6.4 Containment Integrity Analyses

6.4.1 Loss-of-Coolant Accident Containment Integrity

6.4.1.1 Loss-of-Coolant Accident Mass and Energy Releases

The uncontrolled release of pressurized high-temperature reactor coolant, termed a loss-of-coolant accident (LOCA), will result in release of steam and water into the containment. This, in turn, will result in increases in the local subcompartment pressures, and an increase in the global containment pressure and temperature. Therefore, there are both long- and short-term issues relative to a postulated LOCA that must be considered at the uprated core power of 1772 MWt for the Kewaunee Nuclear Power Plant (KNPP).

The long-term LOCA mass and energy releases are analyzed to approximately 10^6 seconds and are utilized as input to the containment integrity analysis. This demonstrates the acceptability of the containment safeguards systems to mitigate the consequences of a hypothetical large-break LOCA (LBLOCA). The containment safeguards systems must be capable of limiting the peak containment pressure to less than the design pressure and to limit the temperature excursion to less than the acceptance limits. For this power uprate program, Westinghouse generated Kewaunee-specific LOCA mass and energy releases for the containment design using the flexible multi-nodal model (hereafter referred to as "the March 1979 model") described in Reference 1. The Nuclear Regulatory Commission (NRC) review and approval letter is included with Reference 1. Subsection 6.4.1.1.1 discusses the long-term LOCA mass and energy releases generated for this Power Uprate Program. The results of this analysis were provided for use in the containment integrity analysis (see subsection 6.4.1.2) and equipment qualification (EQ) (Balance-of-Plant [BOP] Report, Section 3.14).

The short-term LOCA-related mass and energy releases are used as input to the subcompartment analyses. These analyses are performed to ensure that the walls of a subcompartment can maintain their structural integrity during the short pressure pulse (generally less than 3 seconds) accompanying a high-energy line pipe rupture within that subcompartment. The subcompartments that are typically evaluated include the steam generator compartment, the reactor cavity region, and the pressurizer compartment. Kewaunee is approved for leak-before-break (LBB) (References 2, 3, 4, and 5). Any changes associated with the power uprating are typically offset by the LBB benefit of using the smaller Reactor Coolant System

(RCS) nozzle breaks. This demonstrates that the current licensing bases for the subcompartments would remain bounding. The critical mass flux correlation utilized in the SATAN computer program (Reference 6) was used to conservatively estimate the impact of the changes in RCS temperatures on the short-term releases. The evaluation showed that the design basis releases would remain bounding due to LBB. Subsection 6.4.1.1.2 discusses the short-term evaluation conducted for this program.

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

The mass and energy release rates described in this section form the basis of further computations to evaluate the containment following the postulated accident. Discussed in this section are the long-term LOCA mass and energy releases for the hypothetical double-ended pump suction (DEPS) rupture with minimum safeguards and maximum safeguards and double-ended hot leg (DEHL) rupture break cases. The mass and energy releases for these three cases are shown in Tables 6.4-4 through 6.4-17. These three LOCA cases are used for the long-term containment integrity analyses in subsection 6.4.1.2. The basis for using these three cases is discussed in subsections 6.4.1.1.1.5 and 6.4.1.1.1.6.

6.4.1.1.1.1 Input Parameters and Assumptions

The mass and energy release analysis is sensitive to the assumed characteristics of various plant systems, in addition to other key modeling assumptions. Where appropriate, bounding inputs are utilized and instrumentation uncertainties are included. For example, the RCS operating temperatures are chosen to bound the highest average coolant temperature range of all operating cases and a temperature uncertainty allowance of (+6.0°F) is then added. Nominal parameters are used in certain instances. For example, the RCS pressure in this analysis is based on a nominal value of 2250 psia plus an uncertainty allowance (+50.1 psi). All input parameters are chosen consistent with accepted analysis methodology.

Some of the most critical items are the RCS initial conditions, core decay heat, safety injection flow, and primary and secondary metal mass and steam generator heat release modeling. Specific assumptions concerning each of these items are discussed in the following paragraphs. Tables 6.4-1 through 6.4-3 present key data assumed in the analysis.

The core rated power of 1782.6 MWt adjusted for calorimetric error (that is, 100.6 percent of 1772 MWt) was used in the analysis. As previously noted, the use of RCS operating

The core rated power of 1782.6 MWt adjusted for calorimetric error (that is, 100.6 percent of 1772 MWt) was used in the analysis. As previously noted, the use of RCS operating temperatures to bound the highest average coolant temperature range were used as bounding analysis conditions. The use of higher temperatures is conservative because the initial fluid energy is based on coolant temperatures that are at the maximum levels attained in steady-state operation. Additionally, an allowance to account for instrument error and deadband is reflected in the initial RCS temperatures. The selection of 2250 psia as the limiting pressure is considered to affect the blowdown phase results only, since this represents the initial pressure of the RCS. The RCS rapidly depressurizes from this value until the point at which it equilibrates with containment pressure.

The rate at which the RCS blows down 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. Thus, 2250 psia plus uncertainty was selected for the initial pressure as the limiting case for the long-term mass and energy release calculations.

The selection of the fuel design features for the long-term mass and energy release calculation is based on the need to conservatively maximize the energy stored in the fuel at the beginning of the postulated accident (that is, to maximize the core stored energy). The core stored energy that was selected to bound the Westinghouse 422V+ fuel product that will be used at Kewaunee was 4.68 full-power seconds (FPS). The margins in the core stored energy include +15 percent in order to address the thermal fuel model and associated manufacturing uncertainties and the time in the fuel cycle for maximum fuel densification. Thus, the analysis very conservatively accounts for the stored energy in the core.

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

A uniform steam generator tube plugging level of 0 percent was modeled. This assumption maximizes the reactor coolant volume and fluid release by virtue of consideration of the RCS fluid in all steam generator tubes. During the post-blowdown period, the steam generators are active heat sources since significant energy remains in the secondary metal and secondary mass that has the potential to be transferred to the primary side. The 0-percent tube plugging assumption maximizes the heat transfer area and, therefore, the transfer of secondary heat

across the steam generator tubes. Additionally, this assumption reduces the reactor coolant loop resistance, which reduces the ΔP upstream of the break for the pump suction breaks and increases break flow. Thus, the analysis conservatively accounts for the level of steam generator tube plugging (SGTP).

The secondary- to primary-heat transfer is maximized by assuming conservative heat transfer coefficients. This conservative energy transfer is ensured by maximizing the initial internal energy of the inventory in the steam generator secondary side. This internal energy is based on full-power operation plus uncertainties.

Regarding safety injection flow, the mass and energy release calculation considered configurations, component failures, and offsite power assumptions to conservatively bound respective alignments. The cases include:

- A minimum safeguards case (one high-head safety injection [HHSI] and one low-head safety injection [LHSI] pumps) (see Table 6.4-2)
- A maximum safeguards case, (two HHSI and two LHSI pumps) (see Table 6.4-3)

In addition, the containment backpressure is assumed to be equal to the containment design pressure. This assumption was shown in Reference 1 to be conservative for the generation of mass and energy releases.

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

- Maximum expected operating temperature of the RCS (100-percent full-power conditions)
- Allowance for RCS temperature uncertainty (+6.0°F)
- Margin in RCS volume of 3 percent (which is composed of 1.6-percent allowance for thermal expansion, and 1.4-percent allowance for uncertainty)
- Core rated power of 1772 MWt
- Allowance for calorimetric error (+0.6 percent of power)

- Conservative heat transfer coefficients (that is, steam generator primary/secondary heat transfer, and RCS metal heat transfer)
- Allowance in core stored energy for effect of fuel densification
- A margin in core stored energy (+15 percent to account for manufacturing tolerances)
- An allowance for RCS initial pressure uncertainty (+50.1 psi)
- A maximum containment backpressure equal to design pressure (46.0 psig)
- SGTP leveling (0-percent uniform)
  - Maximizes reactor coolant volume and fluid release
  - Maximizes heat transfer area across the steam generator tubes
  - Reduces coolant loop resistance, which reduces the ΔP upstream of the break for the pump suction breaks and increases break flow

Thus, based on the previously discussed conditions and assumptions, an analysis of Kewaunee was made for the release of mass and energy from the RCS in the event of a LBLOCA at 1782.6 MWt.

6.4.1.1.1.2 Description of Analyses

The evaluation model used for the long-term LOCA mass and energy release calculations is the March 1979 model described in Reference 1.

This report section presents the long-term LOCA mass and energy releases generated in support of the Kewaunee 7.4-percent Power Uprate Program. These mass and energy releases are then subsequently used in the containment integrity analysis and EQ evaluation.

6.4.1.1.1.3 Loss-of-Coolant Accident 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, for the LOCA mass and energy analysis, 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.

2. Refill – the period of time when the 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. Thus, the refill period is conservatively neglected in the mass and energy release calculation.

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

4. Post-reflood (FROTH) – describes the period following the reflood phase. 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 exiting the break as steam. After the broken loop steam generator cools, the break flow becomes two phase.

6.4.1.1.1.4 Computer Codes

The Reference 1 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 Kewaunee.

SATAN VI calculates blowdown, the first portion of the thermal-hydraulic transient following break initiation, including pressure, enthalpy, density, mass and 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 primary coolant system has depressurized (blowdown) due to the loss of water through the break and when water supplied by the ECCS refills the reactor vessel and provides cooling to the core. The most important feature of WREFLOOD is the steam/water mixing model (see subsection 6.4.1.1.1.8.2).

FROTH 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.

EPITOME continues the FROTH post-reflood portion of the transient from the time at which the secondary 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.

6.4.1.1.1.5 Break Size and Location

Generic studies have been performed and documented in Reference 1 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 a pipe rupture for mass and energy release purposes:

- Hot leg (between vessel and steam generator)
- Cold leg (between pump and vessel)
- Pump suction (between steam generator and pump)

The break locations analyzed for this program are the DEPS rupture (10.46 ft^2) and the DEHL rupture (9.154 ft^2). Break mass and energy releases have been calculated for the blowdown, reflood, and post-reflood phases of the LOCA for the DEPS cases. For the DEHL case, the releases were calculated only for the blowdown. The following information provides a discussion on each break location.

The DEHL rupture 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 vents directly to containment bypassing the steam generators. 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). Therefore, only the mass and energy releases for the hot leg break blowdown phase are calculated and presented in this section of the report.

The cold leg break location has also 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, in general, less limiting than that for the pump suction break. During reflood, the flooding rate is greatly reduced and the energy release rate into the containment is reduced. Therefore, the cold leg break is bounded by other breaks and no further evaluation is necessary.

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. Thus, only the DEHL and DEPS cases are used to analyze long-term LOCA containment integrity.

6.4.1.1.1.6 Application of Single-Failure Criterion

An analysis of the effects of the single-failure criterion has been performed on the mass and energy release rates for each break analyzed. An inherent assumption in the generation of the mass and energy release is that offsite power is lost coincident with the pipe rupture. This results in the actuation of the emergency diesel generators. Operation of the diesel generators

delays the operation of the Safety Injection System (SIS) that is required to mitigate the transients. This is not an issue for the blowdown period, which is limited by the DEHL break.

Two cases have been analyzed to assess the effects of a single failure. The first case assumes minimum safeguards SI flow based on the postulated single failure of an emergency diesel generator. This results in the loss of one train of safeguards equipment. The other case assumes maximum safeguards SI flow based on no postulated failures that would impact the amount of ECCS flow (note that the single failure for this scenario would be a containment heat removal system component discussed in subsection 6.4.1.2). The analysis of the cases described provides confidence that the effect of credible single failures is bounded.

6.4.1.1.1.7 Acceptance Criteria for Analyses

A large break loss-of-coolant accident is classified as an American Nuclear Society (ANS) Condition IV event, an infrequent fault. To satisfy the NRC acceptance criteria presented in the *Standard Review Plan* (SRP), Section 6.2.1.3, the relevant requirements are the following:

- 10CFR50, Appendix A
- 10CFR50, Appendix K, paragraph I.A

To meet these requirements, the following must be addressed:

- Break size and location
- Calculation of each phase of the accident
- Sources of energy

The description of the modeling of each phase of the transient with the March 1979 model (Reference 1) and the individual sources of energy are provided in the following section. The limiting break size and location was discussed in subsection 6.4.1.1.1.5.

6.4.1.1.1.8 Mass and Energy Release Data

6.4.1.1.1.8.1 Blowdown Mass and Energy Release Data

The SATAN-VI code is used for computing the blowdown transient. The code utilizes the control volume (element or nodal) approach with the capability for modeling a large variety of plant

specific 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 1. A comparison of these two critical flow correlations is shown in Section III-1 of Reference 6.

Table 6.4-4 presents the calculated mass and energy release for the blowdown phase of the DEHL break for Kewaunee. For the hot leg break mass and energy release tables, break path 1 refers to the mass and energy exiting from the reactor vessel side of the break; break path 2 refers to the mass and energy exiting from the steam generator side of the break.

Table 6.4-7 presents the calculated mass and energy releases for the blowdown phase of the DEPS 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.

6.4.1.1.1.8.2 Reflood Mass and Energy Release Data

The WREFLOOD code is used for computing the reflood transient. 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 SI 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 ECCS 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 1 mass and energy release evaluation model in recent analyses (Reference 7). Even though the Reference 1 model credits steam/water mixing only in the intact loop and not in the broken loop, the justification, applicability, and NRC approval for using the mixing model in the broken loop has been documented (Reference 7). Moreover, this assumption is supported by test data and is further discussed below.

The model assumes a complete mixing condition (that is, thermal equilibrium) for the steam/water interaction. The complete mixing process, however, 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 and not the atmosphere.)

The most applicable steam/water mixing test data have been reviewed for validation of the containment integrity reflood steam/water mixing model. This data was generated in 1/3-scale tests (Reference 8), which are the largest scale data available and thus most clearly simulates 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.

A group of 1/3-scale steam/water mixing tests discussed in Reference 8 corresponds directly to containment integrity reflood conditions. The injection flow rates for 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 1. 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 pump suction double-ended rupture 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 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 that is condensed that is taken credit for in this analysis. 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 are contained in References 1 and 7.

Tables 6.4-8 and 6.4-13 present the calculated mass and energy releases for the reflood phase of the pump suction double-ended rupture, minimum safeguards, and maximum safeguards cases, respectively.

The transient response of the principal parameters during reflood are given in Tables 6.4-9 and 6.4-14 for the DEPS cases.

6.4.1.1.1.8.3 Post-Reflood Mass and Energy Release Data

The FROTH code (Reference 6) is used for computing the post-reflood transient. The FROTH code calculates the heat release rates resulting from a two-phase mixture 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. However, the steam generators contain a secondary inventory at an enthalpy that is much higher than the primary side. Therefore, there is a significant amount of reverse heat transfer that 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. During the FROTH calculation, ECCS injection is addressed for both the injection phase and the recirculation phase. The FROTH code calculation stops when the secondary side equilibrates to the saturation temperature (T_{sat}) at the containment design pressure, after this point the EPITOME code completes the steam generator depressurization (see subsection 6.4.1.1.1.8.5 for additional information).

