527387.0	3.2	120.8	101.4	100.6	141.8	2584971.0
2530687.0	3.2	120.8	101.4	100.6	141.7	2584971.0
2533987.0	3.2	120.7	101.4	100.6	141.7	2584971.0
2537287.0	3.2	120.7	101.4	100.6	141.7	2584971.0
2540587.0	3.2	120.7	101.4	100.6	141.7	2584971.0
2543887.0	3.2	120.7	101.4	100.5	141.7	2584971.0
2547187.0	3.2	120.7	101.4	100.5	141.7	2584971.0
2550487.0	3.2	120.7	101.4	100.5	141.7	2584971.0

Table 4.4.3-6 (cont.)	Containment Pressure, Upper and Lower Compartment Temperatures, Active and Inactive Sump Temperatures, and Ice Bed Melted Ice Mass					
Time Seconds	**Pressure Psig**	**Lower Compartment Temperature °F**	**Upper Compartment Temperature °F**	**Active Sump Temperature °F**	**Inactive Sump Temperature °F**	**Melted Ice Pounds**
2553787.0	3.2	120.7	101.4	100.5	141.7	2584971.0
2557087.0	3.2	120.7	101.3	100.5	141.6	2584971.0
2560387.0	3.2	120.6	101.3	100.5	141.6	2584971.0
2563687.0	3.2	120.6	101.3	100.5	141.6	2584971.0
2566987.0	3.2	120.6	101.3	100.5	141.6	2584971.0
2570287.0	3.2	120.6	101.3	100.5	141.6	2584971.0
2573587.0	3.2	120.6	101.3	100.5	141.6	2584971.0
2576887.0	3.2	120.6	101.3	100.5	141.6	2584971.0
2580187.0	3.2	120.6	101.3	100.5	141.6	2584971.0
2583487.0	3.2	120.6	101.3	100.5	141.5	2584971.0
2586787.0	3.2	120.5	101.3	100.5	141.5	2584971.0
2590087.0	3.2	120.5	101.3	100.5	141.5	2584971.0
2593387.0	3.2	120.5	101.3	100.5	141.5	2584971.0
2596687.0	3.2	120.5	101.3	100.4	141.5	2584971.0
2599987.0	3.2	120.5	101.3	100.4	141.5	2584971.0

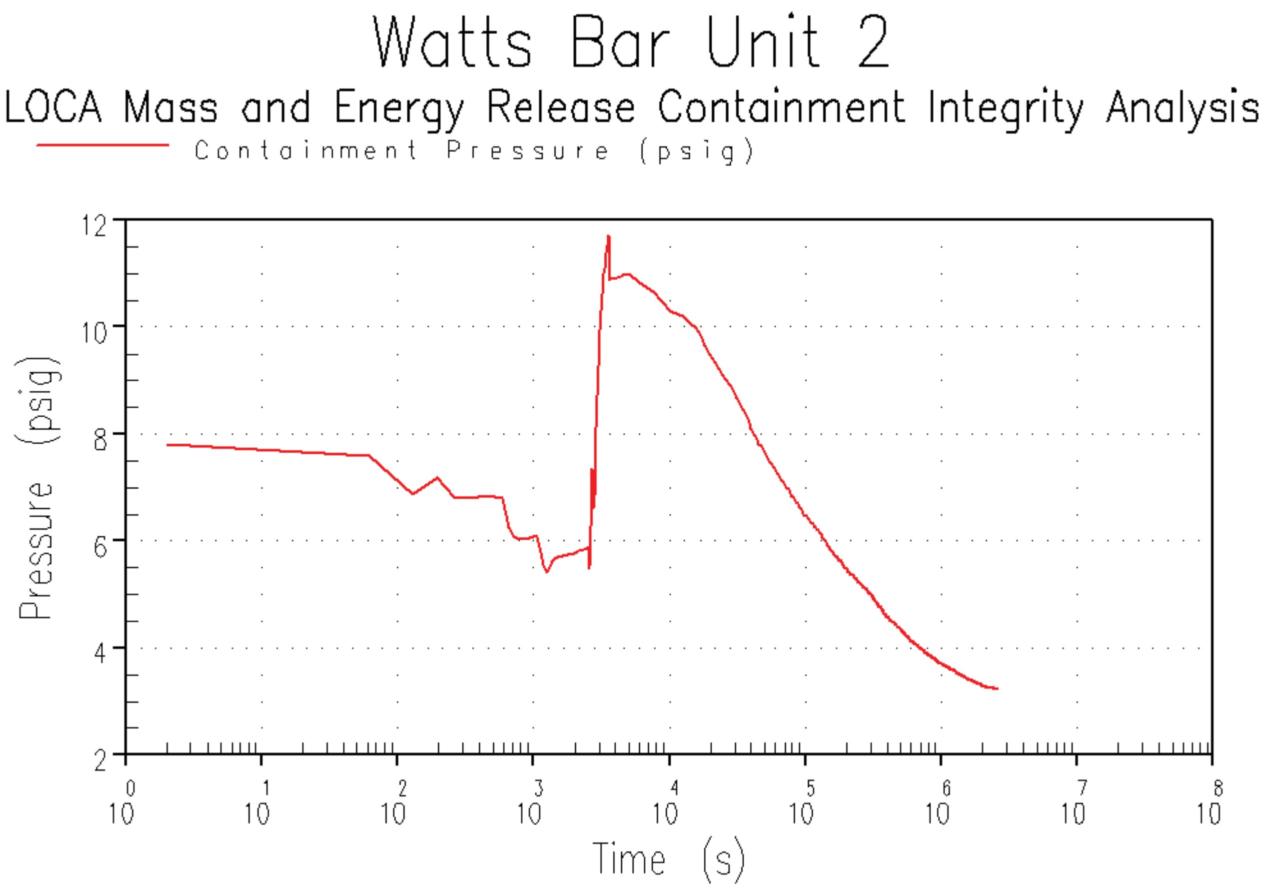


Figure 4.4.3-1 Containment Pressure Transient

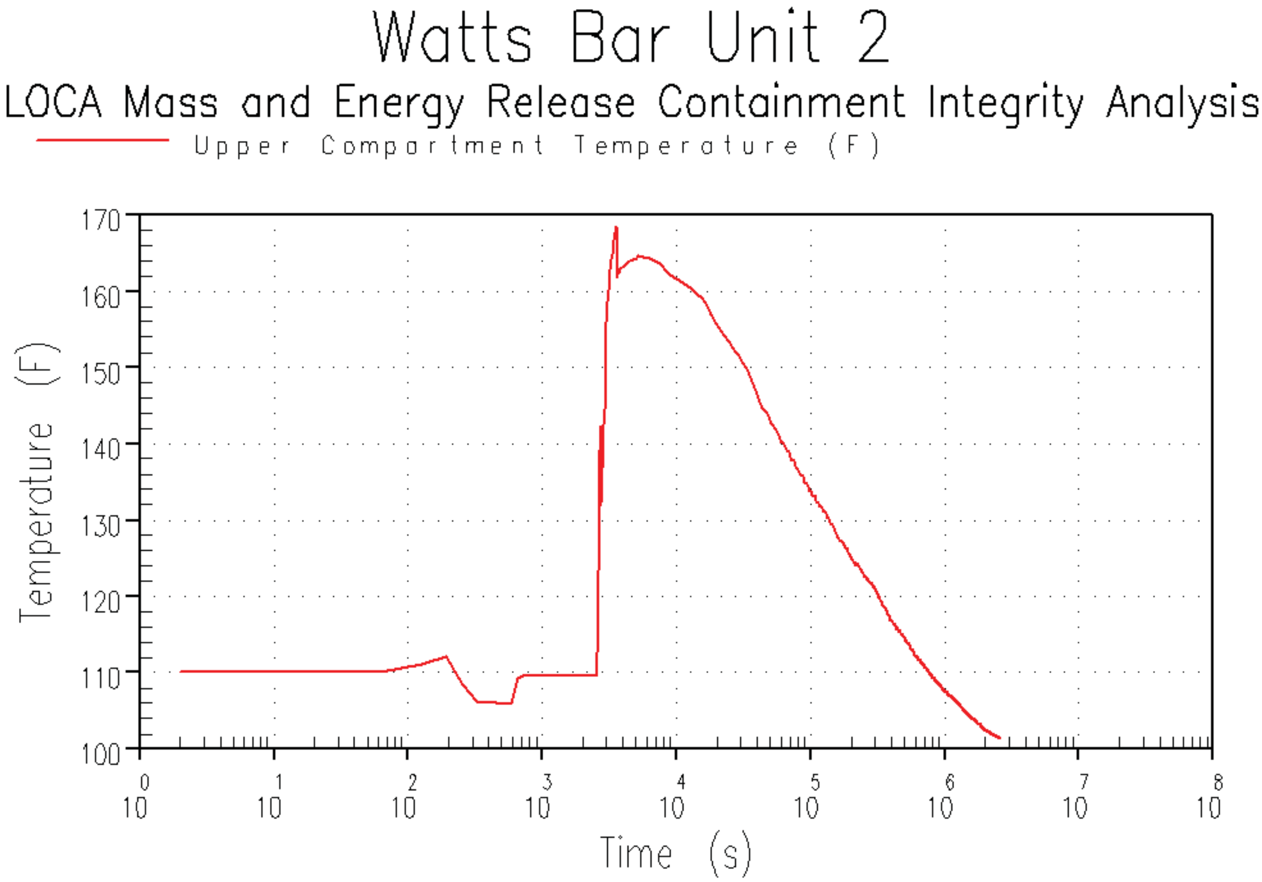


Figure 4.4.3-2 Upper Compartment Temperature Transient

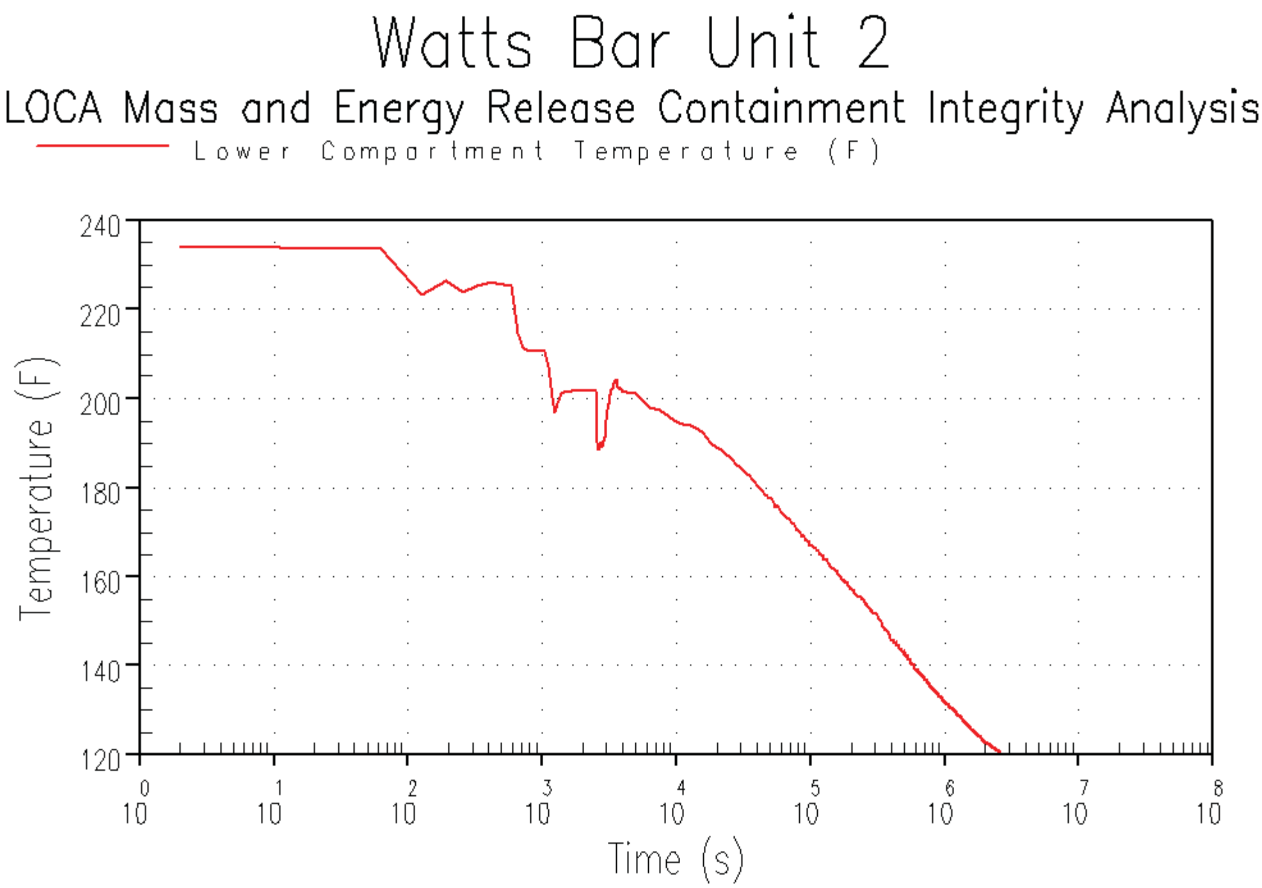


Figure 4.4.3-3 Lower Compartment Temperature Transient

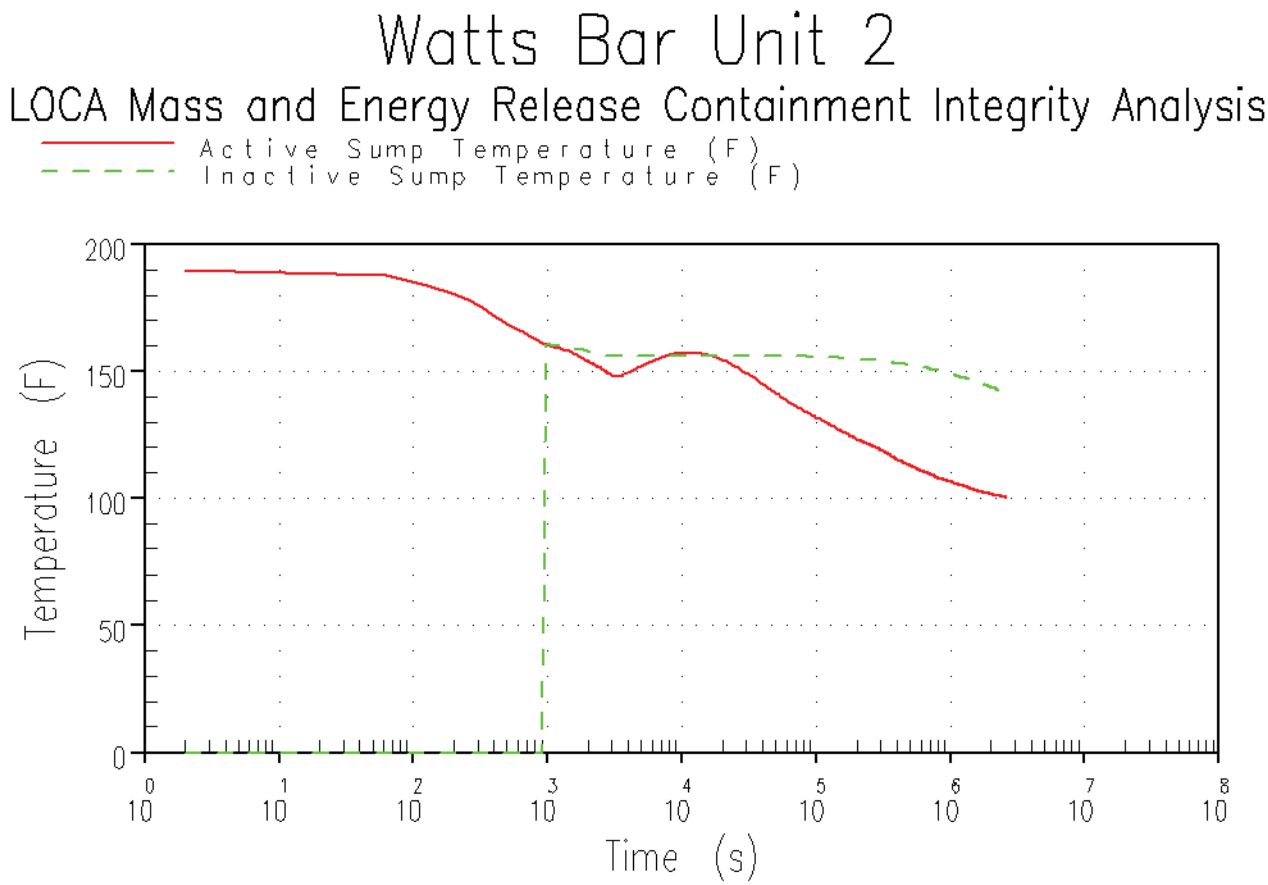


Figure 4.4.3-4 Active Sump and Inactive Sump Temperature Transient

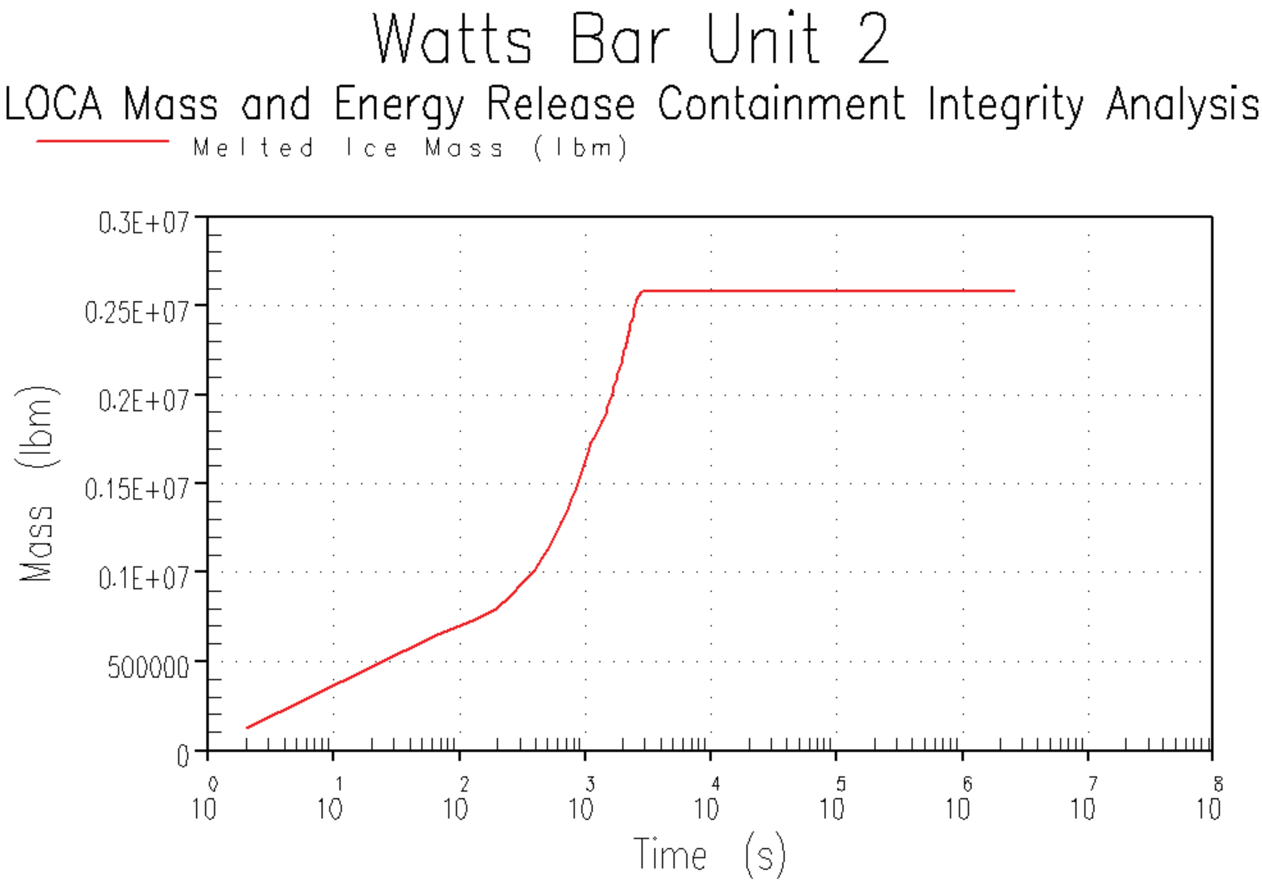


Figure 4.4.3-5 Ice Melt Transient

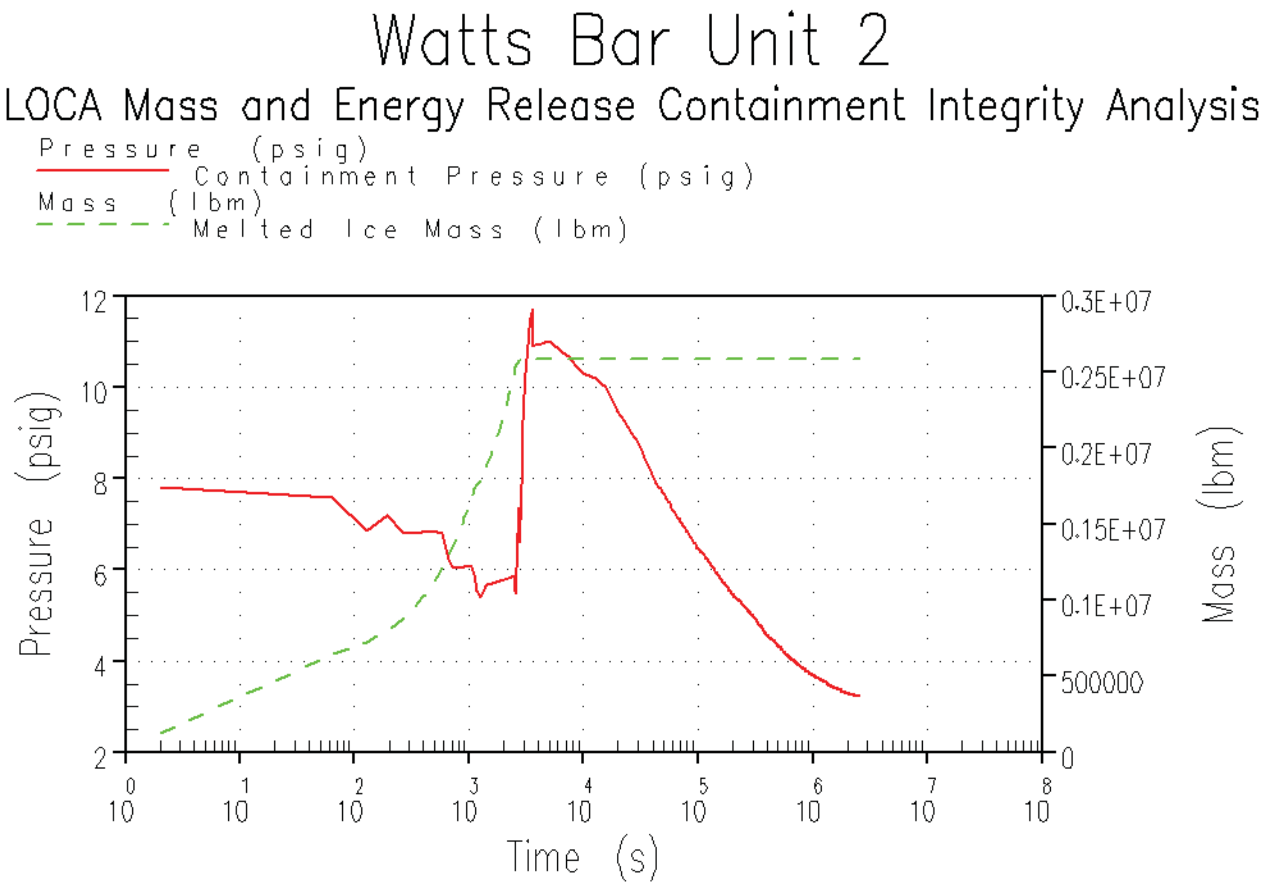


Figure 4.4.3-6 Comparison of Containment Pressure versus Ice Melt Transients

ENCLOSURE 2
Watts Bar Nuclear Plant Unit 2

Revised FSAR Section 6.2.1 Pages

6.1.2.6 Heating and Ventilating Door Seals

Material	Mass, lbs
Neoprene (chloroprene)	100

6.1.2.7 Miscellaneous

Material	Mass, lbs
Catch Basins (polyethylene)	100
Lead Shielding Blankets (Hypalon, Vinyl, Methyllpolysiloxance)	1200

6.1.3 Post-Accident Chemistry

Following a LOCA, the emergency core cooling solution recirculated in containment is composed of boric acid (H_3BO_3) from the reactor coolant, refueling water storage tank (RWST), cold leg accumulators and affected injection piping, lithium hydroxide (LiOH) from the reactor coolant and sodium tetraborate ($Na_2B_4O_7$) from the ice in the ice condenser.

6.1.3.1 Boric Acid, H_3BO_3

Boric acid up to a maximum concentration of 3300 ppm boron, can be found in the reactor coolant loop (4 loops, reactor vessel, pressurizer), and boric acid at a maximum concentration of 3300 ppm boron is found in the cold leg injection accumulators, the refueling water storage tank, and in associated piping. This limit may be exceeded during Mode 6 operation. These subsystems, when at maximum volume, represent a total mass of boric acid in the amount of 93,928 pounds.

LOCA M&E analysis assumes 2.585 x 10^6 lbm of ice

6.1.3.2 Lithium Hydroxide

Lithium Hydroxide at a maxi[illegible] lithium is found in the reactor coolant system for pH control.

6.1.3.3 Sodium Tetraborate

Sodium tetraborate is an additive in the ice stored in the ice condenser for the purpose of maintaining containment sump pH of at least 7.5 after all the ice has melted.

The minimum amount of ice assumed in the Post-LOCA sump pH analysis is 2.26 x 10^6 lbs [Ref. 3]. Boric acid and NaOH are formed during ice melt following a LOCA according to the following equation:

$$Na_2B_4O_7 + 7H_2O \rightarrow 2NaOH + 4H_3BO_3$$

6.2 CONTAINMENT SYSTEMS

6.2.1 Containment Functional Design

6.2.1.1 Design Bases

6.2.1.1.1 Primary Containment Design Bases

The containment is designed to assure that an acceptable upper limit of leakage of radioactive material is not exceeded under design basis accident conditions. For purposes of integrity, the containment may be considered as the containment vessel and containment isolation system. This structure and system are directly relied upon to maintain containment integrity. The emergency gas treatment system and Reactor Building function to keep out-leakage minimal (the Reactor Building also serves as a protective structure), but are not factors in determining the design leak rate.

The containment is specifically designed to meet the intent of the applicable General Design Criteria listed in Section 3.1. This section, Chapter 3, and other portions of Chapter 6 present information showing conformance of design of the containment and related systems to these criteria.

The ice condenser is designed to limit the containment pressure below the design pressure for all reactor coolant pipe break sizes up to and including a double-ended severance. Characterizing the performance of the ice condenser requires consideration of the rate of addition of mass and energy to the containment as well as the total amounts of mass and energy added. Analyses have shown that the accident which produces the highest blowdown rate into a condenser containment will result in the maximum containment pressure rise; that accident is the double-ended guillotine or split severance of a reactor coolant pipe. The design basis accident for containment analysis based on sensitivity studies is therefore the double-ended guillotine severance of a reactor coolant pipe at the reactor coolant pump suction. Post-blowdown energy releases can also be accommodated without exceeding containment design pressure.

The functional design of the containment is based upon the following accident input source term assumptions and conditions:

(1) The design basis blowdown energy of ~~314.9×10^6 Btu~~ 315.5×10^6 Btu and mass of ~~498.1×10^3 lb~~ 498.9×10^3 lb put into the containment. (See Section 6.2.1.3.6)

(2) A core power of 3411 MWt (plus 2% allowance for calorimetric error). (See Section 6.2.1.3.6)

(3) The minimum engineered safety features are (i.e., the single failure criterion applied to each safety system) comprised of the following:

(a) The ice condenser which condenses steam generated during a LOCA, thereby limiting the pressure peak inside the containment (see Section 6.7).

(b) The containment isolation system which closes those fluid penetrations not serving accident-consequence limiting purposes (see Section 6.2.4).

(c) The containment spray system which sprays cool water into the containment atmosphere, thereby limiting the pressure peak (particularly in the long term - see Section 6.2.2).

(d) The emergency gas treatment system (EGTS) which produces a slightly negative pressure within the annulus, thereby precluding out-leakage and relieving the post-accident thermal expansion of air in the annulus (see Section 6.5.1).

(e) The air return fans which return air to the lower compartment (See Section 6.8).

Consideration is given to subcompartment differential pressure resulting from a design basis accident discussed in Sections 3.8.3.3, 6.2.1.3.9, and 6.2.1.3.4. If a design basis accident were to occur due to a pipe rupture in these relatively small volumes, the pressure would build up at a faster rate than in the containment, thus imposing a differential pressure across the wall of these structures.

Parameters affecting the assumed capability for post-accident pressure reduction are discussed in Section 6.2.1.3.3.

Three events that may result in an external pressure on the containment vessel have been considered:

(1) Rupture of a process pipe where it passes through the annulus.

(2) Inadvertent air return fan operation during normal operation.

(3) Inadvertent containment spray system initiation during normal operation.

The design of the guard pipe portion of hot penetrations is such that any process pipe leakage in the annulus is returned to the containment. All process piping which has potential for annulus pressurization upon rupture is routed through hot penetrations. Section 6.2.4 discusses hot penetrations.

Inadvertent air return fan operation during normal operation opens the ice condenser lower inlet doors, which in turn, results in sounding an alarm in the MCR. Sufficient time exists for operator action to terminate fan operation prior to exceeding the containment design external pressure.

The logic and control circuits of the containment spray system are such that inadvertent containment spray would not take place with a single failure. The spray pump must start and the isolation valve must open before there can be any spray. In addition, the Watts Bar containment is so designed that even if an inadvertent spray occurs, containment integrity is preserved without the use of a vacuum relief.

The containment spray system is automatically actuated by a hi-hi containment pressure signal from the solid state protection system (SSPS). To prevent inadvertent automatic actuation, four comparator outputs, one from each protection set are processed through two coincidence gates. Both coincidence gates are required to have at least two high inputs before the output relays, which actuate the containment spray system, are energized. Separate output relays are provided for the pump start logic and discharge valve open logic. Additional protection is provided by an interlock between the pump and discharge valve, which requires the pump to be running before the discharge valve will automatically open.

Section 3.8.2 describes the structural design of the containment vessel. The containment vessel is designed to withstand a net external pressure of 2.0 psi. The containment vessel is designed to withstand the maximum expected net external pressure in accordance with ASME Boiler and Pressure and Vessel Code Section III, paragraph NE-7116.

6.2.1.2 Primary Containment System Design

15.0 psig

The containment consists of a containment vessel and a separate Shield Building enclosing an annulus. The containment vessel is a freestanding, welded steel structure with a vertical cylinder, hemispherical dome, and a flat circular base. The Shield Building is a reinforced concrete structure similar in shape to the containment vessel. The design of these structures is described in Section 3.8.

The design internal pressure for the containment is ~~13.5 psig~~, and the design temperature is 250°F. The design basis leakage rate is 0.25 weight percent/24 hr. The design methods to assure integrity of the containment internal structures and sub-compartments from accident pressure pulses are described in Section 3.8.

6.2.1.3 Design Evaluation

6.2.1.3.1 Primary Containment Evaluation

(1) The leaktightness aspect of the secondary containment is discussed in Section 6.2.3. The primary containment's leaktightness does not depend on the operation of any continuous monitoring or compressor system. The leak testing of the primary containment and its isolation system is discussed in Section 6.2.6.

(2) The acceptance criteria for the leaktightness of the primary containment are such that at containment design pressure, there is a 25% margin between the acceptable maximum leakage rate and the maximum permissible leakage rate.

6.2.1.3.2 General Description of Containment Pressure Analysis

The time history of conditions within an ice condenser containment during a postulated loss of coolant accident can be divided into two periods for calculation purposes:

(1) The initial reactor coolant blowdown, which for the largest assumed pipe break occurs in approximately 10 seconds.

(2) The post blowdown phase of the accident which begins following the blowdown and extends several hours after the start of the accident.

During the first few seconds of the blowdown period of the reactor coolant system, containment conditions are characterized by rapid pressure and temperature transients. It is during this period that the peak transient pressures, differential pressures, temperature and blowdown loads occur. To calculate these transients a detailed spatial and short time increment analysis was necessary. This analysis was performed with the Transient Mass Distribution (TMD) computer code (Reference 4) with the calculation time of interest extending up to a few seconds following the accident initiation (See Section 6.2.1.3.4).

Physically, tests at the ice condenser Waltz Mill test facility have shown that the blowdown phase represents that period of time in which the lower compartment air and a portion of the ice condenser air are displaced and compressed into the upper compartment and the remainder of the ice condenser. The containment pressure at or near the end of blowdown is governed by this air compression process. The containment compression ratio calculation is described in Section 6.2.1.3.4.

Containment pressure during the post blowdown phase of the accident is calculated with the LOTIC code which models the containment structural heat sinks and containment safeguards systems.

6.2.1.3.3 Long-Term Containment Pressure Analysis

Early in the ice condenser development program it was recognized that there was a need for modeling of long-term ice condenser containment 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 solve problems of containment design and optimize the containment and safeguards systems. This has been accomplished in the development of the LOTIC code[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 compartments. The ice condenser control volume with unmelted 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 distinct 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.

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 reactor coolant system, 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 small 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 ASME steam table.

For the purpose of calculation, the condensation of steam is assumed to take place in a condensing node located between the two control volumes in the ice storage compartment.

Containment Pressure Calculation

The following are the major input assumptions used in the LOTIC analysis for the pump suction pipe rupture case with the steam generators considered as an active heat source for the Watts Bar Nuclear Plant containment:

(1) Minimum safeguards are employed in all calculations, e.g., one of two spray pumps and one of two spray heat exchangers; one of two 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; and one of two air return fans.

(2) ~~2.33×10^6 lbs.~~ 2.585×10^6 lbs of ice initially in the ice condenser which is at 27°F.

(3) The blowdown, reflood, and post reflood mass and energy releases described in Section 6.2.1.3.6 were used.

(4) Blowdown and post-blowdown ice condenser drain temperatures of 190°F and 130°F are used[5].

(5) Nitrogen from the accumulators in the amount of 2955.68 lbs. included in the calculations.

(6) Essential raw cooling water temperature of 88°F is used on the spray heat exchanger and the component cooling heat exchanger. Note: The containment analysis was run at an ERCW temperature of 88°F although the containment spray, component cooling, and residual heat removal heat exchanger UA values are based on an ERCW temperature of 85°F to provide additional conservatism.

(7) The air return fan is effective 10 minutes after the transient is initiated. The actual air return fan initiation can take place in 9 ± 1 minutes, with initiation as early as 8 minutes not adversely affecting the analysis results.

(8) No maldistribution of steam flow to the ice bed is assumed.

(9) No ice condenser bypass is assumed. (This assumption depletes the ice in the shortest time and is thus conservative.)

(10) The initial conditions in the containment are a temperature of 120°F in the lower and dead-ended volumes, 110°F in the upper volume, and 27°F in the ice condenser. All 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.

(11) A containment spray pump flow of 4000 gpm is used in the upper compartment. The analyzed diesel loading sequence for the containment sprays to energize and come up to full flow and head in 234 seconds is tabulated in Table 6.2.1-25.

(12) A residual spray (2000 gpm design, 1475 gpm analytical) is used. The residual heat removal pump and spray pump take suction from the sump during recirculation.

During the recirculation phase of a LOCA mass and energy release transient, a portion of the RHR pump flow can be diverted to the RHR sprays. The minimum time before RHR spray can be placed in service, as indicated in the Watts Bar Nuclear Plant System Description N3-72-4001, R19, Containment Heat Removal Spray System, is at least 1 hour after LOCA initiation to ensure adequate RHR flow to the core to remove the initial decay heat. Based on the preceding criteria, the RHR spray initiation was modeled at ~~4346.7~~ 3600.0 seconds into the LOCA containment response transient.

A discussion of the core cooling capability of the emergency core cooling system is given in Section 6.3.1 for this mode of operation.

(13) Containment structural heat sink data is found in Table 6.2.1-1. (Note: The dead-ended compartment structural heat sinks were conservatively neglected.)

3.17 x 10^6

(14) The operation of one containment spray heat exchanger (UA = 2.44 x 10^6 Btu/hr-°F incorporating a 10% tube plugging margin) for containment cooling and the operation of one RHR heat exchanger (UA = 1.496 x 10^6 Btu/hr-°F) for core cooling. The component cooling system heat exchanger UA was modeled at ~~5.778 x 10^6~~ Btu/hr-°F.

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

(16) An active sump volume of 51,000 ft^3 is used.

(17) The pump flowrates vs. time given in Table 6.2.1-2 were used in support of RWST draindown. (These flow values reflect ECCS pumps at runout against the design containment pressure, using the minimum composite pump curves shown in Figures 6.3-2, 6.3-3, and 6.3-4, which are degraded by 5% and bound what is achievable in the plant. Switchover times from injection to recirculation that are achievable in the plant for each ECCS pump were conservatively modeled in the analysis.)

(18) A power rating of 102% of licensed core power (3411 MWt) is assumed, but not explicitly modeled. [Decay heat is based on a reactor power of 3479.22 MWt (+2%) for mass and energy release computations. See Section 6.2.1.3.6.]

(19) 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% of the Zirconium fuel rod cladding in the core, and hydrogen gas assumed to be dissolved in the reactor coolant system water. (This bounds tritium producing core designs.)

(20) 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. For Containment Integrity Analysis, the volumes are adjusted to maximize air mass and the compression ratio.)

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

3,500.0

(22) Essential raw cooling water flow to the containment spray heat exchanger was modeled as 5,200 gpm. Also, the essential raw cooling water flow to the component cooling heat exchanger was modeled as ~~6,250~~ gpm.

(23) The decay heat curve used to calculate mass and energy releases after steam generator equilibration is the same as presented in the mass and energy release section of the FSAR (subsection 6.2.1.3.6).

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

The following plots are provided:

Figure 6.2.1-1, Containment Pressure Versus Time

Figure 6.2.1-2a, Upper Compartment Temperature Versus Time

Figure 6.2.1-2b, Lower Compartment Temperature Versus Time

Figure 6.2.1-3, Active and Inactive Sump Temperature Transients

Figure 6.2.1-4, Melted Ice Mass Transient

Figure 6.2.1-4a, Comparison of Containment Pressure Versus Ice Melt

Tables 6.2.1-3 and 6.2.1-4 give energy accountings at various points in the transient.

As can be seen from Figure 6.2.1-1 the maximum calculated Containment pressure is ~~12.40 psig~~ 11.73 psig, occurring at approximately ~~4346 seconds~~ 3600 seconds.

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 forms accounts for transient conduction into and out of the node and temperature rise of the node. Table 6.2.1-1 is a summary of the containment structural heat sinks used in the analysis. The material property data used is found in Table 6.2.1-5.

The heat transfer coefficient to the containment structures is based primarily on the work of Tagami, Reference [21]. An explanation of the manner of application is given in Reference [3].

When applying the Tagami correlations a conservative limit was placed on the lower compartment stagnant heat transfer coefficients. They were limited to 72 Btu/hr-ft^2. This corresponds 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.

6.2.1.3.4 Short-Term Blowdown Analysis

TMD Code - Short-Term Analysis

(1) Introduction

The basic performance of the ice condenser reactor containment system has been demonstrated for a wide range of conditions by the Waltz Mill Ice

In conclusion, it is apparent that there is a substantial margin between the design deck leakage area of 5 ft^2 and that which can be tolerated without exceeding containment design pressure. A preoperational visual inspection is performed to ensure that the seals between the upper and lower containment have been properly installed.

6.2.1.3.6 Mass and Energy Release Data

Long-Term Loss-of-Coolant Accident Mass and Energy Releases

The evaluation model used for the long-term LOCA mass and energy release calculations is the March 1979 model described in Reference 20. A corrected version of WCAP-10325-P-A computer codes and input, which removed errors reported in References 29, 30 and 31, was used for the containment LOCA M&E release analysis. The NSAL corrections are corrections to calculations in support of the approved methodology, and not a change in methodology. This evaluation model has been reviewed and approved by the NRC.

The time history of conditions within an ice condenser containment during a postulated loss-of-coolant accident (LOCA) can be divided into two periods:

1. The initial reactor coolant blowdown, which for the largest assumed pipe break occurs within approximately 30 seconds.

2. The post blowdown phase of the accident which begins following the blowdown and extends several hours after the start of the accident.

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, the LOCA analysis calculational model 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.

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)

For long-term considerations the break location analyzed is the pump suction double-ended guillotine (DEPSG) (10.46 ft^2). The pump suction 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 tor 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 analysis.

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 all ice condenser plants.

In summary, the analysis of the limiting break location for an ice condenser containment has been performed. 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. Inclusion of these energy sources conservatively results in the maximum amount of ice being melted in the event of a LOCA.

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 pump suction (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.

Basis of the Analysis

I. Significant Modeling Assumptions

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 at 100-percent full-power conditions: (619.1°F)

2. An allowance in temperature for instrument error and dead band was 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 3,411 MWt

5. Allowance for calorimetric error (+2.0 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 clad 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. 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.

11. As noted in Section 2.4 of Reference 20, the option to provide more specific modeling pertaining to decay heat has been exercised to specifically reflect the Watts Bar Nuclear Plant Unit 2 core heat generation, while retaining the two sigma uncertainty to assure conservatism.

12. 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

II. Initial Conditions

Table 6.2.1-15 presents the System Parameters Initial Conditions utilized.

Thus, based on the previously noted conditions and assumptions, a bounding analysis of Watts Bar Nuclear Plant Unit 2 is made for the release of mass and energy from the RCS in the event of a LOCA.

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 22. 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 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 20.

Table 6.2.1-16 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.

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

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 20 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 23). 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 24), 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 20. 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 [illegible]k location and the actual physical presence of the ECCS injection [illegible]iption of the test and test results is contained in References 20 and 24.

Recommend not splitting heading from text on following page.

Table 6.2.1-17 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 6.2.1-18.

Post-Reflood Mass and Energy Release Data

The FROTH code (Reference 9) is used for computing the post-reflood transient. The FROTH code is used for the steam generator heat addition calculation from the broken and intact loop steam generators.