The methodology for the use of this model is described in Reference 1. The mass and energy release rates are calculated by FROTH and EPITOME until the time of containment depressurization. After containment depressurization (14.7 psia), the mass and energy release available to containment is generated directly from core boil-off/decay heat.

Tables 6.4-10 and 6.4-15 present the two-phase post-reflood mass and energy release data for the pump suction double-ended break cases.

6.4.1.1.1.8.4 Decay Heat Model

On November 2, 1978, the Nuclear Power Plant Standards Committee (NUPPSCO) of the ANS approved ANS Standard 5.1 (Reference 9) for the determination of decay heat. This standard was used in the mass and energy release model for Kewaunee. Table 6.4-18 lists the decay heat curve used in the Kewaunee steam generator replacement mass and energy release analysis.

Significant assumptions in the generation of the decay heat curve for use in the LOCA mass and energy releases analysis include the following:

- The decay heat sources considered are fission product decay and heavy element decay of U-239 and Np-239.
- The decay heat power from fissioning isotopes other than U-235 is assumed to be identical to that of U-235.
- The 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 Reference 9.
- The fuel has been assumed to be at full power for 10^8 seconds.
- 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.

Based upon NRC staff review, (*Safety Evaluation Report* [SER] of the March 1979 evaluation model [Reference 1]), use of the ANS Standard-5.1, November 1979, decay heat model was approved for the calculation of mass and energy releases to the containment following a LOCA.

6.4.1.1.1.8.5 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 the T_{sat} at the containment design pressure. After the FROTH calculations, the EPITOME code continues the FROTH calculation for steam generator cooldown removing steam generator secondary energy at different rates (that is, first- and second-stage rates). The first-stage rate is applied 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. Then the second-stage rate is used until the final depressurization, when the secondary reaches the reference temperature of T_{sat} at 14.7 psia, or 212°F. The heat removal of the broken loop 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. 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 during the first heat removal stage is based on the final heat removal rate calculated by FROTH. The steam generator energy available to be released during the first stage interval is determined by calculating the difference in secondary energy available at the containment design pressure and that at the (lower) user-specified intermediate equilibration pressure, assuming saturated conditions. This energy is then divided by the first-stage energy removal rate, resulting in an intermediate equilibration time. At this time, the rate of energy release drops substantially to the second-stage rate. The second-stage rate is determined as the fraction of the difference in secondary energy available between the intermediate equilibration and final depressurization at 212°F, and the time difference from the time of the intermediate equilibration to the user-specified time of the final depressurization at 212°F. With current methodology, all of the secondary energy remaining after the intermediate equilibration is conservatively assumed to be released by imposing a mandatory cooldown and subsequent depressurization down to

atmospheric pressure at 3600 seconds, that is, 14.7 psia and 212°F (the mass and energy balance tables have this point labeled as "Available Energy").

6.4.1.1.1.8.6 Sources of Mass and Energy

The sources of mass considered in the LOCA mass and energy release analysis are given in Tables 6.4-5, 6.4-11, and 6.4-16. These sources are the RCS, accumulators, and pumped SI.

The energy inventories considered in the LOCA mass and energy release analysis are given in Tables 6.4-6, 6.4-12, and 6.4-17. The energy sources are the following.

- RCS water
- Accumulator water (both inject)
- Pumped SI water
- Decay heat
- Core-stored energy
- RCS 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)

The analysis used the following energy reference points:

- Available energy: 212°F; 14.7 psia (energy available that could be released)
- Total energy content: 32°F; 14.7 psia (total internal energy of the RCS)

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
- Time of full depressurization (3600 seconds)

In the mass and energy release data presented, no Zirc-water reaction heat was considered because the cladding temperature does not rise high enough for the rate of the Zirc-water reaction heat to proceed.

The sequence of events for the LOCA transients are shown in Tables 6.4-21 through 6.4-23.

6.4.1.1.1.8.7 Conclusions

The consideration of the various energy sources listed in subsection 6.4.1.1.1.8.6 for the long-term mass and energy release analysis provides assurance that all available sources of energy have been included in this analysis. By addressing all available sources of energy as well as the limiting break size and location and the specific modeling of each phase of the long term LOCA transient , the review guidelines presented in SRP Section 6.2.1.3 have been satisfied. The results of this analysis are provided for use in the containment integrity analysis documented in subsection 6.4.1.2 and the EQ evaluation documented in Reference 10, Section 3.14.

6.4.1.1.2 Short-Term Loss-of-Coolant Accident Mass and Energy Releases

6.4.1.1.2.1 Introduction and Background

The impact of the 7.4-percent power uprate at KNPP on the short-term LOCA mass and energy releases is described in this section. The discussion will encompass the description of the aspects that result in conservative initial conditions, the general acceptance criteria for calculating short-term LOCA mass and energy releases, a comparison of the uprated RCS operating parameters to the current licensing parameters, and the evaluation of the impact of

the pertinent parameters for the uprated core power of 1772 MWt. Provided that the short-term LOCA mass and energy releases are not impacted by the Power Uprate Program, there would not be any impact on the existing subcompartment pressurization analyses.

6.4.1.1.2.2 Accident Description

The subcompartment analysis is performed to ensure that the walls of a subcompartment can maintain their structural integrity during the short pressure pulse (generally less than 3 seconds) that accompanies a high-energy line pipe rupture within the subcompartment. The magnitude of the pressure differential across the walls is a function of several parameters, which include the blowdown mass and energy release rates, the subcompartment volume, vent areas, and vent flow behavior. The blowdown mass and energy release rates are affected by the initial RCS temperature conditions.

6.4.1.1.2.3 Input Parameters and Assumptions

The short-term releases are linked directly to the critical mass flux, which increases with decreasing temperatures. The increase in mass flux is created by an increase in the differential pressure between the reservoir pressure and the saturation pressure at the RCS operating conditions. The critical mass flux is the maximum break flow per cross-sectional flow area based on a reservoir pressure and saturation temperature. The short-term LOCA releases would be expected to increase due to any reductions in RCS coolant temperature conditions.

It is noted that any changes in initial RCS volume and steam generator liquid/steam mass and volume from the proposed parameters for the 7.4-percent Power Uprate Program have no effect on the releases because of the short duration of the postulated accident. The only change that needs to be addressed for this short-term LOCA mass and energy evaluation is the impact of the 7.4-percent Power Uprate Program on the RCS coolant temperatures.

The comparison of the RCS operating conditions for the lower portion of the T_{avg} operating window for the 7.4-percent Power Uprate Program and the current licensed parameters showed that the temperature window from the current licensed parameters would bound the Power Uprate Program. Short-term releases are controlled by density effects, so the lower temperatures from the current licensed operating conditions are more limiting. The comparison of the power uprate data and the current licensed parameters is shown in Table 6.4-19.

6.4.1.1.2.4 Description of Model

Short-term blowdown transients are characterized by a peak mass and energy release rate that occurs during a subcooled condition, thus the Zaloudek correlation (Reference 6), which models this condition, is currently used in the short-term LOCA mass and energy release analyses with the SATAN computer program. This correlation appears in the critical flow routine of SATAN (Reference 6) in the following form:

$$G_{crit} = CK1 * SQRT[K2 * (P - C_1 * P_{sat})]$$

where:

- CK1 = constant
- K2 = constant
- C_1 = constant
- P = reservoir pressure in psia (RCS normal operating pressure with uncertainties)
- P_{sat} = saturation pressure in psia (at the RCS temperature of interest with uncertainties)
- G_{crit} = critical mass flux in lbm/sec-ft^2

This calculation can be used to conservatively evaluate the impact of the changes in RCS temperature conditions due to the 7.4-percent power uprate on the short-term releases from the current licensed operating conditions at KNPP. This is accomplished by maximizing the reservoir pressure and minimizing the RCS inlet and outlet temperatures (which maximizes G_{crit}). Using a lower temperature results in a lower P_{sat}, and a higher G_{crit}. Since this maximizes the change in short-term LOCA mass and energy releases, data representative of the lowest inlet and outlet temperatures with uncertainty subtracted is used for the evaluation for the Power Uprate Program.

6.4.1.1.2.5 Acceptance Criteria

A LBLOCA classified as an ANS Condition IV event, an infrequent fault. To satisfy the NRC acceptance criteria presented in the SRP, Section 6.2.1.3, for short-term LOCA mass and energy releases, the relevant requirements for calculating the releases are the following:

- The mass and energy releases must be calculated with an analytical approach similar to those of an approved ECCS analysis, such as SATAN-V.

- The discharge coefficient used in the applicable choked flow correlation should be equal to 1.0.

- An alternate approach is to assume a constant blowdown profile using the initial conditions with an acceptable choked flow correlation.

6.4.1.1.2.6 Results

No short-term LOCA mass and energy releases are calculated for the Power Uprate Program at Kewaunee because the comparison of the low end of the current licensed temperature window bounds the proposed temperature window for the Power Uprate Program (see Table 6.4-19). In addition, per References 2, 3, 4, and 5, Kewaunee is analyzed and NRC-approved for LBB. LBB eliminates the dynamic effects of postulated primary loop pipe ruptures from the design basis. This means that the current breaks (a double-ended circumferential rupture of the reactor coolant cold leg break for the steam generator compartments, and a reactor vessel inlet break for the reactor cavity region) no longer have to be considered for the short-term effects. Since the RCS piping has been eliminated from consideration, the large-branch nozzles must be considered for design verification. This includes the surge line, accumulator line, and the RHR line. These smaller breaks, which are outside the cavity region, would result in minimal asymmetric pressurization in the reactor cavity region. Additionally, compared to the large RCS double-ended ruptures, the differential loadings are significantly reduced. For example, the reduction in the flow area between the DEHL break and the double-ended surge line break is greater than 90 percent, and the reduction in the flow area between the double-ended cold-leg break and the double-ended accumulator line break is greater than 80 percent. This means that the peak differential pressure that could be exerted across an adjacent wall can be dramatically reduced if the nozzle breaks are considered. Therefore, since Kewaunee is approved for LBB, and the Power Uprate Program conditions are less limiting than the current licensed temperature conditions, the original licensing basis subcompartment analyses that consider breaks in the RCS primary loop piping would remain bounding.

6.4.1.1.2.7 Conclusions

The short-term LOCA-related mass and energy releases for Kewaunee have been reviewed to assess the effects associated with the Kewaunee Power Uprate Program. The results show that the low end of the RCS temperature window proposed for the Power Uprate Program is less limiting than the low end of the current licensed operating temperature window. Thus, the current design basis short-term mass and energy releases are not impacted by the 7.4-percent Power Uprate Program at Kewaunee. In addition, it is noted that the approval of LBB methods provides the basis that the original results from the design basis double-ended ruptures of the primary loop piping would remain bounding.

6.4.1.2 Loss-of-Coolant Accident Containment Response Analysis

The KNPP containment system is designed so that for all LOCA break sizes, up to and including the double-ended severance of a reactor coolant pipe, the containment peak pressure remains below the design pressure. This section details the containment response subsequent to a hypothetical LOCA. The containment response analysis uses the long-term LOCA mass and energy release data from subsection 6.4.1.1.

The containment response analysis demonstrates the acceptability of the containment safeguards systems to mitigate the consequences of a LOCA inside containment. The impact of LOCA mass and energy releases on the containment pressure is addressed to ensure that the containment pressure remains below its design pressure at the licensed core power conditions. In support of equipment design and licensing criteria (for example, qualified operating life), with respect to post-accident environmental conditions, long-term containment pressure and temperature transients are generated to conservatively bound the potential post-LOCA containment conditions.

6.4.1.2.1 Accident Description

A break in the primary RCS piping causes a loss-of-coolant, which results in a rapid release of mass and energy to the containment atmosphere. Typically the blowdown phase for the large LOCA events (DEHL, cold leg, or pump suction pipe breaks) is over in less than 30 seconds. This large and rapid release of high-energy, two-phase fluid causes a rapid increase in the containment pressure, which results in the actuation of the emergency fan cooler and containment spray systems.

The RCS accumulators begin to refill the lower plenum and downcomer of the reactor vessel with water after the end of blowdown. The reflood phase begins after the vessel fluid level reaches the bottom of the fuel. During this phase, the core is quenched with water from both the accumulators and pumped SI. The quenching process creates a large amount of steam and entrained water that is released to containment through the break. This two-phase mixture would have to pass through the steam generators and also absorb energy from the secondary side coolant if the break were located in the cold leg or pump suction piping.

The LOCA mass and energy release decreases with time as the system cools. Core decay heat is removed by nucleate boiling after the reflood phase is complete. The core fluid level is maintained by pumping water back into the vessel from either the SI or sump recirculation system. The containment heat removal systems continue to condense steam and slowly reduce the containment pressure and temperature over time.

6.4.1.2.2 Input Parameters and Assumptions

A series of analyses, using different break sizes and locations, was performed for the LOCA containment response. Subsection 6.4.1.1 documented the mass and energy releases for the DEPS and DEHL breaks. The DEPS break cases were run with both minimum and maximum safeguards. The minimum safeguards case assumes a diesel train failure. This assumption leaves one of two containment spray pumps and two of four containment fan coil units (CFCUs) available for containment heat removal. Two single-failure cases were modeled for the maximum safeguards DEPS case. In the first case, one of the two containment spray pumps was assumed to fail, and in the second case one of the four CFCUs was assumed to fail. Only one RHR heat exchanger was credited for recirculation cooling in all of the DEPS cases.

The containment initial conditions (pressure, temperature, and humidity) assumed for the containment response analyses are shown in Table 6.4-20. Also, values for the initial temperature of the service water (SW) and refueling water storage tank (RWST) are assumed. All of these values are chosen conservatively.

Table 6.4-20 also includes the containment cooling system assumptions used in the analysis. The CFCU performance data (heat removal as a function of containment temperature) is shown in Table 6.4-26.

The major assumptions made in the containment response analysis are listed below:

- The LOCA mass and energy release input to the containment model is described in subsection 6.4.1.1.

- Homogeneous mixing is assumed. The steam-air mixture and the water phases each have uniform properties. More specifically, thermal equilibrium between the air and the steam is assumed. However, this does not imply thermal equilibrium between the steam-air mixture and the water phase.

- Air is taken as an ideal gas, while compressed water and steam tables are employed for water and steam thermo-dynamic properties.

- For the blowdown portion of the LOCA analysis, the discharge flow separates into steam and water phases at the breakpoint. The saturated water phase is at the total containment pressure, while the steam phase is at the partial pressure of the steam in the containment. Steam and water releases are input separately for the post-blowdown portion of the LOCA analysis.

- The saturation temperature at the steam partial pressure is used for heat transfer to the heat sinks and the fan coolers.

6.4.1.2.3 Description of the Kewaunee GOTHIC Containment Model

Calculation of the containment pressure and temperature is accomplished by use of the digital computer code GOTHIC. A description of the basic Kewaunee containment model is provided in WCAP-15427 (Reference 10). WCAP-15427 also documents benchmark comparisons with the previous design basis accident CONTEMPT (for MSLB events) and COCO (for LOCA events) containment models. The benchmark comparisons were made using GOTHIC version 5.0e.