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 20.

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.

After steam generator depressurization/equilibration, the mass and energy release available to containment is generated directly from core boiloff/decay heat. At this time the flow split is assumed to be 100%.

Table 6.2.1-19 presents the two-phase post-reflood (froth) mass and energy release data for the pump suction double-ended break case.

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 T_{sat} 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 26). 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.

Decay Heat Model

ANS Standard 5.1 (Reference 25) was used in the LOCA mass and energy release model for Watts Bar Unit 1 for the determination of decay heat energy. This standard was balloted by the Nuclear Power Plant Standards Committee (NUPPSCO) in October 1978 and subsequently approved. The official standard (Reference 25) was issued in August 1979.

The primary assumptions that make this calculation specific for the Watts Bar Nuclear Plant Unit 2 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 6.2.1-20 lists the decay heat curve used.

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 N_p-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 25 (up to 10,000 seconds) and Table 10 of Reference 25 (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.

Short-Term Mass and Energy Releases

The short-term mass and energy release models and assumptions are described in Reference [9]. The LOCA short-term mass and energy release data used to perform the containment analysis given in Sections 6.2.1.3.4 and 6.2.1.3.9 are listed below:

Section	Break Size and Location	Table
6.2.1.3.4	Double-Ended Cold Leg Guillotine Break Outside the Biological Shield	6.2.1-23
6.2.1.3.4	Double-Ended Hot Leg Guillotine Break Outside the Biological Shield	6.2.1-24
6.2.1.3.9	Double-Ended Pressurizer Spray Line Break	6.2.1-28
6.2.1.3.9	127 in^2 Cold Leg Break at the Reactor Vessel	6.2.1-30

6.2.1.3.7 Accident Chronology

For a double-ended pump suction loss-of-coolant accident, the major events and their time of occurrence are shown in Table 6.2.1-25 for the minimum safeguards case.

6.2.1.3.8 Mass and Energy Balance Tables

Sources of Mass and Energy

The sources of mass considered in the LOCA mass and energy release analysis are given in Table 6.2.1-26a. 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 6.2.1-26b. 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 gener
- Time of intact loop steam generator equilibration to pressure setpoint

recommend not splitting
"WCAP-10325-P-A" over 2 lines

The chronology of events for the DEPS case is shown in Table 6.2.1-25.

The energy release from the zirc-water reaction is considered as part of the WCAP-1 0325-P-A (Reference 20) 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 where the zirc-water reaction is significant. This is in contrast to the 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 methods and assumptions used to release various energy sources are given in Reference 20.

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 Section 6.2.1.3 have been satisfied.

6.2.1.3.9 Containment Pressure Differentials

Consideration is given in the design of the containment internal structures to localized pressure pulses that could occur following a loss-of-coolant accident or a main steam line break. If either type of pipe rupture were to occur in these relatively small volumes,

REFERENCES

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

(2) "Final Report Ice Condenser Full-Scale Section Tests at the Waltz Mill Facility", WCAP-8282, February 1974 (Proprietary).

(3) "Westinghouse Long-Term Ice Condenser Containment Code - LOTIC-3 Code," WCAP-8354-P-A S2, February 1979 (Proprietary), WCAP-8355-NP-S2, February 1979 (Non-Proprietary).

(4) "Ice Condenser Containment Pressure Transient Analysis Method," WCAP-8078, March 1973 (Non-Proprietary).

(5) "Test Plans and Results for the Ice Condenser System, Ice Condenser Full-Scale Section Test at the Waltz Mill Facility," WCAP-8110-S6, May 1974 (Non-proprietary).

(6) Deleted by Amendment 85.

(7) Deleted by Amendment 85.

(8) Deleted by Amendment 85.

(9) "Topical Report Westinghouse Mass and Energy Release Data for Containment Design," WCAP-8264-P-A, Rev. 1, August 1975 (Proprietary), WCAP-8312-A, Rev. 2 (Non-proprietary).

(10) Deleted by Amendment 85.

(11) Yen, Y. C., Zender, A., Zavohik, S. and Tien, C., "Condensation - Melting Heat Transfer in the Presence of Air," Thirteenth National Heat Transfer Conference, AICHE - ASME Denver.

(12) Crane Technical Paper #410, "Flow of Fluid."

(13) "Electrical Hydrogen Recombiner for PWR Containments," WCAP-7709-P-A (Proprietary) and WCAP-7820-A (Non-Proprietary) and Supplements 1, 2, 3, and 4.

(14) Burnett, T. W. T., et al, "LOFTRAN Code Description," WCAP-7907-P-A (Proprietary), April 1984, WCAP-7907-A (Non-Proprietary), April 1984.

(15) King, H. W., "Handbook of Hydraulics," 4th Edition, 1954.

(16) Deleted by Amendment 97.

(17) Deleted by Amendment 97.

(18) Deleted by Amendment 97.

(19) US NRC Regulatory Guide 1.7, Rev. 2, November 1978, "Control of Combustible Gas Concentrations in Containment Following a Loss of Coolant Accident."

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

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

(22) "Topical Report Westinghouse ECCS Evaluation Model 1981 Version," WCAP-9220-P-A, Revision 1, February 1982 (Proprietary), WCAP-9221-A, Revision I, February 1982 (Non-Proprietary).

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

(24) "Mixing of Emergency Core Cooling Water with Steam: 1/3-Scale Test and Summary," WCAP-8423, June 1975 (Proprietary).

(25) ANSI/ANS-5.1-1979, "American National Standard for Decay Heat Power in Light Water Reactor," August 29, 1979.

(26) W. H. McAdams, Heat Transmission, McGraw-Hill 3rd edition, 1954, p. 172.

(27) "Answers to AEC Questions on Report WCAP-8282," WCAP-8282-AD1, May 1974 (Proprietary).

(28) "Long Term Ice Condenser Containment Code - LOTIC Code," WCAP-8354-P-A-S1, April 1976 (Proprietary), WCAP-8355-A-S1, April 1976 (Non–proprietary).

(29) NSAL-06-6, "LOCA Mass and Energy Release Analysis," June 6, 2006.

(30) NSAL-11-5, "Westinghouse LOCA Mass and Energy Release Calculation Issues," July 25, 2011.

(31) NSAL-14-2, "Westinghouse Loss-of-Coolant Accident Mass and Energy Release Calculation Issue for Steam Generator Tube Material Properties," March 31, 2014.

No Changes

Table 6.2.1-1 Structural Heat Sinks
(Page 1 of 2)

	Area (ft^2)	Thickness (ft)	Material
A. Upper Compartment			
1. Operating Deck			
Slab 1	4880	1.066	Concrete
Slab 2	18280	0.0055 1.4	Paint Concrete
Slab 3	760	0.0055 1.5	Paint Concrete
Slab 4	3840	0.0208 1.5	Stainless Steel Concrete
2.Shell and Misc			
Slab 5	56331	0.001 0.079	Paint Steel
B. Lower Compartment			
1. Operating Deck, Crane Wall, and Interior Concrete			
Slab 6	31963	1.43	Concrete
2. Operating Deck			
Slab 7	2830	0.0055 1.1	Paint Concrete
Slab 8	760	0.0055 1.75	Paint Concrete
3. Interior Concrete and Stainless Steel			
Slab 9	2270	0.0208 2.0	Stainless Steel Concrete
4. Floor*			
Slab 10	15921	0.0055 1.6	Paint Concrete
5. Misc Steel			
Slab 11	28500	0.001 0.0656	Paint Steel

75,865

Table 6.2.1-1 Structural Heat Sinks
(Page 2 of 2)

	Area (ft^2)	Thickness (ft)	Material
C. Ice Condenser			
1. Ice Baskets			
Slab 12	149,600	0.00663	Steel
2. Lattice Frames			
Slab 13	~~75,860~~	0.0217	Steel
3. Lower Support Structure			
Slab 14	28,670	0.0587	Steel
4. Ice Condenser Floor			
Slab 15	3,336	0.0055 0.33	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

* In contact with sump.

Replace with Insert A

Table 6.2.1-3 Energy Balances

Sink	Approx. End of Blowdown (t = 10.0 sec)	Approx. End of Reflood (t=239.8 sec)
	(Millions of BTUs)	
Ice Heat Removal*	192.652	245.358
Structural Heat Sinks*	16.805	55.090
RHR Heat Exchanger Heat Removal*	0.0	0.0
Spray Heat Exchanger Heat Removal*	0.0	0.0
Energy Content of Sump**	176.159	230.606
Ice Melted (millions of lbm)	0.6334	0.8497

*Integrated Heat Rates

**Energy Content of Sump Includes Active and Inactive Regions

Replace with Insert B

Table 6.2.1-4 Energy Balances

Sink	Approx. Ice Meltout Time (t=2873.8 sec)	Approx. Time of Peak Pressure (t=4346.0 sec)
	(Millions of BTUs)	
Ice Heat Removal*	606.794	606.794
Structural Heat Sinks*	69.283	95.687
RHR Heat Exchanger Heat Removal*	21.093	38.362
Spray Heat Exchanger Heat Removal*	3.058	31.405
Energy Content of Sump**	606.616	600.618
Ice Melted (millions of lbs)	2.330	2.330

*Integrated Heat Rates

**Energy Content of Sump Includes Active and Anactive Regions

LOTIC1 Model

Table 6.2.1-5 Material Property Data

Material	Thermal Conductivity Btu/hr-ft-°F	Volumetric Heat 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
Carbon Steel*	26.0	56.4
Concrete*	0.8	28.8
Insulation on steel (containment walls)*	0.15	2.75
Insulation on steel (crane walls)*	0.20	3.663

*Located in Ice Condenser Compartment

Pressure[(2)] (psia)

Table 6.2.1-15 System Parameters Initial Conditions

Parameters	Value
Core Thermal Power (MWt)	3,411
Reactor Coolant System Flow Rate, per Loop (gpm)	93,100
Vessel Outlet Temperature [(1)] (°F)	619.1
Core Inlet Temperature [(1)] (°F)	560.6
Initial Steam Generator Steam ~~Pressure (psia)~~	1,021
Steam Generator Design Model	D3-2
Steam Generator Tube Plugging (%)	0
Initial Steam Generator Secondary-Side Mass (lbm)	122,474.0
Accumulator	
Water Volume (ft^3)	1,020/tank plus 24.06 (average) per line
N_2 Cover Gas Pressure (psig)	585
Temperature (°F)	130
Safety Injection Delay (sec) (includes time to reach pressure setpoint)	36.13
Auxiliary Feedwater Flow (gpm/SG)	205

Notes:

1. Analysis value includes an additional +7.0°F allowance for instrument error and dead band.

2. Analysis value includes an additional 13 psi internal steam generator pressure drop.

Replace with Insert C

Table 6.2.1-16 Double-Ended Pump Suction Guillotine Break - Blowdown Mass and Energy Releases (Page 1 of 6)

	Break Side 1 (1)		Break Side 2 (2)	
Time (s)	Mass (lbm/s)	Energy Thousand (Btu/s)	Mass (lbm/s)	Energy Thousand (Btu/s)
0.0	0.0	0.0	0.0	0.0
0.001	89712.7	50762.5	43601.9	24614.6
0.1	43100.7	24412.9	22428.6	12648.0
0.2	43878.9	25045.4	24795.1	13994.7
0.3	44879.2	25882.3	24907.1	14070.4
0.4	45811.0	26740.3	24017.3	13581.4
0.5	46296.6	27360.0	22952.9	12989.7
0.6	46139.4	27584.9	21992.8	12450.9
0.7	45223.7	27319.6	21109.3	11953.3
0.8	43985.4	26824.9	20474.2	11597.1
0.9	42701.9	26278.3	20077.7	11374.8
1.0	41447.1	25735.7	19835.2	11240.1
1.1	40183.1	25190.5	19683.2	11155.2
1.2	38936.7	24657.2	19565.4	11089.2
1.3	37661.1	24105.1	19473.4	11036.9
1.4	36423.5	23568.1	19425.7	11009.6
1.5	35245.2	23054.2	19401.7	10995.8
1.6	34022.9	22492.9	19360.4	10971.9
1.7	32871.0	21946.5	19289.0	10930.6
1.8	31734.6	21380.9	19226.1	10894.3
1.9	30688.3	20849.6	19196.7	10877.7
2.0	29719.0	20347.0	19145.6	10848.7
2.1	28729.9	19813.9	19008.1	10770.4
2.2	27603.1	19171.7	18843.9	10677.2
2.3	26054.1	18218.0	18695.1	10593.3
2.4	23964.7	16858.2	18512.1	10490.0
2.5	22084.8	15634.0	18021.8	10211.8
2.6	21285.1	15167.1	17765.6	10068.3
2.7	20763.4	14860.2	17542.9	9943.5

Table 6.2.1-16 Double-Ended Pump Suction Guillotine Break - Blowdown Mass and Energy Releases (Page 2 of 6)

	Break Side 1 (1)		Break Side 2 (2)	
Time (s)	Mass (lbm/s)	Energy Thousand (Btu/s)	Mass (lbm/s)	Energy Thousand (Btu/s)
2.8	20113.3	14438.6	17324.7	9821.2
2.9	19612.5	14118.9	17108.3	9700.2
3.0	19056.5	13752.9	16874.4	9569.2
3.1	18701.0	13528.4	16638.9	9437.3
3.2	18164.2	13168.1	16437.7	9325.3
3.3	17550.5	12755.2	16245.9	9218.7
3.4	16905.8	12316.9	16072.6	9122.6
3.5	16290.5	11894.8	15926.0	9041.9
3.6	15733.4	11509.7	15746.3	8942.1
3.7	15267.3	11186.9	15600.8	8862.1
3.8	14888.7	10922.5	15448.3	8778.0
3.9	14567.2	10694.3	15300.8	8696.8
4.0	14300.2	10503.0	15167.8	8623.9
4.2	13860.8	10179.7	14921.4	8489.1
4.4	13539.9	9932.3	14723.7	8381.9
4.6	13228.3	9681.8	15759.9	8985.3
4.8	13137.2	9570.7	15954.5	9095.2
5.0	13151.8	9527.6	15920.6	9082.5
5.2	13205.0	9523.0	15764.5	8998.2
5.4	13232.4	9509.8	15580.9	8898.7
5.6	13189.4	9458.9	15412.8	8808.0
5.8	13105.1	9387.9	15225.6	8705.9
6.0	13013.2	9317.7	15045.4	8607.1
6.2	12999.9	9298.3	14936.2	8547.9
6.4	13134.5	9349.8	14823.1	8483.5
6.6	14011.0	9906.3	14660.2	8388.9
6.8	13445.6	9484.1	14593.4	8350.5
7.0	12049.6	9046.1	14491.3	8290.2
7.2	11044.3	8594.8	14269.3	8160.8

Table 6.2.1-16 Double-Ended Pump Suction Guillotine Break - Blowdown Mass and Energy Releases (Page 3 of 6)

	Break Side 1 (1)		Break Side 2 (2)	
Time (s)	Mass (lbm/s)	Energy Thousand (Btu/s)	Mass (lbm/s)	Energy Thousand (Btu/s)
7.4	11199.1	8635.2	14084.0	8055.3
7.6	11516.8	8743.9	13911.1	7958.2
7.8	11772.5	8809.3	13736.9	7858.0
8.0	12099.3	8925.1	13511.5	7727.7
8.2	12523.0	9098.9	13326.6	7621.3
8.4	12903.1	9239.2	13128.9	7507.1
8.6	13164.0	9311.3	12921.7	7387.4
8.8	13327.4	9333.9	12738.1	7281.1
9.0	13300.2	9241.2	12539.1	7165.6
9.2	13024.1	9003.5	12361.6	7062.7
9.4	12592.6	8683.4	12194.7	6965.6
9.6	12076.9	8324.0	12032.4	6871.0
9.8	11448.0	7906.1	11890.3	6788.3
10.0	10863.9	7542.2	11763.0	6714.0
10.2	10447.5	7303.8	11617.5	6629.0
10.4	10060.4	7088.1	11481.3	6550.4
10.6	9689.0	6886.9	11347.1	6473.1
10.8	9367.5	6717.4	11200.1	6388.1
11.0	9071.9	6561.8	11065.2	6310.1
11.2	8791.6	6412.8	10924.1	6228.2
11.4	8536.4	6275.7	10786.4	6148.2
11.6	8299.7	6146.7	10650.8	6069.4
11.8	8079.0	6025.4	10516.0	5991.0
12.0	7872.5	5911.3	10382.0	5913.0
12.2	7681.1	5803.5	10249.4	5836.0
12.4	7496.8	5697.1	10120.8	5761.2
12.6	7314.6	5594.3	9980.8	5679.8
12.8	7128.3	5485.9	9827.3	5591.1
13.0	6944.2	5365.6	9682.1	5507.7

Replace with Insert C

Table 6.2.1-16 Double-Ended Pump Suction Guillotine Break - Blowdown Mass and Energy Releases (Page 4 of 6)

	Break Side 1 (1)		Break Side 2(2)	
Time (s)	Mass (lbm/s)	Energy Thousand (Btu/s)	Mass (lbm/s)	Energy Thousand (Btu/s)
13.2	6780.7	5240.7	9527.5	5418.6
13.4	6638.8	5119.2	9383.0	5335.0
13.6	6508.1	5003.2	9233.5	5248.8
13.8	6384.0	4890.9	9092.0	5167.6
14.0	6265.9	4785.1	8957.2	5090.5
14.2	6158.1	4689.5	8829.1	5017.4
14.4	6055.4	4602.3	8705.3	4947.2
14.6	5955.0	4524.1	8604.9	4891.4
14.8	5856.0	4453.3	8470.3	4815.7
15.0	5760.2	4392.0	8360.3	4755.5
15.2	5684.0	4350.0	8024.8	4580.8
15.4	5654.2	4384.9	7842.4	4529.3
15.6	5523.0	4454.8	7583.4	4416.9
15.8	5252.9	4497.7	7308.6	4275.8
16.0	4896.8	4505.0	6999.7	4065.6
16.2	4495.3	4474.7	6750.1	3833.4
16.4	4070.1	4392.0	6534.3	3584.6
16.6	3653.2	4213.2	6271.4	3301.7
16.8	3281.7	3941.6	5843.1	2955.1
17.0	2989.9	3658.9	5437.5	2650.7
17.2	2706.3	3340.7	5059.0	2385.6
17.4	2471.1	3066.5	4713.7	2156.4
17.6	2273.9	2832.7	4413.1	1964.1
17.8	2114.5	2642.0	4155.4	1805.0
18.0	1988.9	2490.7	3840.0	1631.4
18.2	1870.7	2347.3	3438.2	1425.2
18.4	1736.8	2183.1	3618.8	1451.8
18.6	1577.4	1986.1	5752.8	2254.2
18.8	1415.5	1785.4	6429.3	2514.4

Replace with Insert C

Table 6.2.1-16 Double-Ended Pump Suction Guillotine Break - Blowdown Mass and Energy Releases (Page 5 of 6)

	Break Side 1 (1)		Break Side 2 (2)	
Time (s)	Mass (lbm/s)	Energy Thousand (Btu/s)	Mass (lbm/s)	Energy Thousand (Btu/s)
19.0	1293.6	1635.2	5230.0	2039.3
19.2	1200.0	1519.2	3521.6	1368.4
19.4	1122.0	1422.2	3111.5	1208.0
19.6	1047.2	1328.5	2202.4	851.3
19.8	956.9	1215.0	1617.9	604.6
20.0	862.0	1095.7	2061.4	668.1
20.2	775.2	986.4	3529.8	1073.0
20.4	701.2	893.5	3910.5	1167.4
20.6	635.9	810.8	3386.7	1006.5
20.8	576.2	735.3	3000.5	889.9
21.0	529.7	676.6	2860.7	847.3
21.2	501.1	640.5	2820.9	834.8
21.4	477.5	610.8	2781.0	822.6
21.6	445.2	569.6	2667.2	788.7
21.8	408.4	522.9	2419.3	714.7
22.0	369.4	473.2	2205.5	649.5
22.2	329.3	422.2	1993.8	582.1
22.4	291.2	373.5	1777.1	512.3
22.6	252.1	323.6	1546.6	440.0
22.8	230.2	295.6	1387.1	389.4
23.0	206.7	265.6	1351.7	374.8
23.2	189.4	243.5	1379.9	380.0
23.4	173.9	223.7	1401.8	385.2
23.6	170.9	219.9	1403.5	385.8
23.8	164.1	211.2	1368.0	376.6
24.0	158.1	203.5	1257.6	347.2
24.2	151.4	194.9	1020.1	283.1
24.4	144.7	186.3	587.3	164.8
24.6	138.1	177.9	46.5	13.4

Replace with Insert C

Table 6.2.1-16 Double-Ended Pump Suction Guillotine Break - Blowdown Mass and Energy Releases (Page 6 of 6)

	Break Side 1 (1)		Break Side 2 (2)	
Time (s)	Mass (lbm/s)	Energy Thousand (Btu/s)	Mass (lbm/s)	Energy Thousand (Btu/s)
24.8	129.6	167.0	147.8	44.1
25.0	115.2	148.5	0.0	0.0
25.2	102.2	131.8	178.3	57.8
25.4	89.9	116.1	170.1	56.6
25.6	73.1	94.5	176.1	58.0
25.8	59.5	77.0	106.5	34.3
26.0	46.9	60.7	0.0	0.0
26.2	34.7	45.0	0.0	0.0
26.4	13.8	17.9	0.0	0.0
26.6	12.8	16.6	0.0	0.0
26.8	0.0	0.0	0.0	0.0