GOTHIC version 7.0p2 was used for this analysis. Changes were made to the basic model described in Reference 10 to be able to use the new Mist Diffusion Layer Model (MDLM) heat and mass transfer option and to improve the modeling of drops and water on the floors. These modifications and their impact on the benchmark comparisons are described in NMC Letter NRC-02-082 (Reference 11).

The heat sink data for the Kewaunee containment model is summarized in Table 6.4-24. The thermo-physical properties of the containment heat sink materials are shown in Table 6.4-25.

An improved recirculation heat removal system model was added to the Kewaunee containment model to more accurately determine the RHR and CCWS temperatures during sump recirculation for the LOCA analysis. The containment peak pressure and temperature occur prior to the transfer to recirculation; the improved recirculation model affects the long-term LOCA containment pressure and temperature response.

The recirculation system model uses GOTHIC component models for the RHR and CCW heat exchangers and the CCW pump. The GOTHIC heat exchanger input data was taken from the heat exchanger specification sheets. The heat exchanger models were benchmarked against design conditions and output data from the COCO code.

The RHRS model uses a flow boundary condition to draw suction from the sump through the RHR heat exchanger. The RHR heat exchanger transfers energy from the sump to the CCWS. The CCWS model calculates the secondary side inlet conditions for the RHR heat exchanger. The CCW pump provides flow through the CCW heat exchanger to transfer heat to the Service Water System (SWS). The service water flow rate and temperature are boundary conditions to the CCW heat exchanger model. The CCW heat exchanger outlet flow is split between the RHR heat exchanger and the other CCW heat loads. The other heat loads are modeled using a constant heat source.

6.4.1.2.4 Acceptance Criteria

- The containment response for design-basis containment integrity is an American Nuclear Society (ANS) Condition IV event, an infrequent fault.

The Kewaunee plant was originally licensed with the USAR containing text from the interim criteria that was derived from the draft Atomic Industrial Forum (AIF) GDCs. The Kewaunee SER indicated that the operating license was granted because "...the plant design generally conforms to the intent...." of the requirements of 10CFR50 Appendix A. The specific interim criteria was:

- Interim GDC 10 - Containment
- Interim GDC 49 - Containment Design Basis
- Interim GDC 52 - Containment Heat Removal Systems

The Westinghouse containment analysis methodology satisfies the current NRC acceptance criteria from 10CFR50, Appendix A and SRP 6.2.1.1.A. The relevant general design criteria (GDC) requirements that are met are as follows:

- GDC 16 and GDC 50: To satisfy the requirements of GDC 16 and GDC 50, the peak calculated containment pressure should be less than the containment design pressure of 46 psig, considering the most severe single failure.

- GDC 38 and GDC50: To satisfy the requirements of GDC 38 and GDC 50, the calculated pressure at 24 hours should be less than 50 percent of the peak calculated value. (This is related to the criteria for doses at 24 hours.)

6.4.1.2.5 Analysis Results

The sequence of events for the DEPS-MIN, DEPS-MAX, and DEHL cases is shown in Tables 6.4-21 through 6.4-23. The containment response calculations for the DEPS cases were performed for 1 million seconds (approximately 11.6 days). Since the steam generator secondary side energy is effectively isolated for hot leg breaks, the containment response calculation for the DEHL case was performed for the blowdown phase only (approximately 20 seconds).

The containment pressure, steam temperature, and water (sump) temperature profiles from each of the LOCA cases are shown in Figures 6.4-1 through 6.4-12. Table 6.4-27 summarizes the LOCA containment response results for the three cases studied.

6.4.1.2.5.1 Double-Ended Hot Leg Break

This analysis assumes a loss-of-offsite power coincident with a double-ended rupture of the RCS piping between the reactor vessel outlet nozzle and the steam generator inlet (that is, a break in the RCS hot leg). The associated single-failure assumption is the failure of a diesel to start, resulting in one train of low-head SI and containment safeguards equipment being available. This combination results in a minimum set of safeguards being available. Furthermore, loss-of-offsite power delays the actuation times of the safeguards equipment due to the required diesel-startup time after receipt of the SI signal.

Figures 6.4-1 through 6.4-3 show the containment pressure, atmosphere temperature, and sump temperature transients. The postulated RCS break results in a rapid release of mass and energy to the containment with a resulting rapid rise in both the containment pressure and temperature. This rapid rise in containment pressure results in the generation of a containment high pressure signal at 0.22 seconds and a containment high-high pressure signal at 3.1 seconds. The containment pressure continues to rise rapidly in response to the release of mass and energy until the end of blowdown. The peak pressure for this case was 44.4 psig at 19.9 seconds. The sequence of events for this case is shown in Table 6.4-23.

The end of blowdown marks a time when the initial inventory in the RCS has been exhausted and the process of filling the RCS downcomer in preparation for reflood has begun. Since the reflood for a hot leg break is very fast due to the low resistance to steam venting posed by the broken hot leg, Westinghouse terminates hot leg break mass and energy release transients at end of blowdown. The basis for this is discussed in subsection 6.4.1.1.

6.4.1.2.5.2 Double-Ended Pump Suction Break with Minimum Safeguards

This analysis assumes a loss-of-offsite power coincidence with a double-ended rupture of the RCS piping between the steam generator outlet and the RCS pump inlet (suction). The associated single-failure assumption is the failure of a diesel to start, resulting in one train of SI pumps and containment safeguards equipment being available. This combination results in a minimum set of safeguards being available. Furthermore, loss-of-offsite power delays the actuation times of the safeguards equipment due to the required diesel-startup time after receipt of the SI signal.

Figures 6.4-4 through 6.4-6 show the containment pressure, temperature, and sump temperature transients. Table 6.4-21 shows the detailed sequence of events.

The postulated RCS break results in a rapid release of mass and energy to the containment with a resulting rapid rise in both the containment pressure and temperature. This rapid rise in containment pressure results in the generation of a containment high pressure signal at 0.22 seconds and a containment high-high pressure signal at 2.75 seconds. The containment pressure continues to rise rapidly in response to the release of mass and energy until the end of the blowdown phase.

The end of blowdown marks a time when the initial inventory in the RCS has been exhausted and the process of filling the RCS downcomer in preparation for reflood has begun. The accumulators begin to inject during the blowdown phase and empty during the reflood phase. After the accumulators empty at approximately 38 seconds, the nitrogen cover gas begins to be released to the containment. The containment pressure reaches an overall peak of 42.7 psig. This occurs during the early portion of the reflood phase (at 58.1 seconds) prior to any heat removal by the CFCUs or containment spray.

The LOCA mass and energy release model described in subsection 6.4.1.1 conservatively forces the steam generator secondary energy to be released at a very high rate. The combination of heat removal by the heat sinks, the containment fan coolers, and the CS helps to absorb the core and steam generator energy releases. This causes the containment pressure to slowly decrease for the remainder of the reflood phase.

The containment pressure begins to increase as the heat sinks begin to saturate after reflood. The steam generator secondary energy release rate decreases as the steam generator pressure comes into equilibrium with the containment pressure. The reduction in energy release rate causes the containment pressure to begin decreasing again. Containment pressure continues to decrease until the injection sprays are terminated at 3953 seconds.

The low-head SI is realigned for cold leg recirculation at 6382 seconds. The temperature of the water entering the core increases causing the steaming rate to increase slightly. The containment pressure continues to decrease due to lower decay heat, steam generator energy release, and continued CFCU cooling. This trend continues to the end of the transient at 1.0E+06 seconds.

6.4.1.2.5.3 Double-Ended Pump Suction Break with Maximum Safeguards

The DEPS break with maximum safeguards has a transient history very similar to the minimum safeguards case discussed in subsection 6.4.5.2. Figures 6.4-7 through 6.4-9 provide the containment pressure, steam temperature, and sump temperature for the spray pump failure case. Figures 6.4-10 through 6.4-12 provide the same parameters for the CFCU failure case. Table 6.4-22 provides the key sequence of events, and Table 6.4-27 shows that a peak pressure of 42.3 psig at 58.1 seconds was calculated.

6.4.1.2.6 Conclusions

The LOCA containment response analyses have been performed as part of the Power Uprate Program for Kewaunee. The analyses included long-term pressure and temperature profiles for each case. The calculated peak containment pressure was less than the design pressure (46 psig) for all cases. In addition, the containment pressure was less than 50 percent of the peak value within 24 hours. Based on the results, all applicable containment integrity acceptance criteria for Kewaunee have been met.

6.4.2 Main Steamline Break Containment Integrity

6.4.2.1 Main Steamline Break Mass and Energy Releases Inside Containment

6.4.2.1.1 Introduction and Background

To satisfy the requirement that the mass and energy release to the containment from the limiting steamline break does not cause failure of the containment structure, the mass and energy release from the limiting steamline break must be calculated and the impact on the containment evaluated. Subsection 6.4.2.1 of this report describes the calculation of the mass and energy releases, and subsection 6.4.2.2 describes the calculation of the subsequent impact on the containment.

A steam line break inside containment results in an uncontrolled steam release from a steam generator. The steam release results in an initial increase in steam flow that decreases during the accident as the steam pressure falls. The energy removal from the RCS causes a reduction of coolant temperature and pressure. In the presence of a negative coolant temperature coefficient, the cooldown results in a reduction of core shutdown margin. If the most reactive rod control cluster assembly (RCCA) is assumed stuck in its fully withdrawn position, there is an increased probability that the core becomes critical and returns to power. Assuming the most pessimistic combination of circumstances, which may lead to power generation following a steam line break, the core is ultimately shut down by boric acid injection delivered by the ECCS.

A return to power following a steam line break is a concern due mainly to the high hot channel factors that exist when the most reactive RCCA is assumed to be stuck in its fully withdrawn position. Additionally, a return to power can increase the mass and energy release from the faulted steam generator, which can challenge the containment design requirements. The impact

of the release depends on the plant configuration at the time of the break, plant response to the break, and the size and location of the break. Because of the interrelationship among many of the factors that influence steamline break mass and energy releases and because of the necessity to accommodate the conditions of the Power Uprate and Fuel Upgrade Program, an a-priori determination of a single limiting case with respect to mass and energy releases cannot be made. Therefore, it is necessary to analyze the steamline break event inside containment for different break sizes, locations, initial power levels, and plant configurations.

6.4.2.1.2 Input Parameters and Assumptions

Each steam line has a fast-closing main steam isolation valve (MSIV) with a downstream non-return check valve. These four valves prevent blowdown of more than one steam generator for any break location even if one valve fails to close. For example, in the case of a break upstream of the MSIV in one line, closure of either the non-return check valve in that line or the MSIV in the other line will prevent blowdown of the other steam generator. This arrangement precludes blowdown of more than one steam generator inside the containment and, therefore, prevents structural damage to the containment.

Each steam line contains a 16-inch-diameter venturi-type flow restrictor inside the containment. Additionally, each steam generator possesses a 16-inch-diameter venturi-type flow restrictor integral to the steam generator outlet nozzle. The flow restrictors serve to limit the rate of release of steam. Because of the integral steam generator flow restrictors, the need to specifically analyze breaks upstream of the steamline flow restrictor is precluded, making the releases independent of break location and establishing a maximum break size of 1.4 ft^2.

There are four major factors that influence the release of mass and energy following a steam line break: the initial steam generator fluid inventory, primary-to-secondary heat transfer, protective system operation, and the state of the secondary fluid blowdown. The following is a list of plant conditions and configurations that determine the magnitude of the influence of each of these factors.

- Plant power level
- Main feedwater system design
- Auxiliary Feedwater (AFW) System design
- Break type, break area, break location (prior to integral steam generator flow restrictors)

- Availability of offsite power
- Steam generator design
- Steam system failures
- Steam generator reverse heat transfer and RCS metal heat capacity

All of these variables are considered in the analyses and are conservatively selected based on the KNPP design. Steam line break case evaluations span the following set of five parameters:

- Power level:

- 0-percent, 30-percent, 70-percent, and 102-percent of 1772-MWt-rated core thermal power

- Break size:

- 0.1 ft^2, 0.5 ft^2, 0.8 ft^2, 1.1 ft^2, and 1.4 ft^2

- Single failures:

  — One feedwater-regulating valve fails to isolate ("R").

  — One MSIV fails to isolate ("M").

  — One containment safeguards train fails to activate ("N").

  Note: One containment safeguard train comprises one internal containment spray train and two containment fan cooler units.

- Offsite power:

  — Cases with and without the availability of offsite power are considered.

- Entrainment:

  — The quality of steam exiting the break is explicitly modeled and is dependent on break size and power level.

Further descriptions of the methods for steam line break analysis are the following:

- The main feedwater flow is calculated using the following assumptions:

  — The feedwater pumps are running at full speed at the start of the transient and are tripped off on the SI signal. A conservative flow coastdown is modeled.

  — The condensate pumps are running at full speed throughout the transient.

  — The regulating valve for the unfaulted loop remains at its initial position until the time at which it strokes to its fully closed position at a rate of 5 percent/second following an isolation signal. At that time, the valve closes instantaneously.

  — The behavior of the regulating valve for the faulted loop is assumed to begin opening at t = 0.0 second at an 8-percent/second rate until the time the isolation signal occurs. It is held at that position until the time at which it strokes to its fully closed position at a rate of 5 percent/second following the isolation signal. At that time, the valve closes instantaneously. For cases with a regulating valve failure, isolation is caused by closing the feedwater isolation valve. The assumption used for the isolation valve is that it begins to close at the time of the isolation signal, from full open at a rate of 1.11 percent/second. The initial opening of the regulating valve is the same as for the case without a regulating valve closure failure.

- The AFW flow split between the two steam generators is modeled. The AFW is initiated, prior to the time for the activation signal, at full capacity and using a conservatively high enthalpy. All three AFW pumps are assumed to be operating.

- The core physics parameters are based on a bounding set corresponding to end-of-cycle (EOC) conditions and minimum Core Operating Limit Report (COLR) shutdown requirements. The scram worth includes having the most reactive rod stuck out.

- The dynamic reactor coolant pump (RCP) model is used, which includes the gravity head and pump heat effects.

- Conservative setpoints and time delays are used throughout.

- No credit is taken for charging flow.

- No credit is taken for SGTP.

- The following considerations are made in modeling the steam lines:

  — The pressure-balancing line is modeled to allow communication between the steam lines in an unrestricted manner.

  — Main steam isolation for the unfaulted loop is assumed to occur instantantly at the time required for the non-return check valve to close in the faulted loop, which is conservatively set to 5 seconds after the break occurs.

  — The MSIV failure is modeled as a failure of the non-return check valve in the faulted loop. Steam flow from the unfaulted loop continues until the MSIV in the unfaulted main steam line closes. A closure assumption of 5 seconds is used for the MSIV. The time from the event initiation until MSIV closure signal receipt, plus signal instrumentation delays as applicable to the accident sequence analyzed, is added to the 5-second MSIV closure time assumption. At the time of the MSIV closure, the entire faulted and unfaulted loop steam lines from the MSIV to the turbine and the pressure-balancing line are added to the total fluid mass and energy input to containment.