Notes:

1. M&E exiting from the SG side of the break (path 1).
2. M&E exiting from the pump side of the break (path 2).

Replace with Insert D

Table 6.2.1-17 Double-Ended Pump Suction Guillotine Break - Reflood Mass and Energy Release - Minimum Safety Injection (Page 1 of 7)

	Break Side 1[1]		Break Side 2[2]	
Time (SEC)	Mass (lbm/s)	Energy Thousand (BTU/s)	Mass (lbm/s)	Energy Thousand (BTU/s)
26.8	0.0	0.0	0.0	0.0
27.3	0.0	0.0	0.0	0.0
27.5	0.0	0.0	0.0	0.0
27.6	0.0	0.0	0.0	0.0
27.7	0.0	0.0	0.0	0.0
27.8	0.0	0.0	0.0	0.0
27.8	0.0	0.0	0.0	0.0
27.9	33.0	38.4	0.0	0.0
28.0	13.6	15.8	0.0	0.0
28.2	14.5	16.9	0.0	0.0
28.3	20.1	23.4	0.0	0.0
28.4	25.3	29.5	0.0	0.0
28.5	29.5	34.4	0.0	0.0
28.6	33.6	39.1	0.0	0.0
28.7	37.5	43.6	0.0	0.0
28.8	40.3	47.0	0.0	0.0
28.9	43.2	50.2	0.0	0.0
29.0	45.8	53.4	0.0	0.0
29.1	48.4	56.4	0.0	0.0
29.2	50.9	59.3	0.0	0.0
29.3	53.3	62.1	0.0	0.0
29.4	55.7	64.9	0.0	0.0
29.5	58.2	67.8	0.0	0.0
29.6	59.6	69.3	0.0	0.0
29.6	60.7	70.7	0.0	0.0
29.7	63.1	73.5	0.0	0.0
29.8	65.1	75.9	0.0	0.0
29.9	66.9	77.9	0.0	0.0
30.9	84.9	98.9	0.0	0.0

Table 6.2.1-17 Double-Ended Pump Suction Guillotine Break - Reflood Mass and Energy Release - Minimum Safety Injection (Page 2 of 7)

	Break Side 1(1)		Break Side 2(2)	
Time (SEC)	Mass (lbm/s)	Energy Thousand (BTU/s)	Mass (lbm/s)	Energy Thousand (BTU/s)
31.9	100.3	116.9	0.0	0.0
32.9	213.6	250.2	2799.9	381.2
34.0	336.1	395.6	4535.4	671.9
34.7	335.1	394.4	4521.5	673.8
35.0	333.8	392.9	4504.4	672.1
36.0	329.1	387.2	4438.4	664.3
37.0	350.1	412.4	4765.7	690.7
38.0	345.1	406.4	4698.7	682.0
39.0	340.1	400.5	4631.8	673.3
40.0	335.4	394.7	4566.1	664.6
40.5	333.0	392.0	4533.9	660.3
41.0	330.8	389.3	4502.1	656.0
42.0	326.4	384.0	4439.8	647.7
43.0	322.1	378.9	4379.5	639.7
44.0	317.4	373.3	4321.7	632.0
45.0	312.8	367.8	4265.8	624.6
46.0	308.4	362.6	4211.7	617.5
47.0	304.2	357.6	4159.4	610.5
48.0	300.2	352.8	4108.8	603.8
48.2	299.4	351.8	4098.9	602.5
49.0	296.3	348.1	4059.9	597.4
50.0	292.5	343.7	4012.4	591.1
51.0	288.9	339.4	3966.5	585.0
52.0	285.4	335.3	3921.9	579.1
53.0	282.1	331.3	3878.6	573.4
54.0	278.8	327.4	3836.7	567.9
55.0	275.7	323.7	3795.9	562.5
56.0	272.7	320.1	3756.3	557.3
57.0	269.8	316.7	3717.7	552.3

Replace with Insert D

Table 6.2.1-17 Double-Ended Pump Suction Guillotine Break - Reflood Mass and Energy Release - Minimum Safety Injection (Page 3 of 7)

	Break Side 1(1)		Break Side 2(2)	
Time (SEC)	Mass (lbm/s)	Energy Thousand (BTU/s)	Mass (lbm/s)	Energy Thousand (BTU/s)
57.6	268.0	314.6	3695.1	549.3
58.0	266.9	313.3	3680.3	547.3
59.0	264.2	310.0	3643.8	542.5
60.0	261.5	306.9	3608.2	537.9
61.0	258.9	303.8	3573.6	533.3
62.0	256.4	300.9	3539.8	528.9
63.0	254.0	298.0	3506.8	524.5
64.0	251.6	295.2	3474.7	520.3
65.0	249.3	292.5	3443.3	516.2
66.0	209.2	245.0	2816.4	443.4
67.1	303.8	356.8	271.1	152.2
68.1	360.4	424.7	297.0	188.8
68.2	360.9	425.3	297.3	189.2
69.1	358.1	421.9	295.9	187.4
70.1	351.6	414.2	292.8	183.1
71.1	345.3	406.7	289.7	178.8
72.1	339.6	399.8	286.8	174.8
73.1	334.1	393.2	284.0	171.0
74.1	328.8	386.9	281.3	167.4
75.1	323.4	380.4	278.6	163.6
76.1	318.0	374.0	276.3	160.5
77.1	313.1	368.1	274.1	157.7
78.1	308.4	362.6	272.2	155.0
79.1	303.9	357.2	270.3	152.5
80.1	299.6	352.2	268.5	150.1
81.1	295.6	347.3	266.7	147.8
82.1	291.7	342.7	265.1	145.6
83.1	287.9	338.3	263.5	143.6
84.1	284.4	334.0	262.0	141.6

Table 6.2.1-17 Double-Ended Pump Suction Guillotine Break - Reflood Mass and Energy Release - Minimum Safety Injection (Page 4 of 7)

Time (SEC)	Break Side 1(1) Mass (lbm/s)	Break Side 1(1) Energy Thousand (BTU/s)	Break Side 2(2) Mass (lbm/s)	Break Side 2(2) Energy Thousand (BTU/s)
85.1	281.0	330.0	260.6	139.7
86.1	277.7	326.1	259.3	137.9
87.1	274.6	322.4	258.0	136.2
87.6	273.1	320.6	257.3	135.4
88.1	271.6	318.9	256.7	134.5
90.1	266.0	312.3	254.4	131.5
92.1	260.9	306.2	252.3	128.7
94.1	256.3	300.7	250.4	126.2
96.1	252.0	295.6	248.7	123.9
98.1	248.1	291.0	247.1	121.8
100.1	244.6	286.8	245.6	119.9
102.1	241.3	282.9	244.3	118.2
104.1	238.3	279.4	243.1	116.6
106.1	235.6	276.2	242.0	115.2
108.1	233.1	273.2	241.0	113.9
110.1	230.9	270.6	240.1	112.7
112.1	228.8	268.2	239.3	111.6
113.4	227.6	266.7	238.8	111.0
114.1	227.0	266.0	238.5	110.6
116.1	225.3	264.0	237.9	109.8
118.1	223.8	262.2	237.3	109.0
120.1	222.4	260.6	236.7	108.2
122.1	221.2	259.1	236.2	107.6
124.1	220.1	257.8	235.8	107.0
126.1	219.1	256.7	235.4	106.5
128.1	218.3	255.7	235.0	106.0
130.1	217.5	254.8	234.7	105.6
132.1	216.8	254.0	234.4	105.3
134.1	216.2	253.3	234.2	105.0

Replace with Insert D

Table 6.2.1-17 Double-Ended Pump Suction Guillotine Break - Reflood Mass and Energy Release - Minimum Safety Injection (Page 5 of 7)

	Break Side 1(1)		Break Side 2(2)	
Time (SEC)	Mass (lbm/s)	Energy Thousand (BTU/s)	Mass (lbm/s)	Energy Thousand (BTU/s)
136.1	215.7	252.7	234.0	104.7
138.1	215.3	252.1	233.8	104.4
140.1	214.9	251.7	233.6	104.2
142.1	214.6	251.3	233.5	104.0
143.8	214.3	251.0	233.4	103.9
144.1	214.3	250.9	233.3	103.8
146.1	214.0	250.7	233.2	103.7
148.1	213.8	250.4	233.1	103.6
150.1	213.6	250.1	233.0	103.4
152.1	213.4	249.9	232.9	103.3
154.1	213.2	249.7	232.9	103.2
156.1	213.0	249.5	232.8	103.1
158.1	212.9	249.3	232.7	103.0
160.1	212.8	249.2	232.6	102.9
162.1	212.9	249.3	232.7	103.0
164.1	213.4	249.9	233.1	103.2
166.1	213.9	250.5	233.8	103.4
168.1	214.5	251.2	234.8	103.7
170.1	215.2	252.0	236.1	104.0
172.1	215.9	252.8	237.5	104.4
174.1	216.5	253.6	238.9	104.7
175.6	217.0	254.2	240.1	104.9
176.1	217.1	254.3	240.5	105.0
178.1	217.7	255.0	242.1	105.3
180.1	218.1	255.5	243.6	105.5
182.1	218.5	255.9	245.2	105.7
184.1	218.8	256.3	246.8	105.9
186.1	219.0	256.6	248.4	106.0
188.1	219.2	256.8	250.1	106.1

Replace with Insert D

Table 6.2.1-17 Double-Ended Pump Suction Guillotine Break - Reflood Mass and Energy Release - Minimum Safety Injection (Page 6 of 7)

	Break Side 1(1)		Break Side 2(2)	
Time (SEC)	Mass (lbm/s)	Energy Thousand (BTU/s)	Mass (lbm/s)	Energy Thousand (BTU/s)
190.1	219.3	256.9	251.8	106.2
192.1	219.4	257.0	253.5	106.3
194.1	219.4	257.0	255.3	106.4
196.1	219.3	256.9	257.1	106.4
198.1	219.2	256.8	258.9	106.4
200.1	219.0	256.5	260.8	106.4
202.1	218.7	256.2	262.7	106.3
204.1	218.4	255.9	264.6	106.3
206.1	218.0	255.4	266.6	106.2
207.0	217.8	255.2	267.5	106.2
208.1	217.6	254.9	268.5	106.1
210.1	217.1	254.3	270.6	106.0
212.1	216.6	253.6	272.7	105.9
214.1	216.0	253.0	274.8	105.8
216.1	215.4	252.3	277.0	105.6
218.1	214.7	251.5	279.3	105.5
220.1	214.0	250.7	281.7	105.4
222.1	213.2	249.7	284.0	105.2
224.1	212.4	248.7	286.4	105.1
226.1	211.5	247.6	288.8	104.9
228.1	210.5	246.5	291.2	104.7
230.1	209.5	245.3	293.7	104.5

Replace with Insert D

Table 6.2.1-17 Double-Ended Pump Suction Guillotine Break - Reflood Mass and Energy Release - Minimum Safety Injection (Page 7 of 7)

	Break Side 1 (1)		Break Side 2 (2)	
Time (SEC)	Mass (lbm/s)	Energy Thousand (BTU/s)	Mass (lbm/s)	Energy Thousand (BTU/s)
232.1	208.4	244.0	296.1	104.3
234.1	207.2	242.6	298.5	104.1
236.1	206.0	241.1	300.8	103.8
238.1	204.7	239.6	303.2	103.6
239.8	203.5	238.3	305.3	103.4

Notes:

1. M&E exiting from the SG side of the break (path 1).
2. M&E exiting from the pump side of the break (path 2).

Replace with Insert E

Table 6.2.1-18 Double-Ended Pump Suction Guillotine Break - Minimum Safety Injection Principal Parameters During Reflood (Page 1 of 2)

Time (sec)	Flooding Temp (Deg-F)	Flooding Rate (in/s)	Carryover Fraction	Core Height (ft)	Downcomer Height (ft)	Flow Fraction	Total Injection (lbm/sec)	Accumulator (lbm/sec)	Spill (lbm/sec)	Enthalpy (btu/lbm)
26.8	205.9	0.00	0.00	0.00	0.00	0.25	0.00	0.0	0.0	0.00
27.6	203.1	22.33	0.00	0.66	1.45	0.00	7357.70	7357.7	0.0	99.46
27.8	201.6	24.19	0.00	1.04	1.37	0.00	7305.50	7305.5	0.0	99.46
28.2	201.0	2.35	0.10	1.30	2.16	0.24	7176.60	7176.6	0.0	99.46
28.4	201.0	2.39	0.14	1.34	2.85	0.29	7122.10	7122.1	0.0	99.46
29.6	201.3	2.04	0.33	1.50	6.35	0.35	6851.00	6851.0	0.0	99.46
30.9	201.8	1.98	0.46	1.64	10.39	0.37	6577.20	6577.2	0.0	99.46
34.0	202.7	3.73	0.62	1.93	16.12	0.57	5416.30	5416.3	0.0	99.46
34.7	202.8	3.58	0.64	2.01	16.12	0.57	5311.60	5311.6	0.0	99.46
35.0	202.9	3.52	0.65	2.04	16.12	0.57	5273.40	5273.4	0.0	99.46
36.0	203.2	3.36	0.68	2.13	16.12	0.57	5155.20	5155.2	0.0	99.46
37.0	203.6	3.44	0.69	2.23	16.12	0.58	5495.40	4908.2	0.0	96.64
40.5	205.1	3.15	0.72	2.51	16.12	0.57	5177.60	4584.7	0.0	96.44
48.2	209.2	2.78	0.75	3.00	16.12	0.56	4645.90	4044.6	0.0	96.04
57.6	215.0	2.50	0.76	3.50	16.12	0.55	4174.10	3566.0	0.0	95.62
66.0	220.5	2.07	0.77	3.90	16.12	0.51	3193.60	2573.8	0.0	94.34
67.1	221.1	2.75	0.77	3.94	16.11	0.59	603.00	0.0	0.0	73.06
68.2	221.8	3.10	0.76	4.00	15.96	0.60	581.20	0.0	0.0	73.06

Replace with Insert E

Table 6.2.1-18 Double-Ended Pump Suction Guillotine Break - Minimum Safety Injection Principal Parameters During Reflood (Page 2 of 2)

Time (sec)	Flooding Temp (Deg-F)	Flooding Rate (in/s)	Carryover Fraction	Core Height (ft)	Downcomer Height (ft)	Flow Fraction	Total Injection (lbm/sec)	Accumulator (lbm/sec)	Spill (lbm/sec)	Enthalpy (btu/lbm)
77.1	227.1	2.67	0.77	4.51	14.90	0.60	596.30	0.0	0.0	73.06
87.6	232.2	2.35	0.78	5.00	14.24	0.59	605.00	0.0	0.0	73.06
100.1	237.0	2.11	0.78	5.51	13.94	0.58	610.80	0.0	0.0	73.06
113.4	241.1	1.97	0.79	6.00	13.97	0.58	614.10	0.0	0.0	73.06
130.1	245.3	1.88	0.79	6.56	14.26	0.57	616.00	0.0	0.0	73.06
143.8	247.5	1.85	0.80	7.00	14.62	0.57	616.60	0.0	0.0	73.06
160.1	246.7	1.84	0.80	7.51	15.09	0.57	616.90	0.0	0.0	73.06
175.6	247.5	1.86	0.80	8.00	15.50	0.58	616.20	0.0	0.0	73.06
186.1	247.0	1.87	0.79	8.34	15.71	0.58	615.80	0.0	0.0	73.06
192.1	247.2	1.86	0.79	8.53	15.80	0.58	615.70	0.0	0.0	73.06
207.0	247.3	1.84	0.79	9.00	15.96	0.58	615.90	0.0	0.0	73.06
224.1	247.5	1.78	0.79	9.53	16.07	0.59	616.70	0.0	0.0	73.06
239.8	247.3	1.70	0.79	10.00	16.11	0.59	618.10	0.0	0.0	73.06

Replace with Insert F

Table 6.2.1-19 Double-Ended Pump Suction Guillotine Break - Post-Reflood Mass and Energy Releases - Minimum Safety Injection (Page 1 of 3)

	Break Side 1(1)		Break Side 2(2)	
Time (SEC)	Mass (lbm/s)	Energy Thousand (BTU/s)	Mass (lbm/s)	Energy Thousand (BTU/s)
239.8	210.0	263.1	427.2	118.0
244.8	209.2	262.1	428.0	118.1
249.8	209.7	262.8	427.4	117.9
254.8	208.9	261.8	428.2	117.9
259.8	208.1	260.7	429.1	118.0
264.8	208.6	261.4	428.5	117.8
269.8	207.8	260.3	429.4	117.8
274.8	208.3	260.9	428.9	117.6
279.8	207.4	259.9	429.8	117.7
284.8	206.5	258.8	430.6	117.8
289.8	207.0	259.3	430.2	117.6
294.8	206.1	258.2	431.1	117.7
299.8	206.5	258.7	430.7	117.5
304.8	205.6	257.6	431.6	117.6
309.8	206.0	258.0	431.2	117.4
314.8	205.0	256.9	432.1	117.5
319.8	205.4	257.3	431.8	117.3
324.8	204.4	256.1	432.8	117.4
329.8	204.7	256.5	432.5	117.2
334.8	203.7	255.3	433.4	117.3
339.8	204.0	255.6	433.2	117.1
344.8	203.0	254.3	434.2	117.2
349.8	203.2	254.6	434.0	117.1
354.8	202.2	253.3	435.0	117.2
359.8	202.3	253.5	434.8	117.0
364.8	201.3	252.2	435.9	117.2
369.8	201.4	252.4	435.8	117.0
374.8	201.5	252.5	435.7	116.9
379.8	200.4	251.1	436.8	117.0

Replace with Insert F

Table 6.2.1-19 Double-Ended Pump Suction Guillotine Break - Post-Reflood Mass and Energy Releases - Minimum Safety Injection (Page 2 of 3)

	Break Side 1[1]		Break Side 2[2]	
Time (SEC)	Mass (lbm/s)	Energy Thousand (BTU/s)	Mass (lbm/s)	Energy Thousand (BTU/s)
384.8	200.4	251.1	436.7	116.9
389.8	200.5	251.2	436.7	116.8
394.8	199.3	249.7	437.9	116.9
399.8	199.3	249.7	437.9	116.8
404.8	199.3	249.7	437.8	116.7
409.8	199.3	249.8	437.8	116.6
414.8	198.2	248.4	438.9	116.7
419.8	198.2	248.3	439.0	116.6
424.8	198.1	248.2	439.0	116.5
429.8	198.0	248.1	439.1	116.4
434.8	196.8	246.6	440.4	116.6
439.8	196.6	246.4	440.5	116.5
444.8	196.4	246.1	440.8	116.5
449.8	196.1	245.8	441.0	116.4
454.8	195.8	245.4	441.3	116.4
459.8	195.5	244.9	441.7	116.3
464.8	195.1	244.4	442.1	116.3
469.8	194.6	243.9	442.5	116.3
474.8	194.1	243.2	443.0	116.3
479.8	194.5	243.7	442.6	116.1
484.8	193.9	242.9	443.3	116.2
489.8	193.2	242.1	444.0	116.2
494.8	193.4	242.3	443.8	116.1
499.8	192.5	241.2	444.7	116.1
504.8	192.5	241.2	444.7	116.0
509.8	192.3	241.0	444.8	115.9
514.8	192.1	240.7	445.1	115.9
519.8	191.7	240.2	445.4	115.9
524.8	191.2	239.6	446.0	115.9

Replace with Insert F

Table 6.2.1-19 Double-Ended Pump Suction Guillotine Break - Post-Reflood Mass and Energy Releases - Minimum Safety Injection (Page 3 of 3)

	Break Side 1[1]		Break Side 2[2]	
Time (SEC)	Mass (lbm/s)	Energy Thousand (BTU/s)	Mass (lbm/s)	Energy Thousand (BTU/s)
529.8	190.5	238.7	446.6	115.9
534.8	190.5	238.7	446.6	115.8
539.8	190.3	238.5	446.8	115.7
544.8	189.9	237.9	447.3	115.7
549.8	189.2	237.0	448.0	115.8
554.8	188.9	236.7	448.2	115.7
559.8	188.3	236.0	448.8	115.7
564.8	188.0	235.6	449.1	115.7
569.8	187.9	235.4	449.3	115.6
574.8	187.6	235.1	449.5	115.5
579.8	187.2	234.5	450.0	115.5
584.8	186.7	234.0	450.4	115.5
589.8	186.4	233.5	450.8	115.5
594.8	186.0	233.1	451.1	115.4
599.8	185.6	232.6	451.5	115.4
910.7	185.6	232.6	451.5	115.4
910.8	75.2	94.0	562.0	138.6
914.8	75.1	93.9	562.1	138.5
1204.8	70.2	87.8	566.9	137.5
1207.3	70.2	87.7	566.9	137.4
1262.3	69.4	86.7	567.7	135.7
1267.3	69.3	86.6	573.1	150.7
1342.3	68.2	85.2	574.2	148.4
1344.3	68.1	85.1	356.3	127.4
2267.2	68.1	85.1	356.3	127.4

Notes:

1. M&E exiting from the SG side of the break (path 1).
2. M&E exiting from the pump side of the break (path 2).

Table 6.2.1-20 Decay Heat Curve (Page 1 of 2)

TIME (Sec)	Decay Heat (P/Po)
10.	.0506850
15.	~~0.477187~~ .0477187
20.	.0456218
40.	.0406962
60.	.0378482
80.	.0358667
100.	.0343802
150.	.0318330
200.	.0301404
400.	.0264229
600.	.0242907
800.	.0227336
1000.	.0214999
1500.	.0192069
2000.	.0175824
4000.	.0140451
6000.	.0123786
8000.	.0113975
10000.	.0107264
15000.	.0100411
20000.	.0093567
40000.	.0079090
60000.	.0071368
80000.	.0066021
100000.	.0062046
150000.	.0054924
200000.	.0050014
400000.	.0038711
600000.	.0032712
800000.	.0028872
1000000.	.0026231
1500000.	.0022001

No Changes

Table 6.2.1-20 Decay Heat Curve (Page 2 of 2)

TIME (Sec)	Decay Heat (P/Po)
2000000.	.0019386
4000000.	.0013911
6000000.	.0011338
8000000.	.0009754
10000000.	.0008662

Table 6.2.1-25 Double-Ended Pump Suction LOCA Sequence of Events

Event	Time (sec)
Rupture	0.0
Accumulator Flow Starts	15.6
Assumed Initiation of ECCS	36.13
End of Blowdown	~~26.8~~ 27.0
Accumulators Empty	~~66.700~~ 66.2
Assumed Initiation of Spray System	234.0
End of Reflood	~~239.8~~ 243.6
Low Level Alarm of Refueling Water Storage Tank	1,207.27
Beginning of Recirculation Phase of Safeguards Operation	1,267.27

Replace with Insert G

Table 6.2.1-26a Double-Ended Pump Suction Guillotine Break Minimum Safety Injection - Mass Balance

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)	0.00	26.80	26.80	239.78	910.84	2267.21
	Mass (Thousands lbm)						
Initial	In RCS and ACC	750.32	750.32	750.32	750.32	750.32	750.32
Added Mass	Pumped Injection	0.00	0.00	0.00	124.49	552.04	1220.31
	Total Added	0.00	0.00	0.00	124.49	552.04	1220.31
*****Total Available*****		**750.32**	**750.32**	**750.32**	**874.81**	**1302.36**	**1970.63**
Distribution	Reactor Coolant	492.76	73.81	73.95	135.56	135.56	135.56
	Accumulator	257.56	178.44	178.31	0.00	0.00	0.00
	Total Contents	750.32	252.25	252.25	135.56	135.56	135.56
Effluent	Break Flow	0.00	498.05	498.05	728.64	1156.19	18.24.25
	ECCS Spill	0.00	0.00	0.00	0.00	0.00	.00
	Total Effluent	0.00	498.05	498.05	728.64	1156.19	1824.25
*****Total Accountable*****		**750.32**	**750.30**	**750.30**	**864.20**	**1291.76**	**1959.81**

Replace with Insert H

Table 6.2.1-26b Double-Ended Pump Suction Guillotine Break Minimum Safety Injection - Energy Balance

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)	0.00	26.80	26.80	239.78	910.84	2267.21
	Energy (Million Btu)						
Initial Energy	In RCS, ACC, S Gen	897.41	897.41	897.41	897.41	897.41	897.41
Added Energy	Pumped Injection	0.00	0.00	0.00	9.10	40.33	99.28
	Decay Heat	0.00	7.71	7.71	31.38	86.67	172.38
	Heat from Secondary	0.00	12.38	12.38	12.38	19.63	31.54
	Total Added	0.00	20.08	20.08	52.85	146.62	303.20
*****Total Available*****		**897.41**	**917.50**	**917.50**	**950.26**	**1044.04**	**1200.61**
Distribution	Reactor Coolant	296.93	13.38	13.39	30.09	30.09	30.09
	Accumulator	25.62	17.75	17.73	0.00	0.00	0.00
	Core Stored	25.61	14.17	14.17	3.98	3.62	3.47
	Primary Metal	159.12	151.04	151.04	134.36	82.72	58.16
	Secondary Metal	104.98	104.40	104.40	95.12	70.79	43.31
	Steam Generator	285.15	301.24	301.24	269.84	201.52	132.64
	Total Contents	897.41	601.98	601.98	533.39	388.74	267.68

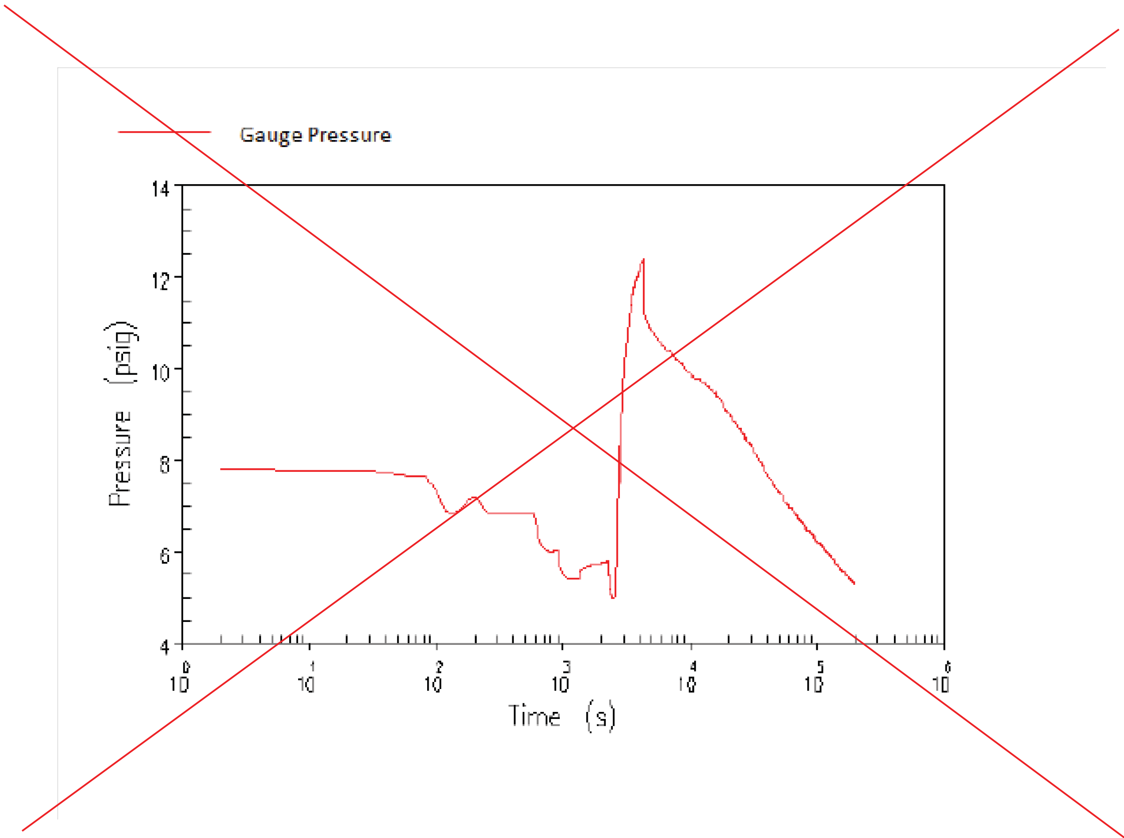


Figure 6.2.1-1 Containment Pressure Versus Time

Replace with Insert J

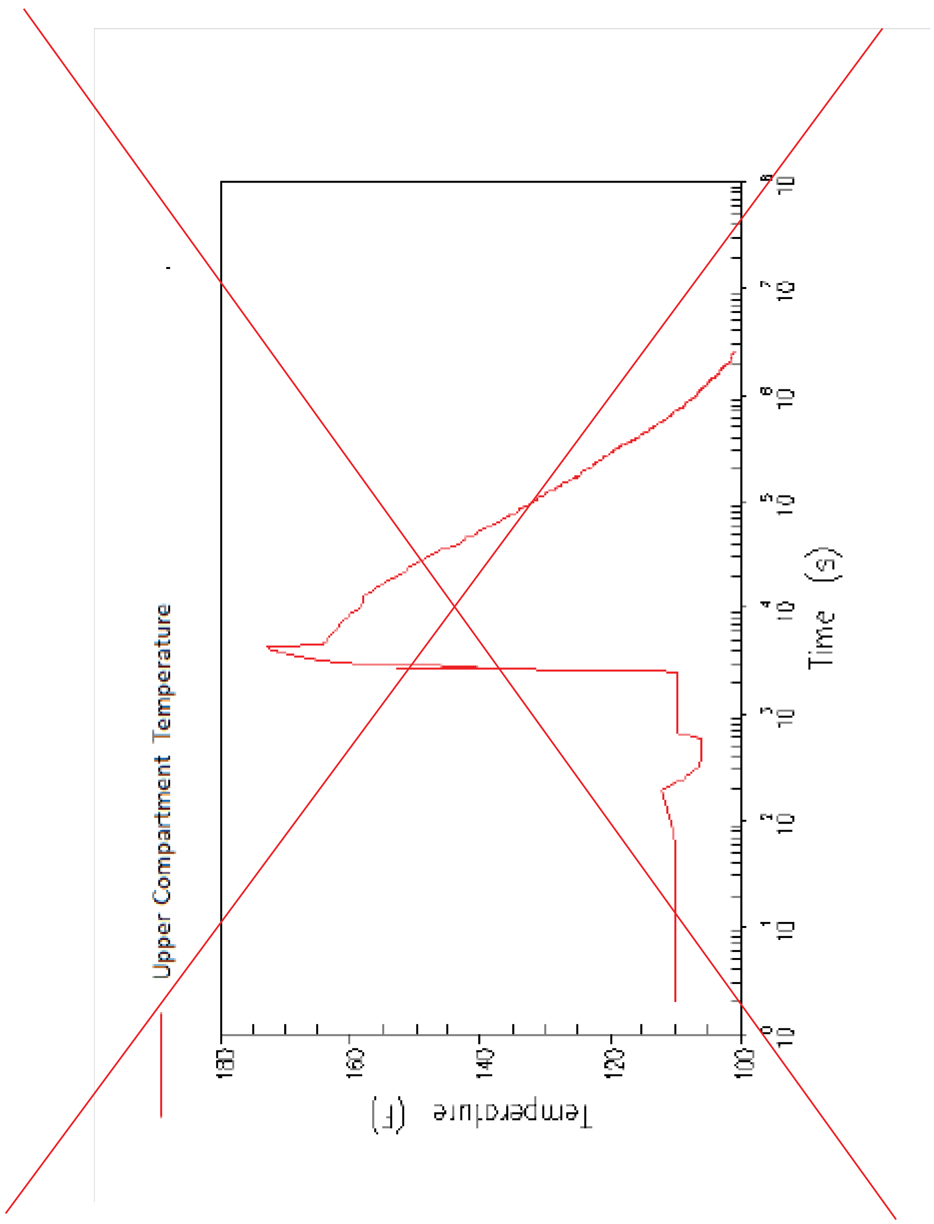


Figure 6.2.1-2a Upper Compartment Temperature Versus Time

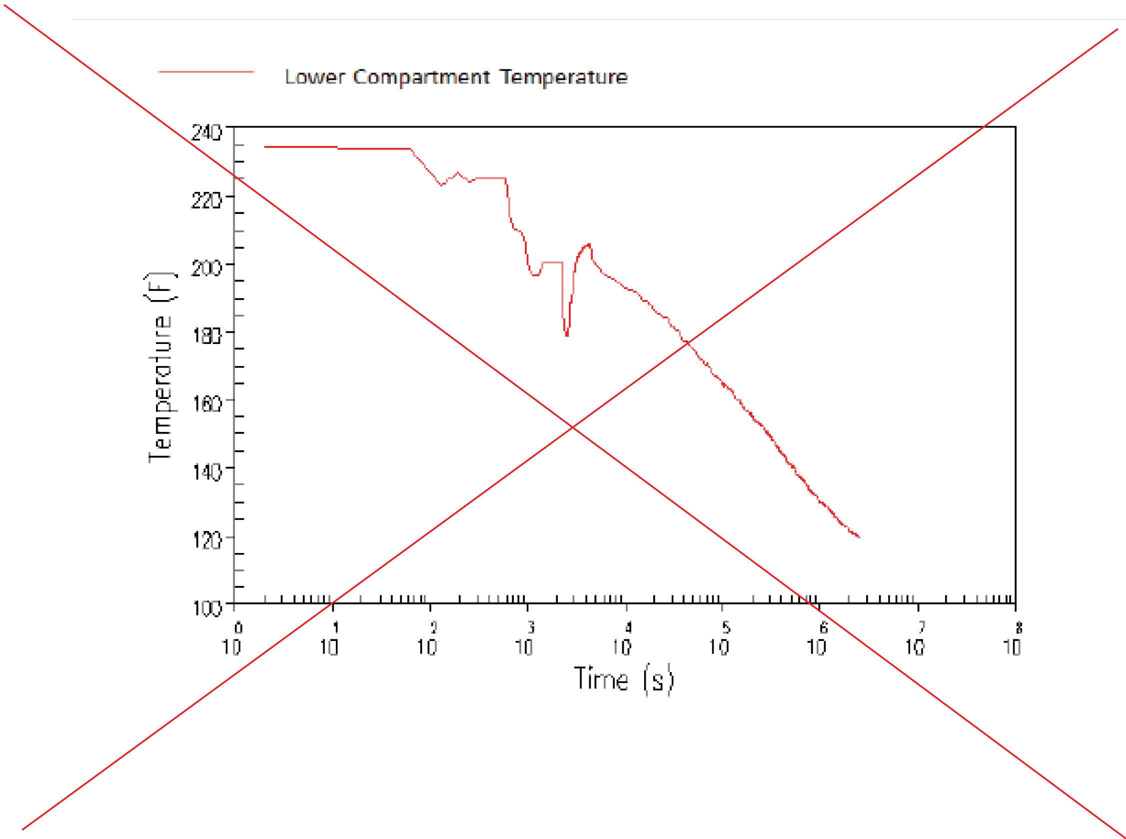


Figure 6.2.1-2b Lower Compartment Temperature Versus Time

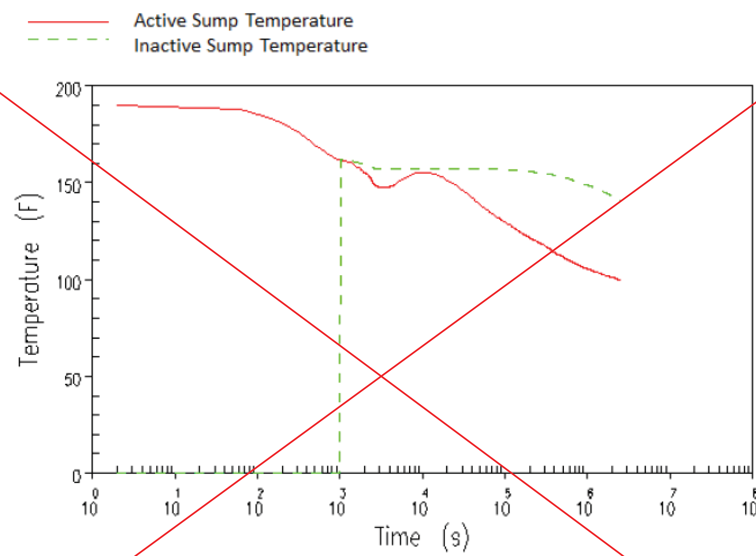


Figure 6.2.1-3 Active and Inactive Sump Temperature Transients

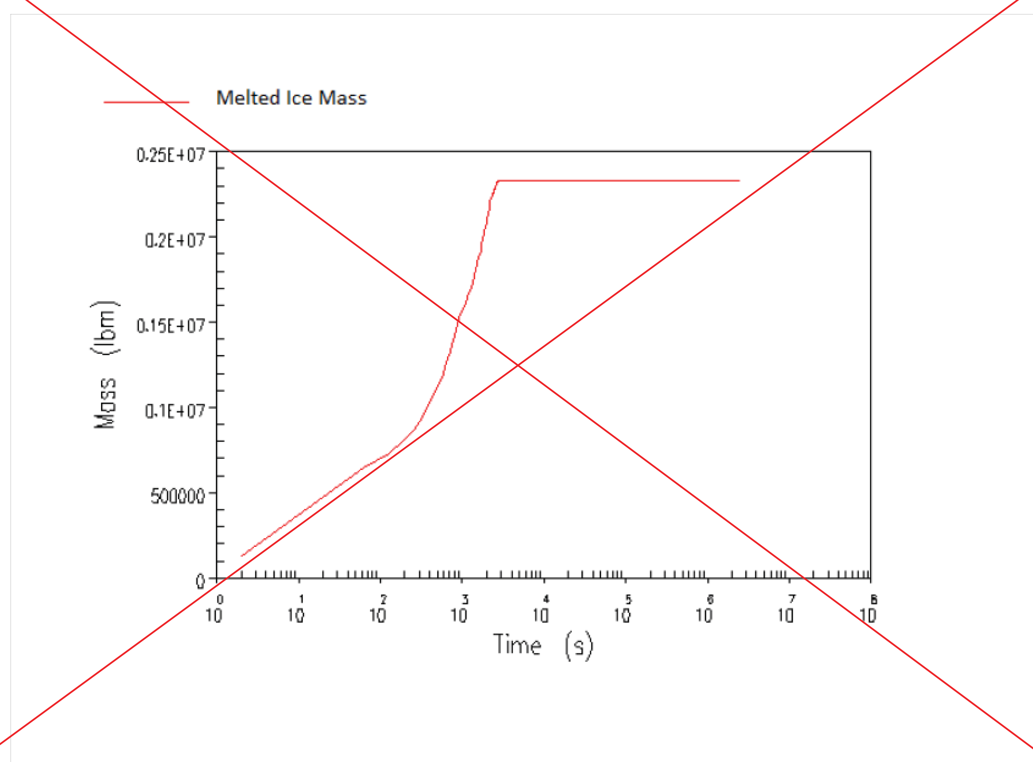


Figure 6.2.1-4 Melted Ice Mass Transient

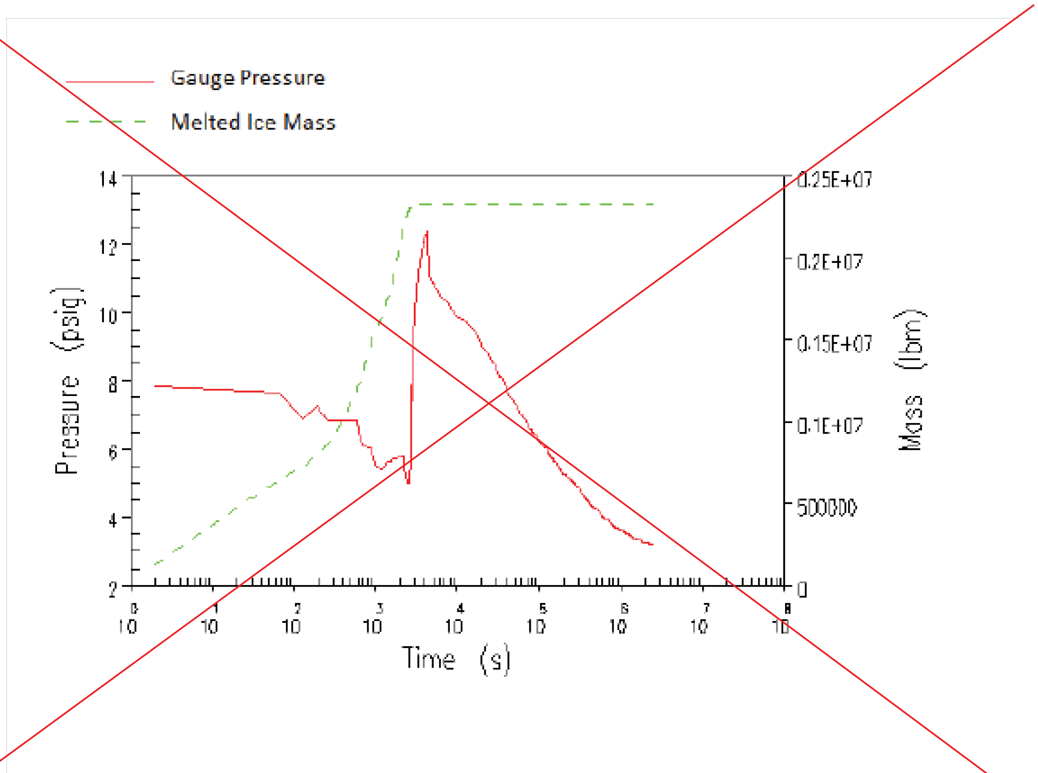


Figure 6.2.1-4a Comparison of Containment Pressure Versus Ice Melt

LOCA M&E analysis assumes 2.585 x 10^6 lbm of ice

(4) Basket Loading

The ice baskets are capable of being loaded by a pneumatic ice distribution system. The baskets contain a minimum of 2.33 x 10^6 pounds of ice.

(5) External Basket Design

The baskets are designed to minimize any external protrusions which would interfere with lifting, weighing, removal and insertion.

(6) Basket Coupling

Baskets are capable of being coupled together in 48-foot columns.