- Entrainment analysis methods are used to obtain the time-dependent quality of the failed steam line break flow, which is power-level and break-size dependent. The quality of the unfaulted steam line break flow is conservatively assumed to be 1.0.

- The turbine is tripped at $t = 0.0$ seconds for 0-percent power cases, and prior to, or at the actual time of reactor trip for at-power cases. These are conservative assumptions that maximize the available steam for blowdowns.

- A constant containment backpressure of 14.7 psia is conservatively assumed in all cases.

- A conservatively high RCS flow rate is assumed.

- Steam generator fluid inventory is maximized. Initial steam generator water level is 44-percent narrow range span (NRS) plus uncertainties depending on power level: for 0-percent power: +7-percent NRS, for 30-percent power: +5-percent NRS, for 70-percent power: +3-percent NRS, for 100-percent power: +1-percent NRS.

Table 6.4-28 provides a summary of the input assumptions for each power level.

6.4.2.1.3 Acceptance Criteria

There are no explicit acceptance criteria for the mass and energy releases calculated in this analysis. Implicit acceptance criteria include the following. The calculations must be performed in compliance with the Nuclear Management Company (NMC) topical report applicable to the KNPP (Reference 12) and the applicable fuel management procedures (Reference 13). The mass and energy releases must be suitable for use in the containment integrity analyses of subsection 6.4.2.2.

6.4.2.1.4 Results

Table 6.4-29 provides the sequence of events for the limiting steamline break containment pressure and temperature response case, 14NYY0. The case represents a 1.4 ft^2 break, with one train of the containment safeguards system failed, with entrainment, with offsite power available, and at 0-percent power.

Table 6.4-30 contains the mass and energy release results for limiting case 14NYY0. The tables show the break mass flowrate and the break enthalpy as a function of time. The time steps included in the tables are a representative sample of the entire transient results.

6.4.2.1.5 Conclusions

The mass and energy releases inside containment applicable to the KNPP for the Fuel Upgrade and Power Uprate Program have been calculated. The calculations were performed in compliance with the NMC topical report applicable to KNPP (Reference 12) and the applicable fuel management procedures (Reference 13). The mass and energy releases are suitable for use in the containment integrity analyses of subsection 6.4.2.2 and are sufficiently conservative so as to represent a valid basis for the transition to, and operation with Westinghouse-fueled

cores at 1772-MWt reactor thermal power, with respect to mass and energy releases inside containment.

6.4.2.2 Main Steamline Break Containment Response Analysis

The KNPP containment system is designed so that at any power level with any steam line break size up to, and including the double-ended severance of the main steam line, the containment peak pressure remains below the design pressure. This section details the containment response subsequent to a hypothetical main steam line break (MSLB). The containment response analysis uses the MSLB mass and energy release data from subsection 6.4.2.1.

The containment response analysis demonstrates the acceptability of the containment safeguards systems to mitigate the consequences of a MSLB inside containment. The impact of MSLB mass and energy releases on the containment pressure is addressed to ensure that the containment pressure remains below its design pressure at the uprated core power conditions.

6.4.2.2.1 Accident Description

A break in the main steam line piping causes a rapid release of secondary side mass and energy to the containment atmosphere. This release of high-energy steam causes the containment pressure to increase, which results in the actuation of the CFCUs and containment spray.

The MSLB mass and energy release decreases with time as the system cools. The containment heat removal systems continue to condense steam and slowly reduce the containment pressure and temperature over time.

6.4.2.2.2 Input Parameters and Assumptions

A series of analyses using different break sizes and power levels was performed for the MSLB containment response. Subsection 6.4.2.1 documents the MSLB mass and energy release analyses. Single active failures were considered in these analyses. In one set of cases, the feedwater regulator valve (FRV) was assumed to fail, and in another set of cases the MSIV was assumed to fail. A third set of MSLB mass and energy release cases was run without any additional steam or feedwater system failures. For this set, a single failure of one of the diesel

generators to start and load one of two trains of safety equipment is assumed. Under these conditions, only one of two spray pumps and two of four fan coolers provide containment cooling.

The containment initial conditions (pressure, temperature, and humidity) assumed for the containment response analyses are shown in Table 6.4-20. All of these values are chosen conservatively.

Table 6.4-20 also includes the containment cooling system assumptions used in the analysis. The CFCU performance data (heat removal as a function of containment temperature) is shown in Table 6.4-26.

The major assumptions made in the containment response analysis are listed below:

- The MSLB mass and energy release input to the containment model is described in subsection 6.4.2.1.

- Homogeneous mixing is assumed. The steam-air mixture and the water phases each have uniform properties. More specifically, thermal equilibrium between the air and the steam is assumed. However, this does not imply thermal equilibrium between the steam-air mixture and the water phase.

- Air is taken as an ideal gas, while compressed water and steam tables are employed for water and steam thermo-dynamic properties.

6.4.2.2.3 Description of the Kewaunee GOTHIC Containment Model

The digital computer code GOTHIC was used to calculate the containment pressure and temperature. A description of the basic Kewaunee containment model is provided in WCAP-15427 (Reference 10). It also documents benchmark comparisons with the previous design basis accident CONTEMPT (for MSLB events), and COCO (for LOCA events) containment models. The benchmark comparisons were made using GOTHIC version 5.0e.

GOTHIC version 7.0p2 was used for this analysis. Changes were made to the basic model described in WCAP-15427 (Reference 10) to be able to use the new Mist Diffusion Layer Model (MDLM) heat and mass transfer option and to improve the modeling of drops and water on the

floors. These modifications and their impact on the benchmark comparisons are described in the NMC letter, NRC-02-082 (Reference 11).

The heat sink data for the Kewaunee containment model is summarized in Table 6.4-24. The thermo-physical properties of the containment heat sink materials are shown in Table 6.4-25.

6.4.2.2.4 Acceptance Criteria

The containment response for design-basis containment integrity is an ANS Condition IV event, an infrequent fault. The containment analysis methodology satisfies the current NRC acceptance criteria from 10CFR50, Appendix A and Standard Review Plan 6.2.1.1.A. The relevant GDC requirements that are met are as follows:

- GDC 16 and GDC 50: To satisfy the requirements of GDC 16 and GDC 50, the peak calculated containment pressure should be less than the containment design pressure of 46 psig, considering the most severe single failure.

- GDC 38 and GDC 50: To satisfy the requirements of GDC 38 and GDC 50, the calculated pressure at 24 hours should be less than 50 percent of the peak calculated value. (This is related to the criteria for doses at 24 hours.)

The Kewaunee plant was originally licensed with the USAR containing text from the interim criteria that was derived from the draft AIF GDCs. The Kewaunee SER indicated that the operating license was granted because "...the plant design generally conforms to the intent...." of the requirements of 10CFR50, Appendix A. The specific interim criteria were:

- Interim GDC 10 - Containment
- Interim GDC 49 - Containment Design Basis
- Interim GDC 52 - Containment Heat Removal Systems

6.4.2.2.5 Analysis Results

The mass and energy release analysis described in subsection 6.4.2.1 and the containment model and assumptions described in subsections 6.4.2.2.2 and 6.4.2.2.3 were used to determine the accident progression and containment response to the MSLB event.

A number of MSLB cases covering various break sizes and power levels were run using the GOTHIC containment model to determine the limiting case. Table 6.4-31 summarizes the peak containment pressures and temperatures calculated for these cases. The limiting MSLB event represents a 1.4 ft^2 break at 0-percent power at the uprated power conditions. Offsite power is available, but a single failure of one train of containment safeguards is assumed.

The containment pressure and temperature response is shown in Figures 6.4-13 and 6.4-14. The containment pressure and temperature increase steadily in response to the steam release. Operator action to terminate AFW flow to the faulted steam generator is assumed to occur at 600 seconds. This significantly reduces the break flow rate from the faulted steam generator causing the containment pressure and temperature to begin decreasing. The containment pressure and temperature will continue to decrease since the break steam release is much less than the heat removal capability of the CFCUs and containmet spray. The calculated peak containment pressure and temperature for this event is 45.9 psig and 267.3 F respectively.

6.4.2.2.6 Conclusions

The MSLB containment response analyses have been performed as part of the Power Uprate Program for Kewaunee. The calculated peak containment pressure was less than the design pressure (46 psig) for all cases. In addition, the containment pressure was less than 50 percent of the peak value within 24 hours. Based on the results, all applicable containment integrity acceptance criteria for Kewaunee have been met.

6.4.3 Generation and Disposition of Hydrogen

6.4.3.1 Introduction and Background

An evaluation of the hydrogen generation in containment following a LOCA for the KNPP was performed based on updated parameters and assumptions that reflect the power uprate conditions. Westinghouse methodologies and the guidance provided in Regulatory Guide 1.7 (Reference 14) were used in this assessment.

The hydrogen control strategies presented in the Kewaunee *Updated Safety Analysis Report* (USAR) (see Section 14.3.9) reflect controlled vent flow and pressurization of containment, with provisions for an external hydrogen recombiner as a third alternative. The projected impact of removal by a recombiner on post-LOCA hydrogen accumulation was addressed in the

Westinghouse evaluation. However, in the event of a LOCA design basis accident (DBA), plant personnel would calculate the effects of a release based on the actual conditions at the time of the release. Thus, it is not necessary to re-evaluate the pressurization and venting control methods, since actual plant conditions will be considered in ensuring that the resultant doses are within acceptable limits.

6.4.3.2 Input Parameters and Assumptions

A listing of the major parameters and assumptions are listed below in Table 6.4-32.

The remaining assumptions are consistent with NRC Regulatory Guide 1.7 (Reference 14).

6.4.3.3 Description of Analyses

The evaluation consists of the calculation of the production of hydrogen following a LOCA and the associated buildup of the concentration of hydrogen inside the containment. The concentrations are compared to the regulatory limit and the impact of removal of hydrogen by a hydrogen recombiner was determined. The sources of hydrogen that are considered in the analysis are:

- Zirc-water reaction
- Corrosion of materials
- Core and sump solution radiolysis
- Initial inventory in the RCS

These sources of hydrogen are comprehensive and bounding for KNPP and KNPP power uprate conditions. The evaluations conducted for the various sources of hydrogen are summarized in the following paragraphs.

Zirconium - Water Reaction

The weight of zirconium cladding based on the current fuel load is 30,858 lbs. However, the core will be transitioned to Westinghouse fuel with a zirconium mass of 26,862 lbs. For conservatism, the higher value (that is, that associated with the current fuel load) is assumed.

Note that this assumption includes an additional degree of conservatism in that only zirconium in the active fuel region need be considered. Per 10CFR50.44, the Zirc-water reaction involves only the region of the fuel that could exceed the temperature required for the chemical reaction of the cladding with the water or steam to occur (that is, the cladding in the active fuel region). Thus, considering the total cladding weight is conservative.

The amount of zirconium cladding that is assumed to undergo the Zirc-water reaction is 5 percent of the zirc cladding mass in the active core region. The amount of zirconium is mandated by 10CFR50 to be 5 times the fraction calculated in the 10CFR50.46 ECCS performance criteria assessment. The assumption of 5 percent is an upper limit since 10CFR50 specifies that the calculated fraction not exceed 1 percent of the cladding in the active core region. Thus, 5 percent is 5 times the limiting calculated value and is a conservative and bounding value.

The total hydrogen produced from the Zirc-water reaction based on these conservative assumptions is 12,190 standard cubic feet (scf). This inventory is assumed to be instantaneously released to the containment atmosphere at the beginning of the LOCA.

Corrosion of Materials

The corrosion of materials in containment following a LOCA is a function of the temperature and pH of the solution in contact with the material, as well as the composition and surface area. The relationships of the aluminum and zinc corrosion rate with temperature and pH are illustrated in Figures 6.4-15 and 6.4-16, respectively. The default corrosion rates as a function of inverse temperature considered in the analysis are shown in these figures. The relationship used for the default aluminum corrosion rates is based on Oak Ridge National Laboratory (ORNL) measurements at a pH of about 9.5 (Reference 15). The default zinc corrosion rates are based on Westinghouse measurements at pH values in the range of 7.0 to 9.6.

Containment Temperature - The post-LOCA temperature profile used in establishing the material corrosion rates is graphically represented in Figure 6.4-17. The temperature profile is conservatively assumed to be that associated with only one train of safeguards in operation as presented in Figure 6.4-5 of this report. It should also be noted that the long-term aluminum corrosion rate is maintained at or above 16 mg/dm^2/hr (200 mils/year) regardless of the prevailing temperature. This assumption is consistent with guidance provided in NRC Regulatory Guide 1.7.

Spray/Sump pH - The pH of the spray and sump water is considered to be in the range of 7.0 to 9.5, per NUREG-0800, Branch Technical Position MTEB 6-1, *pH for Emergency Coolant Water for PWRs* (Reference 16).

Corrodible Materials - Data relative to the inventory of corrodible materials inside containment (for example, aluminum, zinc, and zinc-based paint) are tabulated in Table 6.4-33. These values are those currently listed in the Kewaunee USAR.

Radiolysis

Hydrogen from sump and core radiolysis are time-dependent quantities that are a function of fission product decay energy. Core and sump radiolysis is calculated based on values of energy deposition in the core and sump solutions that reflect TID-14844 (Reference 17) release assumptions and the associated distribution of fission products, as defined in Regulatory Guide 1.7. Plant operation with extended fuel cycles prior to a LOCA was considered. The default decay energy data were derived from the ORIGEN2.1 computer code (Reference 18) and bound decay energy data associated with typical Westinghouse fuel design parameters associated with extended (that is, 18- and 24-month) fuel cycles. The decay energies that are considered in the analyses reflect Regulatory Guide 1.7 assumptions relative to the amount of energy available for deposition in the sump and core solutions.

Initial Reactor Coolant System and Containment Inventories

The initial hydrogen inventory in the RCS prior to the LOCA includes hydrogen in the primary coolant as well as in the pressurizer gas space. The amount of hydrogen contained in the RCS is based on a pre-accident RCS hydrogen concentration of 50 cc/kg. This value is conservatively based on the value associated with the upper end of the operating range of 25 to 50 cc/kg that is recommended by Westinghouse and Electrical Power Research Institute (EPRI) (Reference 19). The hydrogen volume in the liquid, V_L, based on the maximum hydrogen concentration of 50 cc/kg, is 210 scf. An additional RCS H_2 inventory of 440 scf is contained in the pressurizer steam space. This inventory is calculated based on no purge or leakage from the pressurizer, which results in a conservative estimate. Then, the total RCS inventory is:

$$V_{RCS} = V_L + V_P = 210 + 440 = 650 \text{ scf}$$

The associated hydrogen inventory is considered to be instantaneously released to the containment atmosphere.

Recombination

Removal from the containment atmosphere is conservatively assumed to be only by operation of a single electric hydrogen recombiner, and post-LOCA containment venting is not credited in the analyses.

The times at which recombination is assumed are at 24 hours, at the end of the tenth day after a LOCA, and when the containment concentration reaches 3.5 volume percent (v/o) and 4.0 v/o.

6.4.3.4 Acceptance Criteria for Analyses

Regulatory Guide 1.7 indicates that the containment hydrogen concentration should remain below 4 v/o.

The initiation of recombination at 3.5 v/o is based on the NRC SRP criteria for combustible gas control in containment. As stated in NUREG-0800, Section 6.2.5:

"The proposed operation of the combustible gas control equipment, excluding containment atmosphere dilution (CAD) systems, is acceptable if there is an appropriate margin, e.g., on the order of 0.5 v/o, between the limiting hydrogen concentration limit and the hydrogen concentration at which the equipment would be actuated."

6.4.3.5 Results

The hydrogen production rates and containment inventories from the various sources of hydrogen are shown in Figures 6.4-18 and 6.4-19, respectively. The effects of recombination at various times are illustrated in Figure 6.4-20. The results indicate that, without recombination, a containment concentration of 3.5 v/o hydrogen is reached during the ninth day after LOCA, and a containment concentration of 4.0 v/o is reached during the thirteenth day after LOCA. A concentration of 4.1 v/o is reached without recombination during the fourteenth day after LOCA. Figure 6.4-20 shows that with no removal mechanisms in place, the hydrogen concentration builds up to about 5.5 v/o at 30 days following a LOCA. The figure also shows that operation of a single recombiner at a 90-scfm processing rate beginning at the time when the hydrogen

concentration reaches 3.5 v/o results in an immediate termination of the buildup of hydrogen inside the containment. The decreasing hydrogen concentration after recombination is initiated indicates that the recombination rate exceeds the production rate.

The assumed minimum time from the beginning of a LOCA to start of recombiner operation is 10.1 days. As shown in Figure 6.4-20, the start of recombination at this time limits the containment hydrogen concentration to less than 4 v/o for the duration of the accident.

6.4.3.6 Conclusions

The evaluation indicates that: operation of a single recombiner at a 90 scfm processing rate beginning at 24 hours after LOCA or later results in an immediate termination of the buildup of hydrogen inside the containment.

The start of recombination at 10 days after a LOCA limits the containment hydrogen concentration to less than 4 v/o for the duration of the accident. Thus, the regulatory limit is not exceeded.

6.4.4 References

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14. NRC Regulatory Guide 1.7, *Control of Combustible Gas Concentrations in Containment Following a Loss-of-Coolant Accident*, Rev. 2, November 1978.

15. Griess, J. C., and Barcarella, A. L., *Design Considerations of Reactor Containment Spray Systems – Part III. Corrosion of Plant Materials in Spray Solutions*, ORNL-TM-2412 (Part III), December 1969.

16. NUREG-0800, Branch Technical Position MTEB 6-1, *pH for Emergency Coolant Water for PWRs*, Rev. 2, July 1981.

17. TID-14844, *Calculation of Distance Factors for Power and Test Reactor Sites*, Technical Information Document, Atomic Energy Commission – Division of Technical Information, March 23, 1962.

18. CCC-371, *ORIGEN2.1: Isotope Generation and Depletion Code – Matrix Exponential Method, RSICC Computer Code Collection*, Oak Ridge National Laboratory, February 1996.

19. TR-105714-V1R4, *PWR Primary Water Chemistry Guidelines,* Volume 1, Rev. 4, EPRI, Palo Alto, CA, 1999.

Table 6.4-1 System Parameters Initial Conditions	
Parameters	**Value**
Core Thermal Power (MWt)	1782.6
RCS Total Flow Rate (lbm/sec)	18,852.8
Vessel Outlet Temperature (°F)	612.8
Core Inlet Temperature (°F)	545.2
Vessel Average Temperature (°F)	579.0
Initial Steam Generator Steam Pressure (psia)	809
Steam Generator Design	Model 54F
SGTP (%)	0
Initial Steam Generator Secondary Side Mass (lbm)	115,250.3
Assumed Maximum Containment Backpressure (psia)	60.7
Accumulator Water Volume (ft^3) per Accumulator N_2 Cover Gas Pressure (psia) Temperature (°F)	 1275 714.7 120
SI Delay, Total (sec) (from beginning of event)	33.8

Note:
Core thermal power, RCS total flow rate, RCS coolant temperatures, and steam generator secondary side mass include appropriate uncertainty and/or allowance.

Table 6.4-2 SI Flow Minimum Safeguards		
RCS Pressure (psig)	Total Flow (lbm/sec)	
Injection Mode (reflood phase)		
0	305.0	
20	288.9	
40	269.4	
60	247.3	
80	221.9	
100	189.7	
120	142.8	
140	82.1	
160	81.7	
180	81.4	
Recirculation Sequence		
	Vessel Injection (lbm/sec)	
Time (sec)	from RWST	from Sump
3953.0	84.8	0
4143.0	84.8	33.3
6352.0	0.0	33.3
6382.0	0.0	186.2
10,000.0	0.0	186.2
500,000.0	0.0	186.2

Table 6.4-3 SI Flow Maximum Safeguards	
RCS Pressure (psig)	Total Flow (lbm/sec)
Injection Mode (reflood phase)	
0	711.5
20	671.9
40	628.4
60	581.5
80	528.8
100	465.2
120	388.1
140	270.9
160	173.8
180	173.1

Recirculation Sequence		
	Vessel Injection (lbm/sec)	
Time (sec)	from RWST	from Sump
1253.0	304.9	0.0
1443.0	304.9	66.6
1473.0	304.9	186.2
2707.0	0.0	186.2
2919.0	0.0	186.2
500,000.0	0.0	186.2

Table 6.4-4 DEHL Break Blowdown Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
0.00000	0.0	0.0	0.0	0.0
0.00103	42396.4	26654.3	42394.7	26652.2
0.00201	44745.1	28130.3	44498.9	27970.0
0.00307	44345.3	27878.9	43821.4	27538.8
0.00420	43957.2	27635.4	43140.2	27104.9
0.101	36823.2	23468.0	25955.3	16283.4
0.201	33165.5	21137.3	23242.7	14514.3
0.302	32315.6	20548.0	20770.4	12837.5
0.401	31271.3	19873.7	19472.4	11875.1
0.501	30929.2	19661.2	18636.7	11207.3
0.602	30378.2	19358.0	18079.5	10729.0
0.702	29912.3	19144.2	17603.1	10324.7
0.801	29629.5	19094.8	17179.8	9973.0
0.902	28870.5	18746.0	16879.2	9708.6
1.00	27989.8	18316.0	16612.8	9478.6
1.10	27076.7	17870.9	16374.5	9277.0
1.20	26200.0	17460.1	16195.9	9118.7
1.30	25275.4	17021.1	16080.1	9003.1
1.40	24262.3	16516.8	16028.5	8928.9
1.50	23193.8	15965.2	16021.0	8883.7
1.60	22108.0	15389.4	16038.2	8855.5
1.70	21014.9	14746.6	16068.2	8837.1
1.80	20219.3	14179.9	16106.3	8825.8
1.90	19621.0	13752.4	16150.0	8820.6
2.00	19063.2	13409.1	16190.1	8816.2
2.10	18445.3	13069.4	16216.9	8807.7
2.20	17790.1	12623.2	16222.3	8791.1
2.30	17313.0	12239.8	16201.9	8763.3
2.40	16981.1	11936.3	16154.2	8723.9
2.50	16748.9	11711.2	16074.2	8670.0
2.60	16596.1	11520.4	15959.2	8600.1
2.70	16531.6	11365.9	15793.7	8505.3
2.80	16546.1	11256.8	15570.3	8381.8
2.90	16612.5	11190.9	15331.3	8252.2

Table 6.4-4 (Cont.)

DEHL Break Blowdown Mass and Energy Releases

Time (seconds)	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
3.00	16703.4	11153.7	15092.9	8125.3
3.10	16803.2	11135.7	14871.1	8009.4
3.20	16860.9	11096.6	14668.7	7905.8
3.30	16905.1	11052.8	14440.1	7789.0
3.40	16943.4	11011.1	14146.1	7637.5
3.50	16971.3	10969.9	13785.9	7450.8
3.60	16987.3	10930.1	13387.7	7244.6
3.70	16988.3	10889.1	12986.3	7038.1
3.80	16972.4	10844.6	12603.4	6842.9
3.90	16941.4	10796.3	12240.8	6659.4
4.00	16901.0	10744.7	11861.8	6467.7
4.20	16768.6	10634.5	11076.6	6069.8
4.40	16576.2	10512.4	10319.8	5687.5
4.60	16413.5	10395.7	9600.8	5324.4
4.80	16278.0	10274.5	8953.8	4999.3
5.00	16173.8	10164.8	8401.9	4723.8
5.20	16017.0	10024.2	7913.3	4481.2
5.40	15872.1	9889.2	7495.3	4274.6
5.60	15752.7	9761.1	7123.0	4091.3
5.80	12246.4	8181.3	6802.3	3933.9
6.00	12195.2	8148.0	6514.3	3793.1
6.20	11930.0	7965.6	6253.0	3665.7
6.40	11630.2	7750.9	6016.7	3550.8
6.60	11364.2	7582.8	5799.4	3445.5
6.80	11019.4	7353.5	5595.9	3347.0
7.00	10713.1	7176.9	5403.6	3254.3
7.20	10354.1	6933.1	5218.3	3165.2
7.40	9845.3	6666.9	5026.9	3072.4
7.60	9366.6	6368.1	4821.3	2972.7
7.80	8972.8	6134.5	4592.7	2864.1
8.00	8564.6	5895.3	4350.7	2754.7
8.20	7974.0	5535.7	4098.3	2646.4
8.40	7362.0	5205.2	3840.7	2540.3
8.60	6624.9	4767.9	3581.7	2435.8
8.80	5922.9	4314.5	3314.4	2326.2

Table 6.4-4 (Cont.) DEHL Break Blowdown Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
9.00	5343.2	3909.2	3056.1	2222.7
9.20	4827.2	3571.4	2805.9	2120.4
9.40	4332.8	3310.2	2560.9	2019.5
9.60	3831.8	3069.6	2318.7	1920.1
9.80	3264.7	2812.7	2083.1	1833.5
10.0	2747.5	2661.3	1838.4	1757.4
10.2	2222.0	2461.6	1593.8	1687.0
10.4	1920.6	2247.1	1377.4	1599.3
10.6	1926.9	2224.1	1222.8	1481.4
10.8	2112.1	2057.5	1112.1	1366.0
11.0	2063.6	1965.6	1039.9	1284.0
11.2	2012.9	1820.6	994.7	1231.0
11.4	2047.3	1709.9	958.1	1187.5
11.6	2022.1	1598.0	909.1	1128.2
11.8	2141.5	1498.3	839.1	1044.0
12.0	2160.9	1483.8	788.8	983.5
12.2	1953.2	1408.2	735.2	917.5
12.4	1790.9	1338.5	678.1	847.5
12.6	1366.7	1278.7	623.2	779.8
12.8	1050.0	1191.8	562.1	704.2
13.0	1087.4	1029.2	516.0	647.4
13.2	1234.1	931.5	465.8	585.2
13.4	1162.0	970.4	410.7	516.4
13.6	902.1	1008.2	343.2	432.1
13.8	794.4	864.4	280.9	354.6
14.0	624.0	755.2	234.5	296.6
14.2	586.5	636.0	200.4	253.5
14.4	689.6	443.6	183.3	232.8
14.6	943.0	478.2	183.6	233.8
14.8	1042.5	447.4	183.4	233.1
15.0	1188.1	464.8	191.1	243.0
15.2	1325.3	497.0	199.3	253.3
15.4	1490.6	554.1	206.1	262.1
15.6	1477.3	558.3	222.2	282.2
15.8	1705.7	613.3	225.6	286.5

Table 6.4-4 (Cont.) DEHL Break Blowdown Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
16.0	1769.7	623.9	237.9	301.7
16.2	1776.8	627.0	243.1	308.5
16.4	1991.6	709.1	258.4	327.9
16.6	1857.9	698.6	266.4	337.8
16.8	1515.2	632.8	270.6	343.2
17.0	1391.6	665.9	284.8	361.1
17.2	1111.1	633.3	312.1	395.7
17.4	1215.6	607.0	349.3	442.8
17.6	1274.0	626.0	333.6	422.2
17.8	1046.5	588.4	267.2	338.5
18.0	904.0	509.0	260.6	330.8
18.2	895.9	446.9	242.9	308.4
18.4	972.6	441.4	207.3	263.5
18.6	1126.6	470.1	168.1	214.3
18.8	1369.4	550.1	136.0	173.7
19.0	1387.9	584.0	117.3	150.3
19.2	1254.5	607.0	100.9	129.4
19.4	1047.1	646.1	95.9	123.2
19.6	744.6	629.9	92.3	118.8
19.8	451.1	435.6	88.2	113.6
20.0	83.7	89.5	77.4	99.8
20.2	.0	.0	68.3	88.3
20.4	.0	.0	.0	.0

Notes:

1. Mass and energy exiting from the reactor-vessel side of the break.
2. Mass and energy exiting from the steam-generator side of the break.