(7) Basket Couplings and Stiffening Rings

Couplings or rings are located at 6-ft intervals along the basket and have internal inserts to support the ice from falling down to the bottom of the ice column during and after a DBA and/or SSE.

Design and Test Loads

The minimum test and basic design loads are given in Table 6.7-2.

6.7.4.2 System Design

The ice condenser is an insulated cold storage room in which ice is maintained in an array of vertical cylindrical columns. The columns are formed by perforated metal baskets with the space between columns forming the flow channels for steam and air. The ice condenser is contained in the annulus formed by the containment vessel wall and the crane wall circumferentially over a 300° arc.

The ice columns are composed of four baskets approximately 12 feet long each, filled with flake ice. The baskets are formed from a 14 gage (.075) perforated sheet metal, as shown in Figure 6.7-8. The perforations are 1.0 in. x 1.0 in. holes, spaced on a 1.25-inch center. The radius at the junction of the perforation is 1/16 inch. The ice basket material is made from ASTM-569 and/or A1011 which is a commercial quality, low carbon steel. The basket component parts are corrosion protected by a hot dip galvanized process. The perforated basket assembly has an open area of approximately 64% to provide the necessary surface area for heat transfer between the steam/air mixture and the ice to limit the containment pressure within design limits. The basket heat transfer performance was confirmed by the autoclave test.

Interconnection couplings and stiffening rings are located at the bottom and 6-ft. levels, respectively, of each basket section. The bottom coupling and stiffening ring are cylindrical in shape and approximately 3 inches high with a rolled internal lip and/or welded bottom ring. The lip/ring provides stiffening to the basket and a stop for the cruciforms at 6 feet intervals. These cruciforms prevent the ice in the basket from displacing axially in the event of loss of ice caused by sublimation or partial melt down

6.7.6 Refrigeration System

6.7.6.1 Design Basis

Function

The refrigeration system serves to cool down the ice condenser from ambient conditions of the reactor containment and to maintain the desired equilibrium temperature in the ice compartment. It also provides the coolant supply for ice machines A, B, and C during ice loading. The refrigeration system additionally includes a defrost capability for critical surfaces within the ice compartment.

During a postulated loss-of-coolant accident the refrigeration system is not required to provide any heat removal function. However, the refrigeration system components which are physically located within the containment must be structurally secured (not become missiles) and the component materials must be compatible with the post-LOCA environment.

Design Conditions

LOCA M&E analysis assumes 2.585×10^6 lbm of ice

(1) Operating C[...]

See individual component sections:

(A) Floor cooling - Section 6.7.1

(B) Air handling units (AHUs) - Section 6.7.7

(2) Performance Requirements

(A) The mandatory design parameters that relate to refrigeration performance are:

(i)	Maximum total weight of ice in columns	3.0×10^6 lbs
(ii)	Minimum total weight of ice in columns	2.33×10^6 lbs
(iii)	Nominal ice condenser cooling air temperature	10°F - 15°F*

* Technical Specifications limit the maximum ice bed temperature to less than or equal to 27°F.

(B) The design must also provide a sufficiently well-insulated ice condenser annulus such that, with a complete loss of all refrigeration capacity, sufficient time exists for an orderly reactor shutdown prior to ice melting. A design objective is that the insulation of the cavity is adequate to prevent ice melting for approximately 7 days in the unlikely event of a complete loss of refrigeration capability.

Table 6.7-18 Refrigeration System Parameters Continued
(Sheet 2 of 2)

LOCA M&E analysis assumes 2.585 x 10^6 lbm of ice

2.4	Refrigeration Medium (glycol) - UCAR Thermofluid 17 or equal			
	Concentratio[illegible] ght % or [illegible] me %			
	At temperatu[illegible]	-5°F	0°F	100°F
	Specific gravity	1.083	1.082	1.056
	Absolute viscosity (centipoises)	25.0	20.5	2.3
	Kinematic viscosity (centistokes)	23.1	18.9	2.18
3.0	Ice Condenser (per one containment unit)			
3.1	Ice Bed			
	Amount of ice initially stored per unit, maximum			3.0 x 10^6lbs*
	Minimum amount of ice			2.33 x 10^6lbs
	Ice displacement per year, design objective			2%
	Design predicted ice displacement per year to wall panels for normal operation			<0.3%
	Ice melt during maximum LOCA, calculated, approx.			See Section 6.2.1
	Temperature of ice & static air			15°F to 20°F nominal**
	Pressure at lower doors due to cold head, nominal			1 psf
	Inlet opening pressure			1 psf
3.2	Air Handling Units - 30 dual packages installed per Containment			
	Refrigeration requirements per containment, calculated, nominal			51.5 tons
	Gross capacity per dual package rated			2.5 tons
	Glycol entering temperature, approx.			-5°F
	Glycol exit temperature, approx.			1°F
	Glycol flow per air handler (1/2 package)			6 gpm nominal
	Total glycol flow, 30 x 2 x 6			360 gpm nominal
	Glycol pressure drop, estimated			50 feet
	Air blower head			2' H_2O
	Air entering temperature, estimated			15°F
	Air exit temperature			10°F nominal

*Maximum ice weight not to exceed 3.0 x 10^6 lbs. [20]
**Plant Technical Specifications limit the maximum ice bed temperature to less than or equal to 27°F.

closed position upon loss of necessary flow head, and has a leakage area at 15 psig differential pressure of not more than 5.6 square inches. The position of the damper is monitored in the main control room.

Simultaneously with the return of air from the upper compartment to the lower compartment, post severe accident hydrogen mixing capability is provided by the air return fan system in the following regions of the containment: containment dome, each of the four steam generator enclosures, pressurizer enclosure, upper reactor cavity, each of the four accumulator rooms, and the instrument room. These regions are served by separate hydrogen collection headers which terminate on the suction side of each of the two air return fans. A schematic of this system is shown in Figure 9.4-28. The minimum design airflow from each region is sufficient to limit the local concentration of hydrogen to not more than the allowable volume percent range as specified in Section 6.2.5.2. Minimum design flow rates are shown in Figure 9.4-28.

The header systems are airflow-balanced prior to initial plant operation to assure that the actual airflows are at least equal to the minimum design flow when either or both fans are in operation.

6.8.3 Safety Evaluation

The design bases of the fans are to reduce containment pressure after blowdown from a LOCA or other high energy line break, prevent excessive hydrogen concentrations in pocketed areas, and circulate air through the ice condenser. The containment air return fans turn on 9 ± 1 minute after Phase B containment isolation signal. Peak containment pressure, about ~~12.40 psig~~ 11.73 psig, is attained at approximately ~~4346 seconds~~ 3600 seconds. The fans provide a continuous mixing of containment compartment atmosphere for the long-term post-blowdown environment. Mixing of the compartment atmospheres helps to bring fission products in contact with the ice bed and/or the upper compartment spray for removal from the containment atmosphere. The fans also aid in mixing the containment atmosphere to preclude hydrogen pocketing, which is assumed to be produced as a result of the severe accident.

Each fan located in the lower compartment, when operating alone, transfers 40,000 cfm from the upper compartment into the lower compartment and circulates 1,690 cfm from the enclosed areas in the lower compartment through the hydrogen collector duct headers to prevent excessive localized hydrogen buildup following a DBA. A back-draft damper, normally closed, is located upstream of each deck fan to prevent reverse flow during the initial LOCA or other high energy line blowdown.

The air return fans have sufficient head to overcome the compartment differentials that occur after the reactor coolant system blowdown. The fan head is sufficient to overcome the density effects of steam generation and resistance to airflow through the ice condenser and other system losses. After complete ice bed melt out, each fan has sufficient head to deliver 41,690 cfm with the containment pressurized to the design pressure rating.

The fans are designed to withstand the post DBA environment and were shown to survive the beyond-design-basis accident containment environment (Section 6.2.5).

Insert A

Table 6.2.1-3 Energy Balances

	Approx. End of Blowdown (t = 10.0 sec)	Approx. End of Reflood (t = 243.64 sec)
	(Millions of Btus)	
Ice Heat Removal*	192.0	246.37
Structural Heat Sinks*	16.804	54.978
RHR Heat Exchanger Heat Removal*	0.0	0.0
Spray Heat Exchanger Heat Removal*	0.0	0.0
Energy Content of Sump**	176.05	231.28
Ice Melted (millions of lbm)	0.6319	0.855

*Integrated Heat Rates

** Energy Content of Sump Includes Active and Inactive Regions

Insert B

Table 6.2.1-4 Energy Balances

	Approx. Ice Meltout Time	Approx. Time of Peak Pressure
	(t = 2958.95 sec)	(t = 3599.95 sec)
	(Millions of Btus)	
Ice Heat Removal*	668.15	668.15
Structural Heat Sinks*	70.56	85.39
RHR Heat Exchanger Heat Removal*	18.4	24.79
Spray Heat Exchanger Heat Removal*	4.77	17.27
Energy Content of Sump**	633.03	631.28
Ice Melted (millions of lbm)	2.585	2.585

*Integrated Heat Rates

** Energy Content of Sump Includes Active and Inactive Regions

Insert C

Table 6.2.1-16 Double-Ended Pump Suction Guillotine Break – Blowdown Mass and Energy Releases

	BREAK SIDE 1[1]		BREAK SIDE 2[2]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
0.0	0.0	0.0	0.0	0.0
0.001	89712.7	50762.5	43601.9	24614.6
0.1	43100.9	24412.9	22420.4	12643.4
0.2	43877.2	25044.5	24791.5	13992.6
0.3	44879.6	25882.9	24907.2	14070.5
0.4	45812.3	26742.0	24013.0	13579.0
0.5	46294.8	27357.1	22958.7	12992.8
0.6	46137.6	27585.7	21990.2	12449.5
0.7	45218.9	27318.1	21105.9	11951.3
0.8	43979.8	26822.7	20472.3	11595.9
0.9	42697.4	26276.6	20075.2	11373.5
1.0	41445.6	25735.0	19835.3	11240.1
1.1	40189.9	25193.6	19684.3	11155.8
1.2	38936.6	24656.7	19565.1	11088.9
1.3	37663.9	24107.3	19474.0	11037.2
1.4	36421.8	23568.2	19425.9	11009.6
1.5	35245.5	23053.8	19402.1	10996.0
1.6	34025.1	22493.5	19360.8	10972.1
1.7	32869.1	21946.3	19289.5	10930.9
1.8	31738.3	21383.1	19226.6	10894.6

	BREAK SIDE 1[(1)]		**BREAK SIDE 2[(2)]**	
TIME	**MASS**	**ENERGY**	**MASS**	**ENERGY**
(SEC)	**(LBM/SEC)**	**(THOUSAND BTU/SEC)**	**(LBM/SEC)**	**(THOUSAND BTU/SEC)**
1.9	30693.5	20852.4	19197.3	10878.0
2.0	29718.8	20347.6	19145.9	10848.9
2.1	28735.4	19817.5	19009.6	10771.2
2.2	27600.2	19170.6	18844.4	10677.5
2.3	26038.3	18208.8	18694.1	10592.8
2.4	23968.1	16861.3	18514.3	10491.4
2.5	22079.7	15631.9	18021.7	10211.8
2.6	21284.0	15167.6	17765.2	10068.1
2.7	20766.5	14863.3	17544.5	9944.4
2.8	20115.8	14441.4	17326.2	9822.1
2.9	19610.5	14118.7	17108.1	9700.1
3.0	19036.6	13738.9	16876.8	9570.6
3.1	18692.2	13523.2	16641.3	9438.8
3.2	18159.5	13166.0	16438.5	9325.8
3.3	17553.8	12758.6	16248.4	9220.1
3.4	16909.8	12321.0	16075.1	9124.1
3.5	16294.1	11898.8	15885.0	9018.7
3.6	15736.6	11513.4	15749.2	8943.8
3.7	15269.4	11190.0	15603.6	8863.7
3.8	14887.4	10923.3	15450.3	8779.2
3.9	14567.5	10696.3	15303.6	8698.4
4.0	14299.6	10504.3	15170.1	8625.3
4.2	13862.0	10182.4	14924.6	8490.9

	BREAK SIDE 1[1]		BREAK SIDE 2[2]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
4.4	13535.8	9931.2	14727.0	8383.8
4.6	13223.8	9680.6	15804.1	9010.1
4.8	13139.9	9574.1	15969.9	9104.0
5.0	13154.6	9531.5	15926.9	9086.1
5.2	13205.3	9525.7	15772.1	9002.5
5.4	13231.5	9512.0	15585.9	8901.5
5.6	13187.1	9460.4	15418.5	8811.3
5.8	13102.1	9389.5	15233.6	8710.5
6.0	13007.9	9317.8	15050.9	8610.3
6.2	12989.7	9296.0	14940.8	8550.7
6.4	13118.4	9344.6	14829.6	8487.4
6.6	13981.6	9892.5	14665.9	8392.4
6.8	13430.2	9480.6	14599.5	8354.2
7.0	12034.7	9045.0	14496.5	8293.5
7.2	11036.8	8596.6	14275.1	8164.6
7.4	11192.1	8637.2	14091.0	8059.8
7.6	11504.3	8741.4	13917.9	7962.6
7.8	11770.2	8814.9	13745.0	7863.3
8.0	12098.8	8930.1	13518.2	7732.2
8.2	12525.6	9105.6	13333.6	7626.1
8.4	12920.4	9256.5	13135.7	7511.8
8.6	13175.0	9322.6	12927.4	7391.6
8.8	13323.1	9335.8	12744.7	7286.0

	BREAK SIDE 1[(1)]		BREAK SIDE 2[(2)]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
9.0	13301.5	9247.6	12545.5	7170.6
9.2	13029.3	9012.0	12367.4	7067.4
9.4	12588.1	8685.9	12202.2	6971.6
9.6	12062.5	8320.4	12040.0	6877.3
9.8	11438.7	7906.9	11897.4	6794.5
10.0	10867.9	7551.6	11769.8	6720.4
10.2	10443.4	7308.2	11624.7	6636.0
10.2	10441.4	7307.1	11624.0	6635.6
10.4	10057.1	7094.4	11488.9	6557.9
10.6	9690.0	6896.3	11353.4	6480.1
10.8	9367.6	6726.8	11207.4	6396.0
11.0	9070.8	6571.2	11071.0	6317.3
11.2	8792.3	6423.7	10930.6	6236.1
11.4	8536.0	6286.4	10792.4	6156.1
11.6	8298.9	6157.7	10655.2	6076.6
11.8	8078.6	6037.1	10521.3	5998.9
12.0	7874.2	5924.4	10386.8	5920.9
12.2	7682.6	5816.5	10255.7	5844.9
12.4	7499.5	5711.5	10123.8	5768.6
12.6	7317.2	5608.1	9987.3	5689.5
12.8	7132.9	5501.8	9833.4	5600.7
13.0	6948.8	5382.5	9688.4	5517.6
13.2	6783.9	5257.4	9533.7	5428.6

	BREAK SIDE 1[1]		BREAK SIDE 2[2]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
13.4	6641.9	5136.1	9389.5	5345.5
13.6	6511.5	5020.2	9239.8	5259.4
13.8	6386.8	4907.4	9097.9	5178.3
14.0	6270.1	4802.3	8963.9	5101.9
14.2	6162.1	4706.3	8834.6	5028.6
14.4	6059.7	4619.1	8711.8	4959.4
14.6	5959.9	4541.5	8609.0	4902.7
14.8	5860.7	4470.8	8474.2	4827.4
15.0	5764.0	4409.0	8347.0	4757.5
15.2	5686.4	4366.4	8047.2	4600.8
15.4	5655.8	4395.1	7862.3	4547.5
15.6	5539.5	4470.3	7588.2	4428.5
15.8	5271.9	4519.7	7312.2	4288.9
16.0	4917.5	4533.6	7005.7	4084.5
16.2	4516.2	4510.5	6755.0	3855.5
16.4	4088.5	4435.4	6535.5	3605.8
16.6	3670.3	4259.5	6283.1	3328.5
16.8	3343.6	4037.5	5872.8	2987.8
17.0	2989.4	3669.8	5458.3	2675.3
17.2	2705.0	3345.5	5082.0	2408.8
17.4	2469.3	3068.6	4733.4	2175.9
17.6	2272.8	2834.5	4431.7	1981.5
17.8	2110.8	2640.1	4164.2	1816.0

	BREAK SIDE 1[(1)]		BREAK SIDE 2[(2)]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
18.0	1985.1	2488.6	3874.5	1652.3
18.2	1864.4	2341.6	3442.7	1432.9
18.4	1719.4	2163.1	3533.0	1422.2
18.6	1570.0	1978.6	5370.2	2107.1
18.8	1423.0	1796.7	6269.1	2450.5
19.0	1293.4	1636.0	5754.3	2242.0
19.2	1198.5	1518.3	3736.0	1448.5
19.4	1116.5	1416.2	3244.1	1256.9
19.6	1036.0	1315.4	2543.7	983.0
19.8	949.2	1206.2	1686.3	644.5
20.0	858.5	1092.0	1706.9	572.8
20.2	774.1	985.7	2815.8	861.8
20.4	699.1	891.1	3916.1	1163.4
20.6	634.4	809.3	3621.2	1066.7
20.8	575.0	734.1	3138.6	921.8
21.0	524.9	670.9	2842.6	833.5
21.2	493.5	631.3	2762.5	809.1
21.4	468.0	599.1	2737.7	801.2
21.6	440.8	564.4	2707.2	792.0
21.8	408.6	523.4	2594.7	759.0
22.0	371.1	475.6	2341.0	684.4
22.2	334.2	428.7	2135.6	622.8
22.4	297.2	381.4	1922.5	557.0

	BREAK SIDE 1[(1)]		BREAK SIDE 2[(2)]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
22.6	260.9	335.1	1655.6	475.3
22.8	238.7	306.7	1315.6	374.4
23.0	215.9	277.5	1077.3	301.7
23.2	200.0	257.3	1097.2	300.2
23.4	185.6	238.8	1181.7	319.6
23.6	183.1	235.8	1247.5	336.2
23.8	177.6	228.6	1292.9	348.3
24.0	174.0	224.1	1318.9	355.4
24.2	168.5	217.0	1322.1	356.7
24.4	161.2	207.7	1291.9	349.2
24.6	153.2	197.4	1207.4	327.3
24.8	144.3	186.0	1033.7	281.7
25.0	139.0	179.3	698.0	192.0
25.2	125.1	161.3	68.3	19.2
25.4	112.5	145.1	0.0	0.0
25.6	93.2	120.4	0.0	0.0
25.8	85.7	110.7	0.0	0.0
26.0	72.4	93.7	47.3	16.4
26.2	60.3	78.1	156.0	57.3
26.4	48.4	62.8	102.5	38.9
26.6	38.7	50.3	99.8	37.4
26.8	19.9	25.9	0.0	0.0
27.0	0.0	0.0	0.0	0.0

	BREAK SIDE 1[1]		BREAK SIDE 2[2]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)

Notes:

1. M&E exiting from the SG side of the break (path 1)

2. M&E exiting from the pump side of the break (path 2)

Insert D

Table 6.2.1-17 Double-Ended Pump Suction Guillotine Break – Reflood Mass and Energy Releases – Minimum Safety Injection

	BREAK SIDE 1[(1)]		BREAK SIDE 2[(2)]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
27.0	0.0	0.0	0.0	0.0
27.5	0.0	0.0	0.0	0.0
27.7	0.0	0.0	0.0	0.0
27.8	0.0	0.0	0.0	0.0
27.9	0.0	0.0	0.0	0.0
28.0	0.0	0.0	0.0	0.0
28.0	0.0	0.0	0.0	0.0
28.1	34.2	39.8	0.0	0.0
28.2	13.5	15.7	0.0	0.0
28.4	14.1	16.5	0.0	0.0
28.5	18.1	21.1	0.0	0.0
28.6	23.8	27.6	0.0	0.0
28.7	28.0	32.6	0.0	0.0
28.8	32.2	37.4	0.0	0.0
28.9	36.1	42.0	0.0	0.0
29.0	39.2	45.7	0.0	0.0
29.1	42.1	49.0	0.0	0.0
29.2	44.8	52.1	0.0	0.0
29.3	47.4	55.2	0.0	0.0
29.4	49.9	58.1	0.0	0.0

	BREAK SIDE 1[(1)]		BREAK SIDE 2[(2)]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
29.5	52.3	60.9	0.0	0.0
29.6	55.0	64.1	0.0	0.0
29.7	57.6	67.0	0.0	0.0
29.8	59.2	68.9	0.0	0.0
29.8	60.0	69.9	0.0	0.0
29.9	62.4	72.7	0.0	0.0
30.0	64.5	75.1	0.0	0.0
30.1	66.2	77.1	0.0	0.0
31.1	84.4	98.4	0.0	0.0
32.1	99.6	116.2	0.0	0.0
33.1	191.4	223.9	2428.8	327.4
34.2	334.3	393.4	4508.5	668.4
34.9	333.4	392.4	4496.2	670.7
35.2	332.2	390.9	4479.6	669.0
36.2	327.5	385.4	4415.0	661.5
37.2	348.7	410.6	4744.9	688.1
38.2	343.7	404.7	4679.0	679.6
39.2	338.9	399.0	4613.3	671.0
40.2	334.2	393.4	4548.6	662.5
40.7	331.9	390.6	4516.9	658.3
41.2	329.7	388.0	4485.6	654.1
42.2	325.4	382.8	4424.3	645.9
43.2	321.0	377.6	4365.0	638.0