Table 6.4-5 DEHL Break Mass Balance				
Time (seconds)		0.00	20.40	20.40
		Mass (thousand lbm)		
Initial	In RCS and ACC	439.54	439.54	439.54
Added Mass	Pumped Injection	0.00	0.00	0.00
	Total Added	0.00	0.00	0.00
*****Total Available*****		439.54	439.54	439.54
Distribution	Reactor Coolant	278.05	81.43	100.22
	Accumulator	161.25	86.48	67.69
	Total Contents	439.54	167.91	167.91
Effluent	Break Flow	0.00	271.62	271.62
	ECCS Spill	0.00	0.00	0.00
	Total Effluent	0.00	271.62	271.62
*****Total Accountable*****		439.54	439.53	439.53

Table 6.4-6 DEHL Break Energy Balance				
Time (seconds)		0.00	20.40	20.40
		Energy (million Btu)		
Initial Energy	In RCS, ACC, S GEN	444.59	444.59	444.59
Added Energy	Pumped Injection	0.00	0.00	0.00
	Decay Heat	0.00	3.25	3.25
	Heat from Secondary	0.00	-1.96	-1.96
	Total Added	0.00	1.30	1.30
*****Total Available*****		444.59	445.88	445.88
Distribution	Reactor Coolant	162.28	16.87	18.56
	Accumulator	14.48	7.76	6.08
	Core Stored	14.26	4.78	4.78
	Primary Metal	85.25	78.55	78.55
	Secondary Metal	43.61	42.48	42.48
	Steam Generator	124.70	120.67	120.67
	Total Contents	444.59	271.12	270.12
Effluent	Break Flow	0.00	174.15	174.42
	ECCS Spill	0.00	0.00	0.00
	Total Effluent	0.00	174.15	174.42
*****Total Accountable*****		445.59	445.54	445.54

Table 6.4-7

DEPS Suction Break Blowdown Mass and Energy Releases (same for all DEPS runs)

Time (seconds)	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
0.0000	0.0	0.0	0.0	0.0
0.00107	92431.5	49657.0	39968.5	21418.5
0.101	39940.2	21470.4	20407.8	10928.5
0.202	44335.1	23981.4	21659.8	11605.6
0.302	44306.6	24151.6	22099.1	11847.3
0.402	44793.1	24646.3	21893.0	11746.1
0.501	44286.0	24619.6	21465.1	11526.0
0.601	43304.3	24328.2	20891.4	11226.0
0.702	43670.9	24778.2	20279.3	10901.7
0.801	43598.2	24961.3	19661.5	10571.7
0.901	43054.8	24859.0	19070.3	10254.6
1.00	42173.4	24548.5	18580.1	9991.2
1.10	41181.3	24161.5	18173.0	9772.2
1.20	40087.8	23705.2	17782.7	9561.7
1.30	38825.4	23136.9	17391.2	9349.8
1.40	37305.9	22397.6	17084.4	9184.5
1.50	35518.3	21481.2	16995.0	9137.4
1.60	33950.6	20698.4	16883.5	9078.2
1.70	32772.5	20172.5	16655.6	8955.0
1.80	31594.7	19664.3	16392.5	8812.5
1.90	30323.3	19106.4	16160.0	8686.7
2.00	28824.8	18412.2	15929.9	8562.2
2.10	26445.1	17128.0	15685.7	8430.3
2.20	22090.7	14508.2	15413.4	8283.3
2.30	19148.7	12779.5	15139.0	8135.3
2.40	16946.9	11467.1	14923.9	8020.6
2.50	15153.8	10365.8	14840.1	7977.8
2.60	13970.2	9643.0	14753.0	7932.9
2.70	13234.7	9201.6	14652.2	7880.6
2.80	12738.7	8903.1	14556.8	7831.2
2.90	12304.9	8632.2	14436.3	7768.1
3.00	11858.1	8351.6	13806.1	7426.6
3.10	11460.1	8117.4	13461.8	7245.1
3.20	11115.0	7933.7	13308.2	7165.9
3.30	10786.7	7769.7	13126.0	7070.0

Table 6.4-7 (Cont.) DEPS Break Blowdown Mass and Energy Releases (same for all DEPS runs)				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
3.40	10469.2	7614.2	12943.3	6974.1
3.50	10164.6	7465.7	12755.4	6875.7
3.60	9894.2	7338.2	13603.2	7344.2
3.70	9646.1	7223.9	14137.2	7631.3
3.80	9413.0	7116.1	14109.0	7616.4
3.90	9195.0	7014.6	14034.0	7579.0
4.00	8993.3	6920.7	13981.1	7554.1
4.20	8660.4	6765.2	13746.3	7433.4
4.40	8390.8	6623.2	13507.6	7310.1
4.60	8149.0	6479.0	13155.1	7124.5
4.80	7905.5	6305.9	12831.6	6954.7
5.00	7692.1	6115.7	12488.4	6773.9
5.20	7534.6	5927.2	12134.4	6587.7
5.40	7444.7	5759.0	11819.3	6423.3
5.60	7394.6	5613.2	11466.7	6238.9
5.80	7315.4	5469.3	11103.5	6049.4
6.00	7194.9	5317.4	10750.9	5865.7
6.20	7320.7	5332.4	10414.5	5691.0
6.40	7369.3	5408.7	10131.2	5545.9
6.60	6787.8	5257.3	9750.0	5346.5
6.80	6090.8	4891.9	9412.1	5169.7
7.00	5795.4	4630.5	9091.5	4993.0
7.20	5653.0	4451.0	8779.4	4770.6
7.40	5532.2	4304.4	8810.4	4694.1
7.60	5402.1	4171.2	8735.2	4553.9
7.80	5256.2	4041.0	8813.4	4500.2
8.00	5115.6	3924.0	8587.6	4305.2
8.20	4986.8	3829.9	8336.3	4106.9
8.40	4817.4	3725.7	8199.8	3971.2
8.60	4625.8	3606.1	7924.2	3776.6
8.80	4449.4	3495.4	7687.0	3606.5
9.00	4282.8	3397.8	7369.0	3404.1
9.20	4112.5	3303.7	6988.0	3179.5
9.40	3939.2	3213.8	6715.2	3010.0

Table 6.4-7 (Cont.) DEPS Break Blowdown Mass and Energy Releases (same for all DEPS runs)				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
9.60	3763.7	3131.0	6399.9	2823.2
9.80	3573.8	3048.5	6691.9	2878.6
10.0	3360.5	2957.6	7057.6	2941.6
10.2	3146.6	2887.8	6155.7	2517.2
10.4	2944.2	2832.4	5805.4	2326.5
10.4	2943.0	2831.8	5803.8	2325.6
10.4	2942.5	2831.7	5803.2	2325.2
10.6	2732.9	2771.2	5562.9	2170.4
10.8	2511.9	2710.0	5425.2	2057.2
11.0	2251.0	2606.2	5269.4	1945.7
11.2	1896.0	2318.1	5086.8	1834.3
11.4	1569.9	1941.4	4832.7	1705.9
11.6	1343.1	1667.2	4508.1	1558.8
11.8	1152.9	1434.9	4109.4	1390.5
12.0	1001.6	1249.2	3690.9	1220.0
12.2	838.4	1048.2	3271.9	1054.9
12.4	697.0	872.7	2836.7	891.8
12.6	560.9	703.0	2458.7	754.3
12.8	445.7	559.1	2067.0	619.6
13.0	343.2	431.0	1656.8	486.5
13.2	241.6	303.8	1230.2	355.1
13.4	145.2	182.8	784.7	223.8
13.6	78.2	98.8	353.6	100.3
13.8	31.5	40.0	0.0	0.0
14.0	0.0	0.0	0.0	0.0

Notes:

1. Mass and energy exiting from the steam-generator side of the break (path 1).
2. Mass and energy exiting from the pump-side of the break (path 2).

Table 6.4-8 DEPS Break Minimum Safeguards Reflood Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
14.0	0.0	0.0	0.0	0.0
14.4	0.0	0.0	0.0	0.0
14.6	0.0	0.0	0.0	0.0
14.7	0.0	0.0	0.0	0.0
14.7	0.0	0.0	0.0	0.0
14.8	0.4	0.5	0.0	0.0
15.0	29.2	34.4	0.0	0.0
15.1	34.5	40.7	0.0	0.0
15.2	41.1	48.4	0.0	0.0
15.3	47.7	56.2	0.0	0.0
15.4	54.0	63.7	0.0	0.0
15.5	58.2	68.6	0.0	0.0
15.6	62.8	74.0	0.0	0.0
15.7	68.2	80.4	0.0	0.0
15.8	72.3	85.2	0.0	0.0
15.9	74.3	87.5	0.0	0.0
15.9	76.3	89.8	0.0	0.0
16.0	80.0	94.3	0.0	0.0
16.1	83.7	98.6	0.0	0.0
16.2	87.2	102.7	0.0	0.0
16.3	90.6	106.7	0.0	0.0
16.4	93.9	110.6	0.0	0.0
16.5	97.1	114.4	0.0	0.0
16.6	99.4	117.2	0.0	0.0
16.7	103.2	121.6	0.0	0.0
16.8	106.2	125.2	0.0	0.0
16.9	108.3	127.7	0.0	0.0
17.0	111.9	131.8	0.0	0.0
18.0	137.0	161.4	0.0	0.0
19.0	243.4	287.3	2100.6	227.2
19.6	412.2	488.0	4072.4	448.0
20.1	427.7	506.6	4200.8	467.6
21.1	421.1	498.7	4134.6	462.0
22.1	412.4	488.3	4051.3	454.0

Table 6.4-8 (Cont.) DEPS Break Minimum Safeguards Reflood Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
23.0	404.7	479.2	3976.4	446.7
23.1	403.9	478.2	3968.1	445.9
24.1	395.7	468.4	3887.1	438.0
25.1	387.9	459.1	3808.7	430.4
26.1	380.6	450.4	3733.4	423.1
27.1	373.6	442.0	3661.0	416.1
27.5	370.9	438.8	3632.9	413.4
28.1	367.0	434.1	3591.6	409.4
29.1	360.7	426.7	3524.9	403.0
30.1	354.7	419.6	3460.8	396.8
31.1	349.1	412.8	3399.3	390.9
32.1	343.7	406.4	3340.0	385.2
32.6	341.1	403.3	3311.2	382.4
33.1	338.5	400.3	3283.0	379.7
34.1	350.1	414.0	3421.4	393.2
35.1	345.5	408.6	3368.9	388.2
36.1	341.0	403.3	3318.6	383.4
37.1	336.8	398.2	3269.9	378.8
38.1	223.4	263.7	1723.6	235.2
38.1	216.8	255.8	1730.8	233.2
39.2	213.7	252.2	192.2	85.7
40.2	211.3	249.3	191.4	84.7
41.2	208.8	246.4	190.7	83.8
42.2	206.3	243.4	189.9	82.8
43.2	203.9	240.5	189.2	81.9
44.2	201.4	237.6	188.5	81.0
45.2	198.9	234.6	187.7	80.0
46.2	196.4	231.7	187.0	79.1
47.2	194.0	228.8	186.3	78.2
48.2	191.6	226.0	185.5	77.3
49.2	189.2	223.2	184.8	76.4
50.2	186.8	220.3	184.1	75.5
51.2	184.4	217.5	183.4	74.6
52.2	182.0	214.7	182.7	73.8

Table 6.4-8 (Cont.) DEPS Break Minimum Safeguards Reflood Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
53.2	179.7	211.9	182.0	72.9
54.0	177.8	209.6	181.5	72.2
54.2	177.3	209.1	181.4	72.0
55.2	174.9	206.3	180.7	71.2
56.2	172.5	203.5	180.0	70.3
57.2	170.2	200.7	179.3	69.5
58.2	167.8	197.9	178.6	68.6
59.2	165.5	195.1	178.0	67.8
60.2	163.1	192.4	177.3	67.0
61.2	160.8	189.6	176.7	66.2
62.2	158.5	186.8	176.0	65.3
63.2	156.1	184.1	175.4	64.5
64.2	153.8	181.3	174.7	63.7
65.2	151.5	178.6	174.1	62.9
66.2	149.2	175.9	173.5	62.1
67.2	146.9	173.2	172.8	61.4
68.2	144.6	170.5	172.2	60.6
69.2	142.3	167.8	171.6	59.8
70.2	140.1	165.1	171.0	59.1
71.2	137.8	162.4	170.4	58.3
72.2	135.6	159.8	169.8	57.6
73.1	133.6	157.4	169.3	56.9
73.2	133.4	157.2	169.2	56.9
74.2	131.2	154.6	168.6	56.1
75.2	129.0	152.0	168.1	55.4
77.2	124.6	146.9	167.0	54.1
79.2	120.4	141.9	165.9	52.7
81.2	116.2	136.9	164.8	51.4
83.2	112.1	132.1	163.8	50.1
85.2	108.1	127.4	162.8	48.9
87.2	104.2	122.8	161.9	47.8
89.2	100.4	118.3	161.0	46.7
91.2	96.7	113.9	160.1	45.6
93.2	93.1	109.7	159.3	44.6
95.2	89.7	105.6	158.5	43.6

Table 6.4-8 (Cont.) DEPS Break Minimum Safeguards Reflood Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
97.2	86.3	101.7	157.8	42.7
97.6	85.7	100.9	157.7	42.5
99.2	83.1	97.9	157.1	41.8
101.2	80.3	94.6	156.4	41.0
103.2	79.1	93.2	155.7	40.2
105.2	77.9	91.8	155.1	39.4
107.2	76.8	90.5	154.4	38.7
109.2	75.7	89.2	153.8	37.9
111.2	74.6	87.9	153.2	37.2
113.2	73.6	86.7	152.6	36.5
115.2	72.6	85.6	152.1	35.9
117.2	71.7	84.4	151.5	35.2
119.2	70.8	83.4	151.0	34.6
121.2	69.9	82.3	150.5	34.0
123.2	69.1	81.4	150.0	33.4
125.2	68.3	80.4	149.5	32.9
127.2	67.5	79.5	149.0	32.3
129.2	66.8	78.7	148.6	31.8
129.3	66.8	78.6	148.6	31.8
131.2	66.1	77.9	148.2	31.3
133.2	65.4	77.1	147.8	30.8
135.2	64.8	76.3	147.4	30.3
137.2	64.2	75.6	147.0	29.9
139.2	63.6	75.0	146.6	29.5
141.2	63.1	74.3	146.3	29.1
143.2	62.6	73.7	145.9	28.7
145.2	62.1	73.2	145.6	28.3
147.2	61.6	72.6	145.3	27.9
149.2	61.2	72.1	145.0	27.6
151.2	60.8	71.6	144.7	27.2
153.2	60.4	71.2	144.5	26.9
155.2	60.1	70.7	144.2	26.6
157.2	59.7	70.3	144.0	26.3
159.2	59.4	70.0	143.7	26.0
161.2	59.1	69.6	143.5	25.8

Table 6.4-8 (Cont.) DEPS Break Minimum Safeguards Reflood Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
163.2	58.8	69.3	143.3	25.5
165.2	58.5	69.0	143.1	25.3
166.7	58.4	68.7	142.9	25.1
167.2	58.3	68.7	142.9	25.0
169.2	58.1	68.4	142.7	24.8
171.2	57.9	68.2	142.5	24.6
173.2	57.7	67.9	142.3	24.4
175.2	57.5	67.7	142.2	24.2
177.2	57.3	67.5	142.0	24.0
179.2	57.2	67.4	141.9	23.9
181.2	57.0	67.2	141.7	23.7
183.2	56.9	67.0	141.6	23.5
185.2	56.8	66.9	141.5	23.4
187.2	56.7	66.8	141.4	23.3
189.2	56.6	66.7	141.2	23.1
191.2	56.5	66.6	141.1	23.0
193.2	56.5	66.5	141.0	22.9
195.2	56.4	66.4	140.9	22.8
197.2	56.4	66.4	140.9	22.7
199.2	56.3	66.3	140.8	22.6
201.2	56.3	66.3	140.7	22.5
203.2	56.3	66.3	140.6	22.4
205.2	56.2	66.2	140.5	22.3
207.2	56.2	66.2	140.5	22.2
208.4	56.2	66.2	140.4	22.2

Notes:

1. Mass and energy exiting from the steam-generator side of the break (path 1).
2. Mass and energy exiting from the pump-side of the break (path 2).