	BREAK SIDE 1[(1)]		BREAK SIDE 2[(2)]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
44.2	316.4	372.1	4308.0	630.5
45.2	311.9	366.7	4252.9	623.2
46.2	307.5	361.6	4199.6	616.2
47.2	303.4	356.6	4148.1	609.4
48.2	299.4	351.9	4098.2	602.8
48.7	297.5	349.6	4073.8	599.6
49.2	295.6	347.3	4049.9	596.4
50.2	291.9	342.9	4003.1	590.3
51.2	288.3	338.7	3957.7	584.3
52.2	284.9	334.6	3913.7	578.5
53.2	281.5	330.7	3871.0	572.9
54.2	278.4	326.9	3829.6	567.4
55.2	275.3	323.2	3789.3	562.1
56.2	272.3	319.6	3750.1	557.0
57.2	269.4	316.2	3712.0	552.0
58.2	266.6	312.9	3675.0	547.1
58.4	266.0	312.2	3667.7	546.2
59.2	263.9	309.7	3638.9	542.4
60.2	261.2	306.6	3603.7	537.8
61.2	258.7	303.5	3569.5	533.3
62.2	256.2	300.6	3536.0	528.9
63.2	253.8	297.7	3503.4	524.7
64.2	251.5	295.0	3471.6	520.5

	BREAK SIDE 1[1]		BREAK SIDE 2[2]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
65.2	249.2	292.3	3440.5	516.4
66.2	208.7	244.4	2828.2	442.4
67.2	327.6	385.3	281.0	165.8
68.2	361.9	426.5	297.8	189.9
69.1	358.7	422.6	296.2	187.9
69.2	358.1	421.9	295.9	187.5
70.2	351.6	414.2	292.8	183.2
71.2	345.5	406.9	289.8	179.0
72.2	339.9	400.1	287.0	175.1
73.2	334.5	393.8	284.3	171.4
74.2	329.4	387.6	281.7	167.9
75.2	324.1	381.3	279.1	164.3
76.2	319.0	375.2	276.8	161.1
77.2	314.2	369.5	274.7	158.4
78.2	309.7	364.1	272.8	155.8
79.2	305.4	359.0	270.9	153.4
80.2	301.3	354.1	269.2	151.1
81.2	297.3	349.4	267.5	148.9
82.2	293.6	345.0	266.0	146.8
83.2	290.0	340.7	264.5	144.8
84.2	286.6	336.7	263.0	142.9
85.2	283.4	332.8	261.7	141.1
86.2	280.3	329.1	260.4	139.4

	BREAK SIDE 1(1)		BREAK SIDE 2(2)	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
87.2	277.3	325.6	259.2	137.8
88.2	274.5	322.3	258.0	136.2
89.9	270.0	316.9	256.1	133.7
90.2	269.2	316.0	255.8	133.3
92.2	264.4	310.2	253.8	130.7
94.2	259.9	305.0	252.0	128.3
96.2	255.9	300.2	250.3	126.1
98.2	252.1	295.8	248.8	124.1
100.2	248.7	291.7	247.4	122.2
102.2	245.5	287.9	246.1	120.5
104.2	242.6	284.4	244.9	118.9
106.2	239.9	281.2	243.8	117.5
108.2	237.4	278.3	242.8	116.2
110.2	235.1	275.6	241.9	115.0
112.2	233.1	273.2	241.0	113.9
114.2	231.2	270.9	240.3	112.9
116.2	229.5	268.9	239.6	112.0
117.1	228.8	268.1	239.3	111.6
118.2	227.9	267.1	238.9	111.1
120.2	226.5	265.4	238.3	110.4
122.2	225.2	263.9	237.8	109.7
124.2	224.0	262.5	237.3	109.1
126.2	222.9	261.2	236.9	108.5

	BREAK SIDE 1[(1)]		BREAK SIDE 2[(2)]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
128.2	221.9	260.0	236.5	107.9
130.2	221.0	258.9	236.1	107.5
132.2	220.2	257.9	235.8	107.0
134.2	219.4	257.0	235.5	106.6
136.2	218.7	256.2	235.2	106.2
138.2	218.1	255.4	234.9	105.9
140.2	217.5	254.8	234.7	105.6
142.2	217.0	254.2	234.4	105.3
144.2	216.5	253.6	234.2	105.0
146.2	216.1	253.1	234.1	104.8
147.8	215.8	252.8	233.9	104.6
148.2	215.8	252.7	233.9	104.6
150.2	215.4	252.3	233.8	104.4
152.2	215.1	252.0	233.6	104.2
154.2	214.8	251.6	233.5	104.0
156.2	214.5	251.3	233.4	103.9
158.2	214.3	251.0	233.3	103.7
160.2	214.1	250.7	233.1	103.6
162.2	213.9	250.5	233.0	103.5
164.2	213.7	250.2	233.0	103.3
166.2	214.1	250.8	233.3	103.5
168.2	214.5	251.2	233.8	103.7
170.2	215.0	251.8	234.6	103.9

	BREAK SIDE 1(1)		BREAK SIDE 2(2)	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
172.2	215.5	252.5	235.7	104.2
174.2	216.1	253.2	236.9	104.5
176.2	216.7	253.9	238.3	104.8
178.2	217.3	254.5	239.7	105.1
179.4	217.6	254.9	240.6	105.2
180.2	217.8	255.1	241.2	105.3
182.2	218.2	255.6	242.7	105.5
184.2	218.6	256.1	244.2	105.7
186.2	218.9	256.4	245.7	105.9
188.2	219.1	256.7	247.3	106.0
190.2	219.3	256.9	249.0	106.2
192.2	219.5	257.1	250.6	106.3
194.2	219.6	257.2	252.4	106.4
196.2	219.6	257.2	254.1	106.4
198.2	219.5	257.2	255.8	106.4
200.2	219.4	257.0	257.6	106.4
202.2	219.2	256.8	259.4	106.4
204.2	219.0	256.5	261.3	106.4
206.2	218.7	256.1	263.1	106.3
208.2	218.3	255.7	265.0	106.2
210.2	217.9	255.2	267.0	106.1
210.8	217.8	255.1	267.6	106.1
212.2	217.5	254.7	269.0	106.1

	BREAK SIDE 1[(1)]		BREAK SIDE 2[(2)]	
TIME	**MASS**	**ENERGY**	**MASS**	**ENERGY**
(SEC)	**(LBM/SEC)**	**(THOUSAND BTU/SEC)**	**(LBM/SEC)**	**(THOUSAND BTU/SEC)**
214.2	217.0	254.2	271.1	106.0
216.2	216.5	253.6	273.3	105.9
218.2	215.9	252.9	275.5	105.8
220.2	215.3	252.1	277.7	105.6
222.2	214.6	251.3	280.0	105.5
224.2	213.8	250.4	282.3	105.3
226.2	213.0	249.5	284.6	105.2
228.2	212.1	248.4	286.9	105.0
230.2	211.2	247.3	289.3	104.8
232.2	210.2	246.1	291.7	104.6
234.2	209.2	244.9	294.2	104.4
236.2	208.1	243.7	296.7	104.3
238.2	206.9	242.3	299.1	104.0
240.2	205.7	240.8	301.5	103.8
242.2	204.4	239.3	304.0	103.5
243.6	203.4	238.2	305.7	103.4

Notes:

1. M&E exiting from the SG side of the break (path 1)

2. M&E exiting from the pump side of the break (path 2)

Insert E

Table 6.2.1-18 Double-Ended Pump Suction Guillotine Break – Minimum Safety Injection Principal Parameters During Reflood

TIME (SECONDS)	FLOODING		CARRYOVER FRACTION (-)	CORE HEIGHT (FT)	DOWNCOMER HEIGHT (FT)	FLOW FRAC (-)	TOTAL	INJECTION ACCUM	SPILL	ENTHALPY (BTU/LBM)
	TEMP (°F)	RATE (IN/SEC)					(POUNDS MASS PER SECOND)			
27.0	206.5	0.000	0.000	0.00	0.00	0.250	0.0	0.0	0.0	0.00
27.8	203.7	22.205	0.000	0.65	1.44	0.000	7306.6	7306.6	0.0	99.46
28.0	202.2	24.049	0.000	1.04	1.35	0.000	7255.4	7255.4	0.0	99.46
28.4	201.7	2.345	0.100	1.30	2.13	0.235	7129.0	7129.0	0.0	99.46
28.6	201.8	2.385	0.137	1.33	2.74	0.286	7081.5	7081.5	0.0	99.46
29.8	202.6	2.033	0.323	1.50	6.33	0.352	6806.9	6806.9	0.0	99.46
31.1	203.6	1.973	0.456	1.63	10.27	0.367	6540.3	6540.3	0.0	99.46
34.2	205.7	3.711	0.619	1.93	16.12	0.567	5385.1	5385.1	0.0	99.46
34.9	206.2	3.557	0.644	2.00	16.12	0.566	5281.5	5281.5	0.0	99.46
35.2	206.4	3.499	0.653	2.03	16.12	0.566	5243.8	5243.8	0.0	99.46
36.2	207.2	3.341	0.675	2.13	16.12	0.566	5127.2	5127.2	0.0	99.46
37.2	208.0	3.426	0.691	2.23	16.12	0.574	5469.6	4881.9	0.0	96.62
40.7	211.1	3.131	0.724	2.50	16.12	0.572	5155.8	4562.6	0.0	96.42
48.7	219.0	2.745	0.753	3.00	16.12	0.562	4611.9	4010.2	0.0	96.02
58.4	227.8	2.459	0.769	3.50	16.12	0.550	4135.4	3526.9	0.0	95.58
66.2	233.6	2.039	0.781	3.85	16.12	0.513	3193.9	2573.8	0.0	94.34
67.2	234.3	2.867	0.774	3.89	16.09	0.596	596.3	0.0	0.0	73.06
68.2	235.0	3.085	0.768	3.95	15.95	0.598	580.8	0.0	0.0	73.06
69.1	235.6	3.050	0.769	4.00	15.82	0.598	581.5	0.0	0.0	73.06
79.2	241.7	2.582	0.779	4.54	14.76	0.593	598.0	0.0	0.0	73.06
89.9	246.9	2.287	0.787	5.00	14.21	0.587	605.6	0.0	0.0	73.06
104.2	246.2	2.073	0.790	5.55	13.98	0.580	611.2	0.0	0.0	73.06
117.1	247.0	1.962	0.793	6.00	14.04	0.576	613.8	0.0	0.0	73.06

TIME (SECONDS)	FLOODING		CARRYOVER FRACTION (-)	CORE HEIGHT (FT)	DOWNCOMER HEIGHT (FT)	FLOW FRAC (-)	TOTAL	INJECTION ACCUM	SPILL	ENTHALPY (BTU/LBM)
	TEMP (°F)	RATE (IN/SEC)					(POUNDS MASS PER SECOND)			
134.2	246.5	1.891	0.793	6.57	14.34	0.573	615.6	0.0	0.0	73.06
147.8	247.5	1.859	0.795	7.00	14.67	0.572	616.3	0.0	0.0	73.06
164.2	246.8	1.843	0.795	7.52	15.12	0.571	616.8	0.0	0.0	73.06
179.4	247.5	1.863	0.795	8.00	15.52	0.575	616.1	0.0	0.0	73.06
188.2	247.0	1.869	0.794	8.28	15.68	0.578	615.8	0.0	0.0	73.06
196.2	247.5	1.864	0.795	8.54	15.81	0.580	615.7	0.0	0.0	73.06
210.8	247.1	1.838	0.794	9.00	15.97	0.584	615.9	0.0	0.0	73.06
228.2	247.3	1.778	0.794	9.54	16.07	0.588	616.7	0.0	0.0	73.06
243.6	247.5	1.700	0.795	10.00	16.11	0.590	618.1	0.0	0.0	73.06

Insert F

Table 6.2.1-19 Double-Ended Pump Suction Guillotine Break – Post-Reflood Mass and Energy Releases – Minimum Safety Injection

	BREAK SIDE 1[1]		BREAK SIDE 2[2]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
243.7	213.0	268.4	424.1	119.1
248.7	212.3	267.4	424.9	119.2
253.7	211.5	266.5	425.6	119.2
258.7	212.3	267.4	424.9	119.0
263.7	211.5	266.5	425.6	119.1
268.7	210.8	265.5	426.4	119.1
273.7	211.5	266.4	425.7	118.9
278.7	210.7	265.4	426.5	118.9
283.7	209.9	264.4	427.3	119.0
288.7	210.6	265.3	426.6	118.7
293.7	209.8	264.2	427.4	118.8
298.7	210.4	265.0	426.8	118.6
303.7	209.6	264.0	427.6	118.7
308.7	208.8	263.0	428.4	118.7
313.7	209.4	263.7	427.8	118.5
318.7	208.5	262.7	428.6	118.6
323.7	207.7	261.6	429.5	118.7
328.7	208.2	262.3	428.9	118.4
333.7	207.4	261.2	429.8	118.5

	BREAK SIDE 1[(1)]		BREAK SIDE 2[(2)]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
338.7	207.9	261.9	429.3	118.3
343.7	207.0	260.8	430.2	118.4
348.7	206.1	259.6	431.0	118.5
353.7	206.6	260.2	430.6	118.3
358.7	205.7	259.1	431.5	118.4
363.7	206.1	259.7	431.0	118.2
368.7	205.2	258.5	432.0	118.3
373.7	205.6	259.0	431.6	118.1
378.7	204.6	257.8	432.5	118.2
383.7	205.0	258.3	432.1	118.0
388.7	204.0	257.0	433.1	118.1
393.7	204.4	257.4	432.8	117.9
398.7	203.4	256.2	433.8	118.0
403.7	203.7	256.7	433.4	117.8
408.7	202.8	255.5	434.3	117.9
413.7	203.2	256.0	433.9	117.8
418.7	202.3	254.8	434.9	117.9
423.7	202.6	255.3	434.5	117.7
428.7	201.7	254.1	435.5	117.8
433.7	202.0	254.4	435.2	117.6
438.7	201.0	253.2	436.2	117.8
443.7	201.2	253.5	435.9	117.6
448.7	201.4	253.7	435.7	117.5

	BREAK SIDE 1[1]		BREAK SIDE 2[2]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
453.7	200.4	252.4	436.8	117.6
458.7	200.5	252.6	436.6	117.5
463.7	199.5	251.3	437.7	117.6
468.7	199.6	251.4	437.6	117.5
473.7	199.6	251.5	437.5	117.4
478.7	199.6	251.5	437.5	117.3
483.7	198.5	250.0	438.7	117.4
488.7	198.4	250.0	438.7	117.3
493.7	198.4	249.9	438.8	117.2
498.7	198.3	249.7	438.9	117.2
503.7	198.1	249.5	439.1	117.1
508.7	197.9	249.3	439.3	117.0
513.7	196.5	247.6	440.6	117.2
518.7	196.3	247.2	440.9	117.2
523.7	197.0	248.2	440.2	116.9
528.7	196.6	247.7	440.5	116.9
533.7	196.2	247.1	441.0	116.9
538.7	195.7	246.5	441.5	116.9
543.7	195.1	245.8	442.1	116.9
548.7	194.5	245.0	442.7	117.0
553.7	194.8	245.4	442.4	116.8
558.7	194.0	244.4	443.2	116.9
563.7	194.1	244.5	443.0	116.7

	BREAK SIDE 1(1)		BREAK SIDE 2(2)	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
568.7	194.1	244.6	443.0	116.6
573.7	193.1	243.3	444.1	116.8
578.7	192.9	243.0	444.3	116.7
583.7	192.6	242.6	444.6	116.7
588.7	192.1	242.0	445.1	116.7
593.7	192.3	242.3	444.8	116.5
598.7	191.5	241.3	445.6	116.6
603.7	191.4	241.1	445.7	116.5
608.7	191.1	240.7	446.1	116.5
613.7	190.5	240.0	446.7	116.5
618.7	190.4	239.9	446.8	116.4
623.7	189.9	239.3	447.2	116.4
628.7	189.8	239.1	447.4	116.4
633.7	189.8	239.1	447.4	116.3
638.7	189.1	238.2	448.0	116.3
643.7	188.9	238.0	448.2	116.2
648.7	188.8	237.9	448.3	116.2
653.7	188.3	237.2	448.8	116.2
658.7	187.6	236.4	449.5	116.2
663.7	187.5	236.2	449.6	116.1
1096.9	187.5	236.2	449.6	116.1
1097.0	72.9	91.5	564.3	138.2
1098.7	72.9	91.5	564.3	138.2

	BREAK SIDE 1[1]		BREAK SIDE 2[2]	
TIME	MASS	ENERGY	MASS	ENERGY
(SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)	(LBM/SEC)	(THOUSAND BTU/SEC)
1203.7	71.3	89.4	565.9	135.9
1207.3	71.2	89.4	565.8	135.8
1262.3	70.4	88.3	566.7	134.5
1267.3	70.3	88.2	571.3	152.7
1342.3	69.2	86.8	572.4	150.9
1344.3	69.1	86.8	354.8	128.9
2568.96	69.1	86.8	354.8	128.9

Notes:

1. M&E exiting from the SG side of the break (path 1)

2. M&E exiting from the pump side of the break (path 2)

Insert G

Table 6.2.1-26a Double-Ended Pump Suction Guillotine Break Minimum Safety Injection – Mass Balance

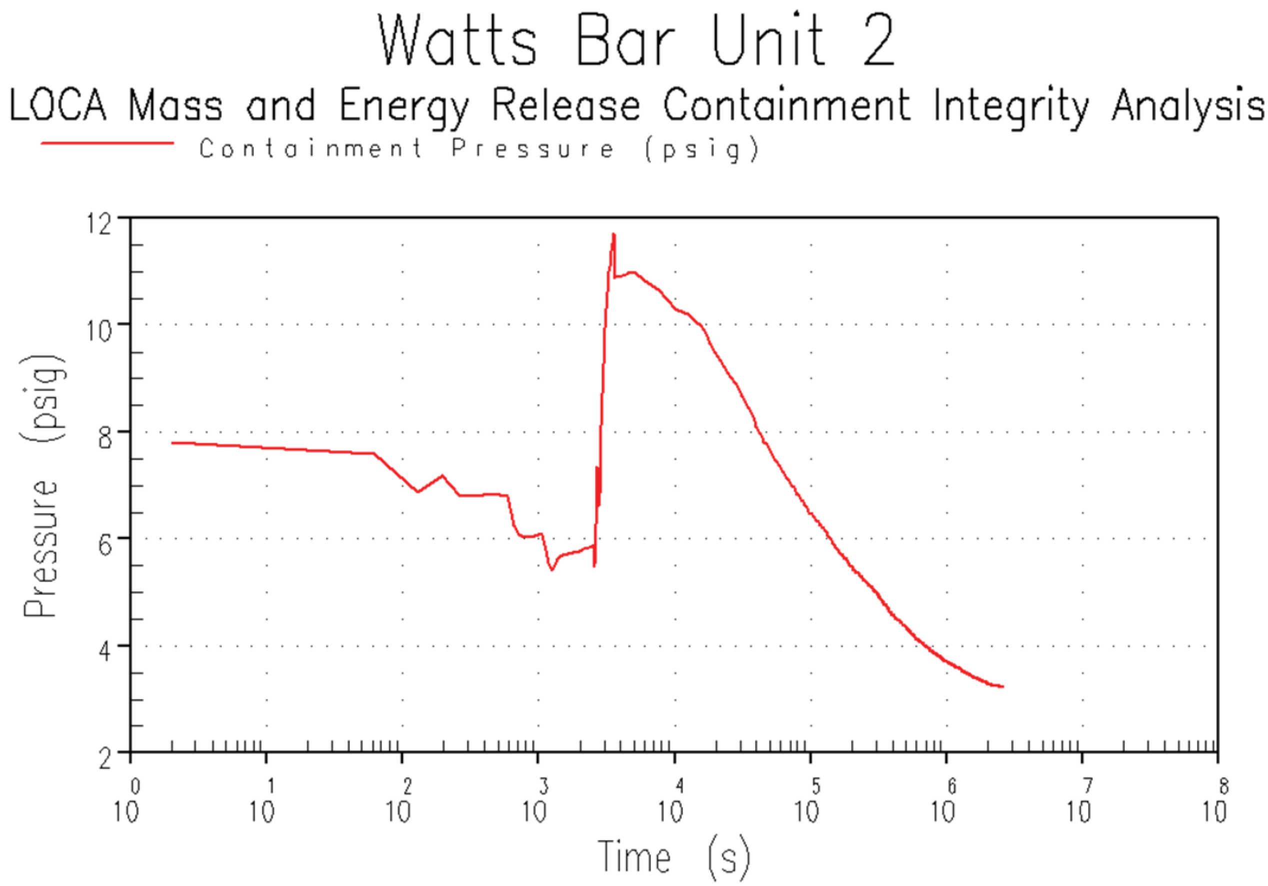
Mass Balance		**Start of Accident**	**End of Blowdown**	**Bottom of Core Recovery**	**End of Reflood**	**Broken Loop SG Equilibration**	**Intact Loop SG Equilibration**
	Time (Seconds)	0.00	27.00	27.00	243.64	1097.04	2568.96
	Mass (Thousands lbm)						
Initial	In RCS and ACC	750.32	750.32	750.32	750.32	750.32	750.32
Added Mass	Pumped Injection	0.00	0.00	0.00	126.79	670.50	1347.51
	Total Added	0.00	0.00	0.00	126.79	670.50	1347.51
*****Total Available*****		**750.32**	**750.32**	**750.32**	**877.11**	**1420.82**	**2097.83**
Distribution	Reactor Coolant	492.76	74.45	74.60	136.14	136.14	136.14
	Accumulator	257.56	176.99	176.83	0.00	0.00	0.00
	Total Contents	750.32	251.44	251.44	136.14	136.14	136.14
Effluent	Break Flow	0.00	498.87	498.87	730.36	1274.08	1950.88
	ECCS Spill	0.00	0.00	0.00	0.00	0.00	0.00
	Total Effluent	0.00	498.87	498.87	730.36	1274.08	1950.88
*****Total Accountable*****		**750.32**	**750.30**	**750.30**	**866.50**	**1410.21**	**2087.02**