Table 6.4-9

DEPS Break - Minimum Safeguards Principal Parameters during Reflood

Time Seconds	Flooding Temp °F	Flooding Rate in/sec	Carryover Fraction	Core Height (ft)	Downcomer Height (ft)	Flow Frac	Total (pounds mass per second)	Injection Accum (pounds mass per second)	Spill (pounds mass per second)	Enthalpy Btu/lbm
14.0	167.2	.000	0.000	0.00	0.00	0.500	0.0	0.0	0.0	0.00
14.6	165.6	28.507	0.000	0.58	1.60	0.498	6223.7	6223.7	0.0	89.79
14.8	164.4	35.044	0.000	1.12	1.81	0.443	6157.1	6157.1	0.0	89.79
15.9	164.1	3.037	0.301	1.50	5.34	0.599	5924.8	5924.8	0.0	89.79
16.7	164.2	2.917	0.423	1.63	8.19	0.618	5764.8	5764.8	0.0	89.79
19.6	164.5	5.921	0.636	2.01	15.78	0.813	5026.9	5026.9	0.0	89.79
21.1	164.4	5.563	0.686	2.25	15.80	0.811	4809.8	4809.8	0.0	89.79
23.0	164.6	5.180	0.713	2.51	15.80	0.807	4598.6	4598.6	0.0	89.79
27.5	165.3	4.663	0.735	3.01	15.80	0.798	4185.1	4185.1	0.0	89.79
32.6	166.7	4.302	0.742	3.51	15.80	0.788	3814.8	3814.8	0.0	89.79
33.1	166.9	4.273	0.742	3.55	15.80	0.787	3782.7	3782.7	0.0	89.79
34.1	167.2	4.397	0.744	3.64	15.80	0.789	3935.9	3690.7	0.0	89.68
38.1	168.6	3.094	0.734	4.00	15.80	0.703	2067.2	1808.2	0.0	89.57
38.1	168.7	3.062	0.734	4.00	15.80	0.705	2064.4	1805.6	0.0	89.57
39.2	169.0	3.038	0.734	4.07	15.71	0.707	258.5	0.0	0.0	88.00
46.2	172.2	2.812	0.732	4.53	14.68	0.704	259.3	0.0	0.0	88.00
54.0	176.7	2.574	0.730	5.00	13.69	0.698	260.0	0.0	0.0	88.00

Table 6.4-9 (Cont.)

DEPS Break - Minimum Safeguards Principal Parameters during Reflood

Time Seconds	Flooding Temp °F	Flooding Rate in/sec	Carryover Fraction	Core Height (ft)	Downcomer Height (ft)	Flow Frac	Total (pounds mass per second)	Injection Accum (pounds mass per second)	Spill (pounds mass per second)	Enthalpy Btu/lbm
63.2	182.7	2.301	0.720	5.51	12.73	0.690	260.8	0.0	0.0	88.00
73.1	189.7	2.020	0.720	6.00	11.93	0.677	261.5	0.0	0.0	88.00
85.2	198.5	1.706	0.713	6.53	11.26	0.655	262.3	0.0	0.0	88.00
97.6	207.5	1.433	0.706	7.00	10.88	0.625	262.8	0.0	0.0	88.00
113.2	217.5	1.262	0.702	7.52	10.71	0.614	262.9	0.0	0.0	88.00
129.3	226.2	1.150	0.700	8.00	10.72	0.612	262.9	0.0	0.0	88.00
149.2	235.3	1.056	0.699	8.55	10.90	0.613	262.9	0.0	0.0	88.00
166.7	242.1	1.002	0.700	9.00	11.17	0.614	262.9	0.0	0.0	88.00
187.2	249.0	0.965	0.702	9.50	11.56	0.618	262.9	0.0	0.0	88.00
208.4	255.3	0.945	0.706	10.00	12.02	0.622	262.9	0.0	0.0	88.00

Table 6.4-10

DEPS Break Minimum Safeguards Post-Reflood Mass and Energy Releases

Time (seconds)	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
208.4	97.5	123.6	165.4	48.6
213.4	97.2	123.3	165.7	48.6
218.4	98.2	124.5	164.7	48.3
223.4	97.9	124.2	165.0	48.3
228.4	97.7	123.8	165.2	48.3
233.4	97.4	123.5	165.5	48.2
238.4	98.3	124.7	164.6	47.9
243.4	98.1	124.3	164.8	47.9
248.4	97.8	124.0	165.1	47.9
253.4	97.5	123.7	165.4	47.9
258.4	98.5	124.8	164.4	47.5
263.4	98.2	124.5	164.7	47.5
268.4	97.9	124.2	165.0	47.5
273.4	97.7	123.8	165.2	47.5
278.4	98.6	125.0	164.3	47.2
283.4	98.3	124.6	164.6	47.2
288.4	98.0	124.3	164.9	47.2
293.4	97.7	123.9	165.2	47.1
298.4	98.6	125.0	164.3	46.8
303.4	98.3	124.7	164.6	46.8
308.4	98.0	124.3	164.8	46.8
313.4	97.8	124.0	165.1	46.8
318.4	98.6	125.1	164.3	46.5
323.4	98.3	124.7	164.6	46.5
328.4	98.1	124.3	164.8	46.5
333.4	98.9	125.4	164.0	46.1
338.4	98.6	125.0	164.3	46.1
343.4	98.3	124.7	164.6	46.1
348.4	98.0	124.3	164.9	46.1
353.4	98.9	125.3	164.0	45.8
358.4	98.6	125.0	164.3	45.8
363.4	98.2	124.6	164.6	45.8
368.4	99.1	125.6	163.8	45.5
373.4	98.8	125.2	164.1	45.5

Table 6.4-10 (Cont.) DEPS Break Minimum Safeguards Post-Reflood Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
378.4	98.4	124.8	164.5	45.5
383.4	99.2	125.8	163.7	45.2
388.4	98.9	125.4	164.0	45.2
393.4	98.6	125.0	164.3	45.2
398.4	98.3	124.6	164.6	45.2
403.4	99.1	125.7	163.8	44.9
408.4	98.9	125.4	164.0	44.8
413.4	96.4	122.3	166.5	46.8
418.4	96.2	122.0	166.7	46.8
423.4	96.0	121.7	166.9	46.8
428.4	96.8	122.7	166.1	46.5
433.4	96.5	122.4	166.3	46.4
438.4	96.3	122.1	166.6	46.4
443.4	97.1	123.1	165.8	46.1
448.4	96.9	122.8	166.0	46.1
453.4	96.6	122.5	166.3	46.1
458.4	97.4	123.5	165.5	45.7
463.4	97.1	123.2	165.8	45.7
468.4	96.9	122.8	166.0	45.7
473.4	97.7	123.8	165.2	45.4
478.4	97.4	123.5	165.5	45.4
483.4	97.1	123.1	165.8	45.4
488.4	97.9	124.1	165.0	45.1
493.4	97.6	123.7	165.3	45.0
498.4	98.3	124.7	164.6	44.7
503.4	98.0	124.3	164.9	44.7
508.4	97.7	123.9	165.1	44.7
513.4	98.5	124.9	164.4	44.4
518.4	98.2	124.5	164.7	44.4
523.4	98.9	125.4	164.0	44.1
528.4	98.6	125.0	164.3	44.1
533.4	98.2	124.6	164.7	44.1
538.4	98.9	125.4	164.0	43.8
543.4	98.6	125.0	164.3	43.8

Table 6.4-10 (Cont.) DEPS Break Minimum Safeguards Post-Reflood Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
548.4	99.3	125.9	163.6	43.5
553.4	98.9	125.4	164.0	43.5
558.4	96.6	122.5	166.3	45.4
563.4	96.3	122.1	166.6	45.4
568.4	97.0	122.9	165.9	45.1
573.4	96.6	122.5	166.3	45.1
578.4	97.2	123.3	165.6	44.8
583.4	96.9	122.9	166.0	44.8
588.4	97.5	123.6	165.4	44.5
593.4	97.2	123.2	165.7	44.5
598.4	97.7	123.9	165.2	44.3
603.4	97.4	123.5	165.5	44.2
608.4	98.0	124.2	164.9	44.0
613.4	97.6	123.8	165.3	44.0
618.4	98.2	124.5	164.7	43.7
623.4	97.8	124.0	165.1	43.7
628.4	98.4	124.7	164.5	43.5
633.4	98.9	125.4	164.0	43.2
638.4	98.5	124.9	164.4	43.2
643.4	99.0	125.5	163.9	43.0
648.4	98.6	125.0	164.3	43.0
653.4	98.2	124.5	164.7	43.0
658.4	96.9	122.8	166.0	44.5
663.4	96.5	122.3	166.4	44.5
668.4	96.9	122.9	166.0	44.3
673.4	97.4	123.5	165.5	44.0
678.4	97.8	124.0	165.1	43.8
683.4	97.3	123.4	165.6	43.8
688.4	97.7	123.9	165.2	43.6
693.4	98.1	124.4	164.8	43.4
698.4	97.6	123.8	165.3	43.4
703.4	97.9	124.2	165.0	43.2
708.4	97.4	123.5	165.5	43.2
713.4	97.7	123.9	165.2	43.0
718.4	98.0	124.3	164.9	42.8

Table 6.4-10 (Cont.) DEPS Break Minimum Safeguards Post-Reflood Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
723.4	97.5	123.6	165.4	42.8
728.4	97.7	123.9	165.2	42.6
733.4	97.1	123.2	165.8	42.7
738.4	97.3	123.4	165.6	43.7
743.4	97.5	123.6	165.4	43.6
748.4	96.9	122.9	166.0	43.6
753.4	97.0	123.0	165.9	43.4
758.4	97.1	123.2	165.8	43.3
763.4	97.2	123.3	165.7	43.1
768.4	97.2	123.3	165.7	43.0
773.4	97.2	123.3	165.6	42.8
778.4	96.5	122.4	166.4	42.9
783.4	96.5	122.3	166.4	42.8
788.4	96.4	122.2	166.5	42.7
793.4	96.9	122.9	165.9	42.4
798.4	96.8	122.7	166.1	42.3
803.4	96.6	122.4	166.3	43.4
808.4	96.3	122.1	166.6	43.4
813.4	96.7	122.6	166.2	43.1
818.4	96.3	122.1	166.6	43.1
823.4	96.5	122.3	166.4	42.9
828.4	96.0	121.7	166.9	42.9
833.4	96.0	121.8	166.9	42.7
838.4	96.0	121.7	166.9	42.6
843.4	95.8	121.5	167.1	42.5
848.4	96.1	121.8	166.8	42.3
853.4	96.2	122.0	166.7	42.1
858.4	96.1	121.9	166.8	43.1
863.4	95.8	121.5	167.1	43.0
868.4	95.8	121.5	167.1	42.9
873.4	40.3	51.1	222.6	57.3
1083.8	40.3	51.1	222.6	57.3
1083.9	46.2	57.7	216.6	55.0
1088.4	46.2	57.7	216.7	54.8
1367.6	46.2	57.7	216.7	54.8

Table 6.4-10 (Cont.) DEPS Break Minimum Safeguards Post-Reflood Mass and Energy Releases				
	Break Path No. 1 Flow[1]		Break Path No. 2 Flow[2]	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
1367.7	43.7	50.3	219.2	20.6
3600.0	35.0	40.2	227.9	22.2
3600.1	24.6	28.3	238.3	21.0
3953.0	23.6	27.2	239.3	21.1
3953.1	23.6	27.2	61.2	5.4
4143.0	23.3	26.8	61.5	5.4
4143.1	23.8	27.4	94.3	10.3
6352.0	20.9	24.0	97.2	10.6
6352.1	21.5	24.7	11.8	1.6
6382.0	21.4	24.7	11.9	1.6
6382.1	21.4	24.6	164.8	22.6
10000.0	18.8	21.6	167.4	22.9
10000.1	18.5	21.2	167.7	20.1
50000.0	12.1	13.9	174.1	20.9
50000.1	11.9	13.7	174.3	18.8
100000.0	9.8	11.2	176.4	19.1
100000.1	9.6	11.1	176.6	16.4
500000.0	5.6	6.4	180.6	16.8
500000.1	5.5	6.3	180.7	14.8
1000000.0	4.1	4.7	182.1	14.9
10000000.0	1.3	1.5	184.9	15.2

Notes:

1. Mass and energy exiting from the steam-generator side of the break (path 1).
2. Mass and energy exiting from the pump-side of the break (path 2).

Table 6.4-11

DEPS Break
Mass Balance Minimum Safeguards

Mass Balance								
	Time (seconds)	0.00	14.00	14.00	208.36	1083.88	1367.56	3600.00
Mass (thousand lbm)								
Initial	In RCS and ACC	439.54	439.54	439.54	439.54	439.54	439.54	439.54
Added Mass	Pumped injection	0.00	0.00	0.00	45.71	275.87	350.45	937.34
	Total added	0.00	0.00	0.00	45.71	275.87	350.45	937.34
*** Total Available ***		439.54	439.54	439.54	485.25	715.41	789.98	1376.88
Distribution	Reactor coolant	278.29	25.90	43.94	79.13	79.13	79.13	79.13
	Accumulator	161.25	126.44	108.40	0.00	0.00	0.00	0.00
	Total contents	439.54	152.35	152.35	79.13	79.13	79.13	79.13
Effluent	Break flow	0.00	287.18	287.18	406.11	636.27	710.85	1297.74
	ECCS spill	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total effluent	0.00	287.18	287.18	406.11	636.27	710.85	1297.74
*** Total Accountable ***		439.54	439.53	439.53	485.24	715.40	789.97	1376.87

Table 6.4-12

DEPS Break
Energy Balance Minimum Safeguards

Energy Balance								
Time (seconds)		0.00	14.00	14.00	208.36	1082.881	1367.56	3600.00
Energy (million BTU)								
Initial Energy	In RCS, ACC, steam generator	444.59	444.59	444.59	444.59	444.59	444.59	444.59
Added Energy	Pumped injection	0.00	0.00	0.00	4.02	24.28	30.84	82.49
	Decay heat	0.00	2.43	2.43	14.36	51.57	61.72	127.66
	Heat from secondary	0.00	-1.17	-1.17	-1.17	2.22	2.82	2.82
	Total added	0.00	-1.17	-1.17	-1.17	2.22	2.82	2.82
*** Total Available ***		444.59	445.85	445.85	461.80	522.66	539.96	657.55
Distribution	Reactor coolant	162.28	5.97	7.59	19.96	19.96	19.96	19.96
	Accumulator	14.48	11.35	9.73	0.00	0.00	0.00	0.00
	Core stored	14.26	8.89	8.89	2.63	2.51	2.44	1.81
	Primary metal	85.25	81.33	81.33	67.30	41.18	37.80	28.70
	Secondary metal	43.61	43.48	43.48	40.78	25.49	22.71	17.43
	Steam generator	124.70	124.22	124.22	114.67	70.77	63.80	49.48
	Total contents	444.59	275.25	275.25	245.34	159.91	146.70	117.38
Effluent	Break flow	0.00	170.28	170.28	212.42	358.70	379.09	527.97
	ECCS spill	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total effluent	0.00	170.28	170.28	212.42	358.70	379.09	527.97
*** Total Accountable ***		444.59	445.53	445.53	457.76	518.62	525.79	645.35

Table 6.4-13

DEPS Break Maximum Safeguards Reflood Mass and Energy Releases

Time (seconds)	Break Path No. 1 Flow		Break Path No. 2 Flow	
	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
14.0	0.0	0.0	0.0	0.0
14.4	0.0	0.0	0.0	0.0
14.6	0.0	0.0	0.0	0.0
14.7	0.0	0.0	0.0	0.0
14.7	0.0	0.0	0.0	0.0
14.8	0.4	0.5	0.0	0.0
15.0	29.2	34.4	0.0	0.0
15.1	34.5	40.7	0.0	0.0
15.2	41.1	48.4	0.0	0.0
15.3	47.7	56.2	0.0	0.0
15.4	54.0	63.7	0.0	0.0
15.5	58.2	68.6	0.0	0.0
15.6	62.8	74.0	0.0	0.0
15.7	68.2	80.4	0.0	0.0
15.8	72.3	85.2	0.0	0.0
15.9	74.3	87.5	0.0	0.0
15.9	76.3	89.8	0.0	0.0
16.0	80.0	94.3	0.0	0.0
16.1	83.7	98.6	0.0	0.0
16.2	87.2	102.7	0.0	0.0
16.3	90.6	106.7	0.0	0.0
16.4	93.9	110.6	0.0	0.0
16.5	97.1	114.4	0.0	0.0
16.6	99.4	117.2	0.0	0.0
16.7	103.2	121.6	0.0	0.0
16.8	106.2	125.2	0.0	0.0
16.9	108.3	127.7	0.0	0.0
17.0	111.9	131.8	0.0	0.0
18.0	137.0	161.4	0.0	0.0
19.0	243.4	287.3	2100.6	227.2
19.6	412.2	488.0	4072.4	448.0
20.1	427.7	506.6	4200.8	467.6
21.1	421.1	498.7	4134.6	462.0
22.1	412.4	488.3	4051.3	454.0

Table 6.4-13 (Cont.)