Insert H

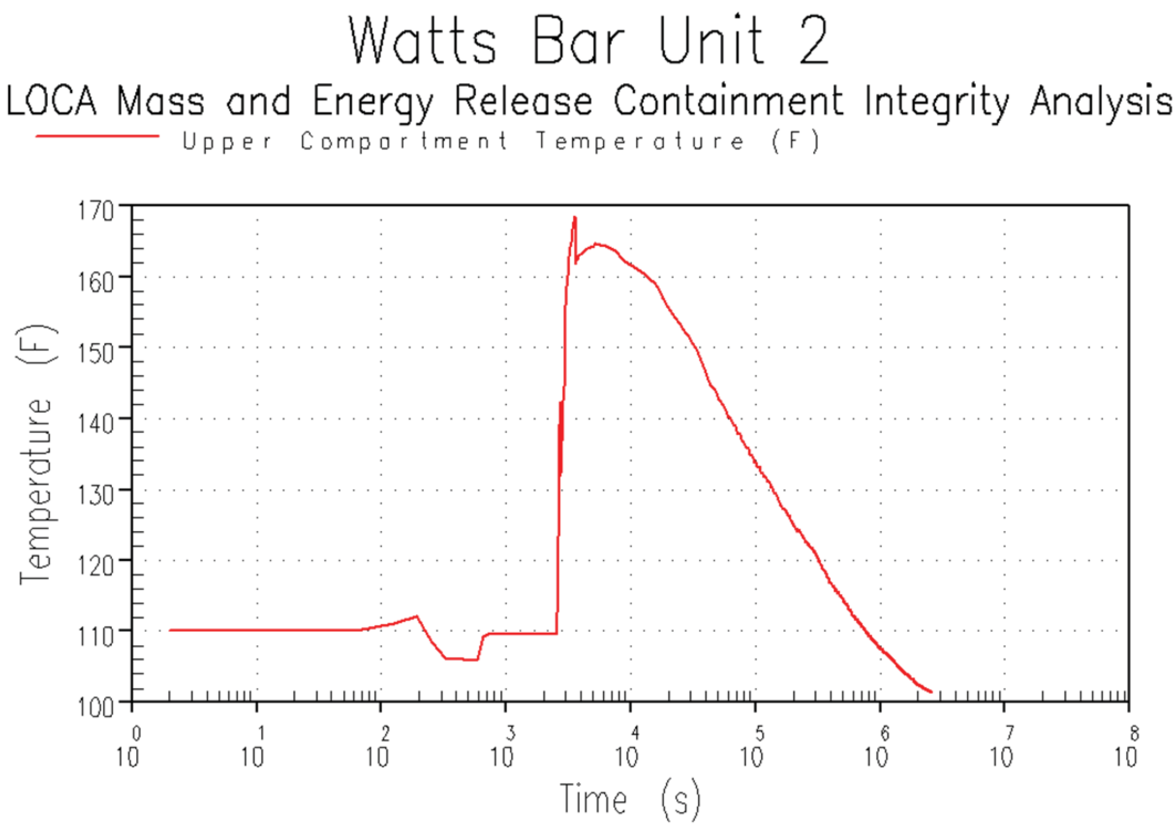
Table 6.2.1-26b Double-Ended Pump Suction Guillotine Break Minimum Safety Injection – Energy Balance

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)	0.00	27.00	27.00	243.64	1097.04	2568.96
	Energy (Million Btu)						
Initial Energy	In RCS, ACC, S Gen	984.47	984.47	984.47	984.47	984.47	984.47
Added Energy	Pumped Injection	0.00	0.00	0.00	9.26	48.99	114.34
	Decay Heat	0.00	7.74	7.74	31.76	99.91	189.17
	Heat from Secondary	0.00	12.23	12.23	12.23	21.45	31.41
	Total Added	0.00	19.97	19.97	53.25	170.34	334.91
*****Total Available*****		**984.47**	**1004.44**	**1004.44**	**1037.72**	**1154.81**	**1319.38**
Distribution	Reactor Coolant	296.93	13.54	13.55	29.66	29.66	29.66
	Accumulator	25.62	17.60	17.59	0.00	0.00	0.00
	Core Stored	25.61	14.16	14.16	3.98	3.65	3.46
	Primary Metal	214.29	205.63	205.63	185.27	108.49	77.54
	Secondary Metal	136.88	136.16	136.16	125.62	90.43	55.90
	Steam Generator	285.15	301.32	301.32	273.92	198.94	131.47
	Total Contents	984.47	688.40	688.40	618.45	431.17	298.03
Effluent	Break Flow	0.00	315.46	315.46	416.07	720.43	1045.25
	ECCS Spill	0.00	0.00	0.00	0.00	0.00	0.00
	Total Effluent	0.00	315.46	315.46	416.07	720.43	1045.25
*****Total Accountable*****		**984.47**	**1003.86**	**1003.86**	**1034.52**	**1151.61**	**1343.28**

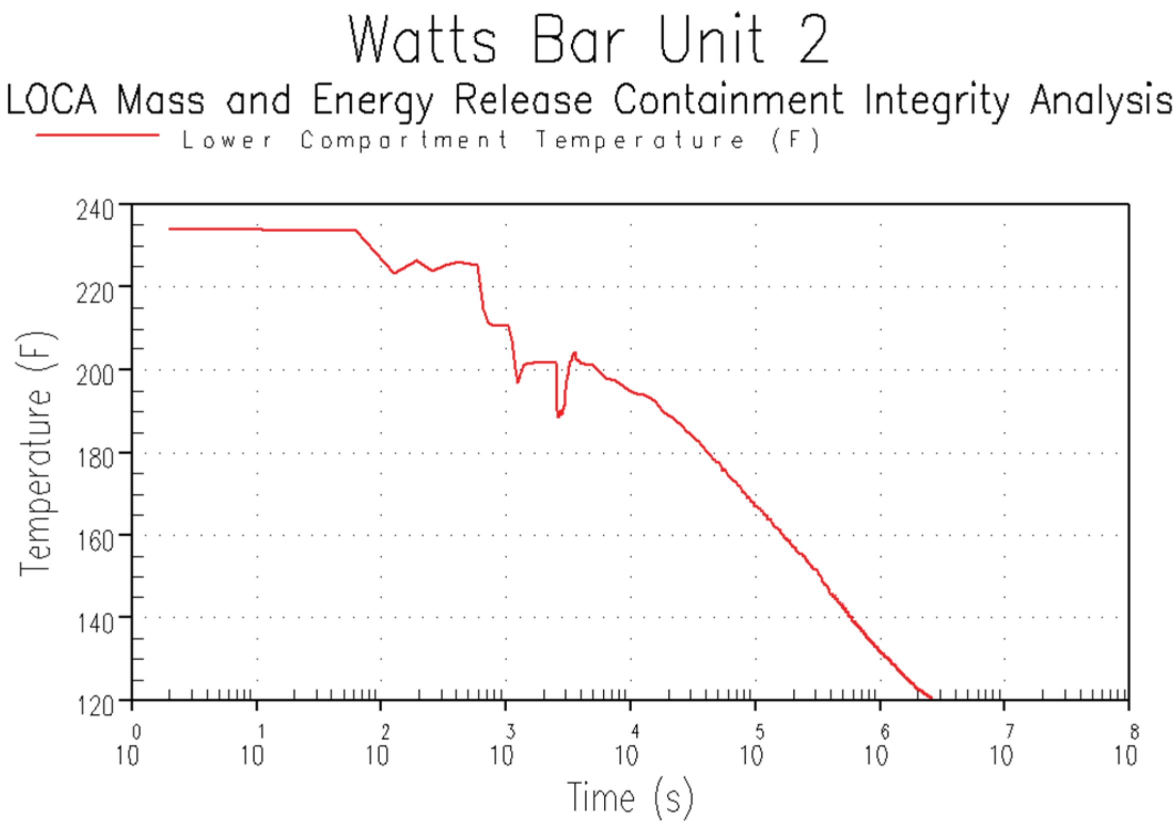
Insert I


Watts Bar Unit 2
LOCA Mass and Energy Release Containment Integrity Analysis
Containment Pressure (psig)
Pressure (psig)
12
10
8
6
4
2
Time (s)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8

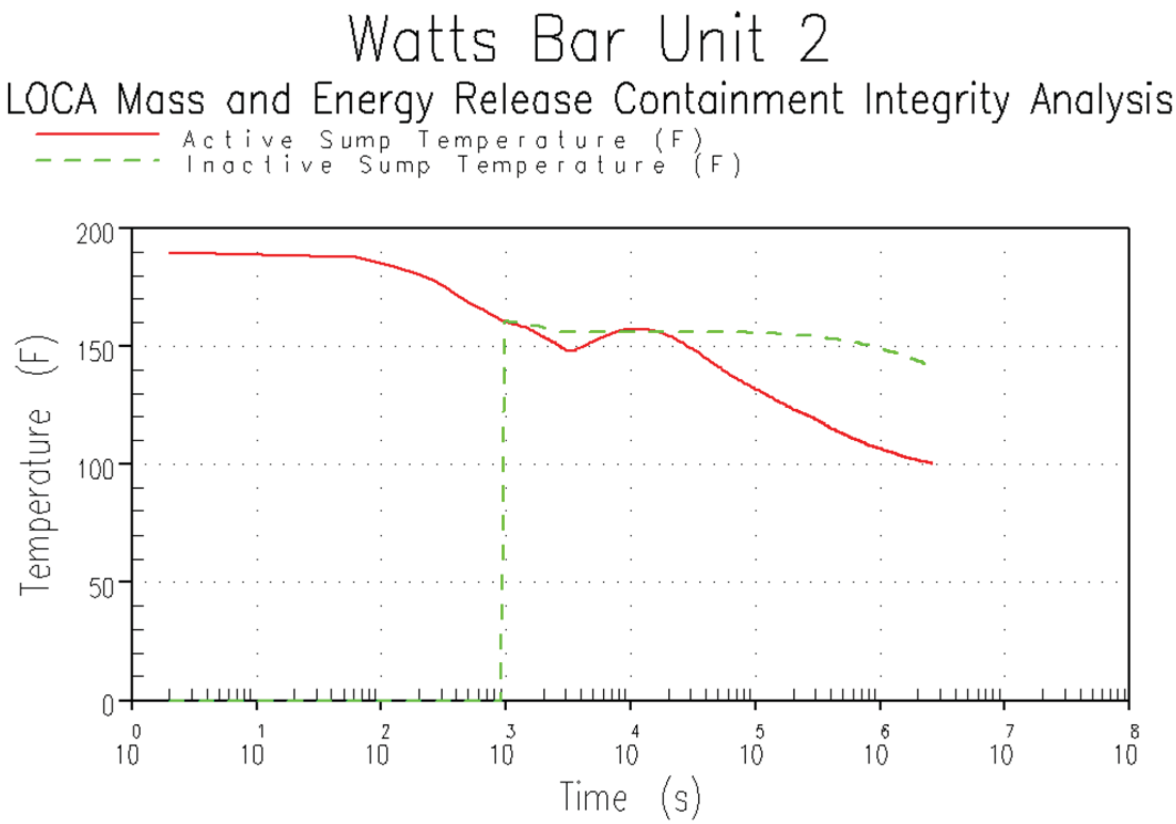
Insert J


Watts Bar Unit 2
LOCA Mass and Energy Release Containment Integrity Analysis
Upper Compartment Temperature (F)
Temperature (F)
170
160
150
140
130
120
110
100
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
Time (s)

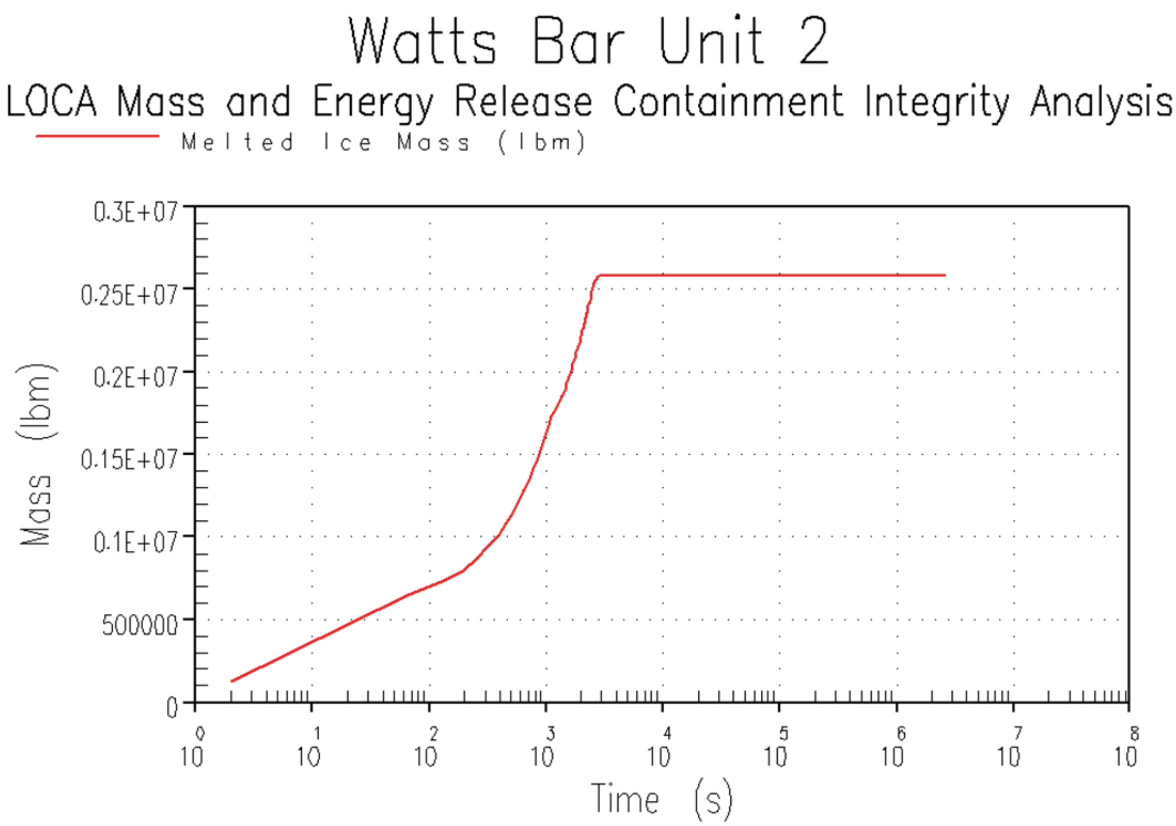
Insert K


Watts Bar Unit 2
LOCA Mass and Energy Release Containment Integrity Analysis
Lower Compartment Temperature (F)
Temperature (F)
240
220
200
180
160
140
120
Time (s)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8

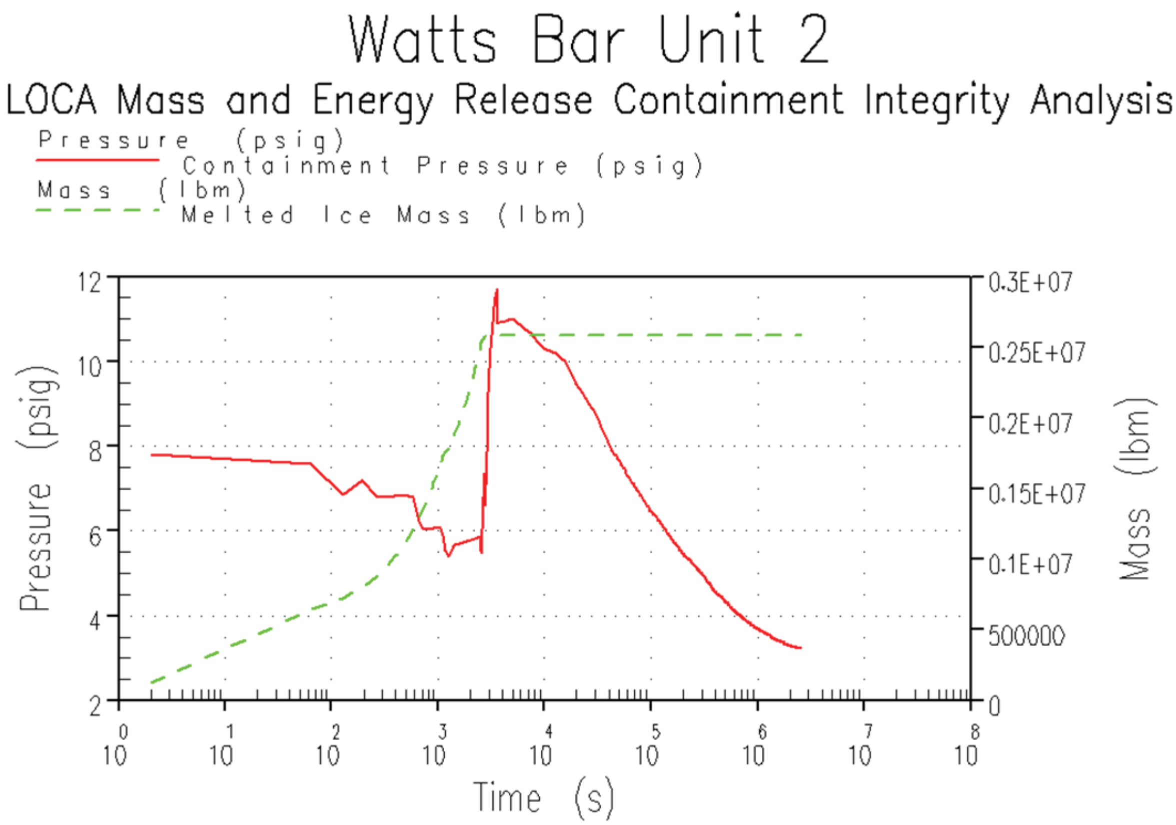
Insert L


Watts Bar Unit 2
LOCA Mass and Energy Release Containment Integrity Analysis
Active Sump Temperature (F)
Inactive Sump Temperature (F)
Temperature (F)
200
150
100
50
0
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
Time (s)

Insert M


Watts Bar Unit 2
LOCA Mass and Energy Release Containment Integrity Analysis
Melted Ice Mass (lbm)
Mass (lbm)
0.3E+07
0.25E+07
0.2E+07
0.15E+07
0.1E+07
500000
0
Time (s)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8

Insert N


Watts Bar Unit 2
LOCA Mass and Energy Release Containment Integrity Analysis
Pressure (psig)
Containment Pressure (psig)
Mass (lbm)
Melted Ice Mass (lbm)
Pressure (psig)
Mass (lbm)
Time (s)
12
10
8
6
4
2
0.3E+07
0.25E+07
0.2E+07
0.15E+07
0.1E+07
500000
0
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8

ENCLOSURE 3
Watts Bar Nuclear Plant Unit 2

Revised Pages for TS and TS Bases 3.6.11

3.6 CONTAINMENT SYSTEMS

3.6.11 Ice Bed

LCO 3.6.11 The ice bed shall be OPERABLE

APPLICABILITY: MODES 1, 2, 3, and 4.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Ice bed inoperable.	A.1 Restore ice bed to OPERABLE status.	48 hours
B. Required Action and associated Completion Time not met.	B.1 Be in MODE 3. <u>AND</u> B.2 Be in MODE 5.	6 hours 36 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.6.11.1	Verify maximum ice bed temperature is $\leq$ 27°F.	12 hours

(continued)

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.6.11.2	Verify total weight of stored ice is greater than or equal to ~~2,479,000~~ **2,750,700** lb by: a. Weighing a representative sample of ≥ 144 ice baskets and verifying each basket contains greater than or equal to ~~1276~~ **1415** 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 ~~1276~~ **1415** 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 3.6.11 Ice Bed

BASES

BACKGROUND

The ice bed consists of over ~~2,479,000~~ **2,750,700** 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.

(continued)

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 ~~1276~~ **1415** 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 ~~1276~~ **1415** 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 less than ~~1276~~ **1415** 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.

SR 3.6.11.3

This SR ensures that the azimuthal distribution of ice is reasonably uniform, by verifying that the average ice weight in each of three azimuthal groups of ice condenser bays is within the limit. 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

NEW COMMITMENTS

1. The long term containment pressure analysis will be included in WBN Unit 2 FSAR Amendment 114.

2. Revised ice weights for the ice bed and ice baskets will be incorporated in SR 3.6.11.2 and SR 3.6.11.3, respectively, in WBN Unit 2 TS Revision 0.