DEPS Break Maximum Safeguards
Reflood Mass and Energy Releases

Time (seconds)	Break Path No. 1 Flow		Break Path No. 2 Flow	
	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
23.0	404.7	479.2	3976.4	446.7
23.1	403.9	478.2	3968.1	445.9
24.1	395.7	468.4	3887.1	438.0
25.1	387.9	459.1	3808.7	430.4
26.1	380.6	450.4	3733.4	423.1
27.1	373.6	442.0	3661.0	416.1
27.5	370.9	438.8	3632.9	413.4
28.1	367.0	434.1	3591.6	409.4
29.1	360.7	426.7	3524.9	403.0
30.1	354.7	419.6	3460.8	396.8
31.1	349.1	412.8	3399.3	390.9
32.1	343.7	406.4	3340.0	385.2
32.6	341.1	403.3	3311.2	382.4
33.1	338.5	400.3	3283.0	379.7
34.1	372.4	440.7	3675.0	415.0
35.1	368.0	435.4	3623.8	410.4
36.1	363.6	430.1	3574.6	405.7
37.1	359.4	425.1	3527.1	401.2
37.9	356.1	421.2	3490.1	397.7
38.1	240.2	283.6	2032.3	261.7
39.2	154.3	181.9	382.1	72.2
40.2	153.9	181.5	382.7	72.2
41.2	153.6	181.1	383.3	72.2
42.2	153.3	180.7	383.9	72.1
43.2	152.9	180.3	384.5	72.1
44.2	152.6	179.9	385.1	72.1
45.2	152.3	179.5	385.6	72.0
46.2	152.0	179.2	386.2	72.0
47.2	151.7	178.8	386.7	72.0
48.2	151.4	178.4	387.3	71.9
49.2	151.0	178.1	387.8	71.9
50.2	150.7	177.7	388.4	71.8
51.2	150.4	177.3	388.9	71.8
52.2	150.1	177.0	389.4	71.7

Table 6.4-13 (Cont.)

DEPS Break Maximum Safeguards Reflood Mass and Energy Releases

Time (seconds)	Break Path No. 1 Flow		Break Path No. 2 Flow	
	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
53.2	149.8	176.6	389.9	71.7
54.2	149.5	176.3	390.5	71.7
55.2	149.2	175.9	391.0	71.6
55.7	149.1	175.8	391.2	71.6
56.2	148.9	175.6	391.5	71.6
57.2	148.6	175.2	392.0	71.5
58.2	148.3	174.9	392.5	71.5
59.2	148.0	174.5	393.0	71.4
60.2	147.8	174.2	393.5	71.4
61.2	147.5	173.8	394.0	71.4
62.2	147.2	173.5	394.5	71.3
63.2	146.9	173.1	395.1	71.3
64.2	146.6	172.8	395.6	71.2
65.2	146.3	172.4	396.1	71.2
66.2	146.0	172.1	396.6	71.1
67.2	145.7	171.7	397.1	71.1
68.2	145.4	171.4	397.6	71.0
69.2	145.1	171.0	398.1	71.0
70.2	144.8	170.6	398.7	70.9
71.2	144.5	170.3	399.2	70.9
72.2	144.2	169.9	399.7	70.8
73.2	143.8	169.6	400.2	70.8
74.2	143.5	169.2	400.8	70.8
74.7	143.4	169.0	401.0	70.7
75.2	143.2	168.8	401.3	70.7
77.2	142.6	168.1	402.4	70.6
79.2	142.0	167.4	403.4	70.5
81.2	141.3	166.6	404.5	70.4
83.2	140.7	165.8	405.6	70.3
85.2	140.0	165.1	406.7	70.2
87.2	139.4	164.3	407.9	70.1
89.2	138.7	163.5	409.0	70.1
91.2	138.0	162.7	410.2	70.0
93.2	137.3	161.9	411.3	69.9

Table 6.4-13 (Cont.)

DEPS Break Maximum Safeguards
Reflood Mass and Energy Releases

Time (seconds)	Break Path No. 1 Flow		Break Path No. 2 Flow	
	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
95.0	136.7	161.1	412.4	69.8
95.2	136.6	161.0	412.5	69.8
97.2	135.9	160.2	413.7	69.7
99.2	135.2	159.4	414.9	69.6
101.2	134.5	158.5	416.1	69.5
103.2	133.8	157.7	417.3	69.4
105.2	133.0	156.8	418.5	69.3
107.2	132.3	155.9	419.8	69.2
109.2	131.6	155.1	421.0	69.1
111.2	130.8	154.2	422.2	69.0
113.2	130.1	153.3	423.5	68.9
115.2	129.3	152.4	424.7	68.8
116.8	128.7	151.7	425.7	68.7
117.2	128.5	151.5	425.9	68.7
119.2	127.8	150.6	427.2	68.6
121.2	127.0	149.7	428.4	68.5
123.2	126.3	148.8	429.6	68.4
125.2	125.5	147.9	430.9	68.3
127.2	124.8	147.0	432.1	68.2
129.2	124.0	146.1	433.3	68.0
131.2	123.2	145.2	434.5	67.9
133.2	122.5	144.3	435.8	67.8
135.2	121.7	143.4	437.0	67.7
137.2	120.9	142.5	438.2	67.6
139.2	120.2	141.6	439.4	67.5
140.7	119.6	141.0	440.3	67.4
141.2	119.4	140.7	440.6	67.4
143.2	118.7	139.8	441.8	67.2
145.2	117.9	139.0	443.0	67.1
147.2	117.2	138.1	444.2	67.0
149.2	116.4	137.2	445.4	66.9
151.2	115.7	136.3	446.6	66.8
153.2	114.9	135.4	447.8	66.6
155.2	114.1	134.5	449.0	66.5

Table 6.4-13 (Cont.) DEPS Break Maximum Safeguards Reflood Mass and Energy Releases				
	Break Path No. 1 Flow		Break Path No. 2 Flow	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
157.2	113.4	133.6	450.1	66.4
159.2	112.6	132.7	451.3	66.3
161.2	111.9	131.9	452.5	66.2
163.2	111.1	131.0	453.7	66.0
165.2	110.4	130.1	454.8	65.9
167.2	109.8	129.3	455.8	66.0
167.3	109.7	129.3	455.8	66.0

Table 6.4-14

DEPS Break - Maximum Safeguards
Principal Parameters during Reflood

Time (seconds)	Flooding Temp °F	Flooding Rate in/sec	Carryover Fraction	Core Height (ft)	Downcomer Height (ft)	Flow Frac	Total (pounds mass per second)	Injection Accum (pounds mass per second)	Spill (pounds mass per second)	Enthalpy Btu/lbm
14.0	167.2	0.000	0.000	0.00	0.00	0.500	0.0	0.0	0.0	0.00
14.6	165.6	28.507	0.000	0.58	1.60	0.498	6223.7	6223.7	0.0	89.79
14.8	164.4	35.044	0.000	1.12	1.81	0.443	6157.1	6157.1	0.0	89.79
15.9	164.1	3.037	0.301	1.50	5.34	0.599	5924.8	5924.8	0.0	89.79
16.7	164.2	2.917	0.423	1.63	8.19	0.618	5764.8	5764.8	0.0	89.79
19.6	164.5	5.921	0.636	2.01	15.78	0.813	5026.9	5026.9	0.0	89.79
21.1	164.4	5.563	0.686	2.25	15.80	0.811	4809.8	4809.8	0.0	89.79
23.0	164.6	5.180	0.713	2.51	15.80	0.807	4598.6	4598.6	0.0	89.79
27.5	165.3	4.663	0.735	3.01	15.80	0.798	4185.1	4185.1	0.0	89.79
32.6	166.7	4.302	0.742	3.51	15.80	0.788	3814.8	3814.8	0.0	89.79
33.1	166.9	4.273	0.742	3.55	15.80	0.787	3782.7	3782.7	0.0	89.79
34.1	167.2	4.611	0.746	3.64	15.80	0.800	4219.3	3648.7	0.0	89.55
37.9	168.6	4.428	0.748	4.01	15.80	0.793	4009.8	3434.4	0.0	89.53
39.2	169.0	2.460	0.723	4.09	15.80	0.640	614.6	0.0	0.0	88.00
47.2	172.8	2.412	0.725	4.54	15.80	0.641	614.6	0.0	0.0	88.00
55.7	178.0	2.364	0.726	5.00	15.80	0.641	614.5	0.0	0.0	88.00

Table 6.4-14 (Cont.)

DEPS Break - Maximum Safeguards
Principal Parameters during Reflood

Time (seconds)	Flooding Temp °F	Flooding Rate in/sec	Carryover Fraction	Core Height (ft)	Downcomer Height (ft)	Flow Frac	Total (pounds mass per second)	Injection Accum (pounds mass per second)	Spill (pounds mass per second)	Enthalpy Btu/lbm
65.2	184.9	2.311	0.727	5.51	15.80	0.642	614.5	0.0	0.0	88.00
74.7	192.4	2.258	0.729	6.00	15.80	0.643	614.4	0.0	0.0	88.00
85.2	201.2	2.197	0.730	6.53	15.80	0.644	614.4	0.0	0.0	88.00
95.0	209.6	2.137	0.732	7.00	15.80	0.645	614.3	0.0	0.0	88.00
107.2	220.0	2.058	0.734	7.57	15.80	0.646	614.3	0.0	0.0	88.00
116.8	227.4	1.995	0.736	8.00	15.80	0.647	614.2	0.0	0.0	88.00
129.2	235.8	1.913	0.738	8.53	15.80	0.648	614.2	0.0	0.0	88.00
140.7	242.6	1.837	0.740	9.00	15.80	0.649	614.1	0.0	0.0	88.00
155.2	250.0	1.744	0.742	9.56	15.80	0.651	614.1	0.0	0.0	88.00
167.3	255.3	1.668	0.744	10.00	15.80	0.653	614.0	0.0	0.0	88.00

Table 6.4-15 DEPS Break Maximum Safeguards Post-Reflood Mass and Energy Releases				
	Break Path No. 1 Flow		Break Path No. 2 Flow	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
167.3	127.0	160.3	487.6	74.3
172.3	126.5	159.6	488.2	74.3
177.3	125.9	158.9	488.7	74.4
182.3	125.4	158.2	489.3	74.4
187.3	125.9	158.9	488.7	74.2
192.3	125.4	158.2	489.3	74.2
197.3	124.8	157.5	489.8	74.3
202.3	125.4	158.2	489.3	74.0
207.3	125.0	157.7	489.7	74.0
212.3	124.6	157.2	490.1	74.0
217.3	124.1	156.7	490.5	74.0
222.3	124.8	157.5	489.9	73.8
227.3	124.3	156.9	490.3	73.8
232.3	123.9	156.4	490.7	73.8
237.3	124.5	157.1	490.1	73.6
242.3	124.1	156.6	490.6	73.6
247.3	123.6	156.0	491.0	73.6
252.3	123.2	155.5	491.5	73.6
257.3	123.8	156.2	490.9	73.4
262.3	123.3	155.6	491.3	73.4
267.3	122.9	155.0	491.8	73.4
272.3	123.4	155.8	491.2	73.2
277.3	123.0	155.2	491.7	73.2
282.3	122.5	154.6	492.2	73.2
287.3	123.0	155.2	491.6	73.0
292.3	122.5	154.6	492.1	73.0
297.3	122.0	154.0	492.6	73.0
302.3	122.6	154.7	492.1	72.8
307.3	122.1	154.0	492.6	72.8
312.3	122.5	154.6	492.1	72.6
317.3	122.0	154.0	492.6	72.6
322.3	121.5	153.4	493.1	72.7
327.3	122.0	153.9	492.7	72.5

Table 6.4-15 (Cont.) DEPS Break Maximum Safeguards Post-Reflood Mass and Energy Releases				
	Break Path No. 1 Flow		Break Path No. 2 Flow	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
332.3	121.4	153.3	493.2	72.5
337.3	121.9	153.8	492.8	72.3
342.3	121.3	153.1	493.3	72.3
347.3	120.8	152.4	493.9	72.4
352.3	121.2	152.9	493.4	72.2
357.3	120.6	152.2	494.0	72.2
362.3	121.0	152.7	493.6	73.4
367.3	120.4	152.0	494.2	73.4
372.3	120.8	152.4	493.9	73.2
377.3	120.2	151.7	494.4	73.3
382.3	120.5	152.1	494.1	73.1
387.3	119.9	151.3	494.7	73.1
392.3	120.2	151.7	494.4	73.0
397.3	119.6	150.9	495.1	73.0
402.3	119.9	151.3	494.8	72.8
407.3	119.3	150.6	495.3	72.9
412.3	119.6	151.0	495.0	72.7
417.3	119.0	150.2	495.6	72.7
422.3	119.3	150.6	495.3	72.5
427.3	119.6	150.9	495.1	72.4
432.3	119.0	150.1	495.7	72.4
437.3	119.2	150.4	495.5	72.3
442.3	118.5	149.6	496.1	72.3
447.3	118.7	149.8	495.9	72.2
452.3	118.9	150.0	495.8	72.0
457.3	119.0	150.2	495.6	71.9
462.3	118.3	149.3	496.3	71.9
467.3	118.4	149.4	496.2	71.8
472.3	118.5	149.5	496.2	71.7
477.3	118.5	149.6	496.1	71.6
482.3	118.5	149.6	496.1	71.4
487.3	118.5	149.6	496.1	71.3
492.3	118.5	149.5	496.2	72.5
497.3	118.4	149.4	496.3	72.5
502.3	118.3	149.2	496.4	72.4

Table 6.4-15 (Cont.) DEPS Break Maximum Safeguards Post-Reflood Mass and Energy Releases				
	Break Path No. 1 Flow		Break Path No. 2 Flow	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
512.3	117.9	148.8	496.7	72.2
517.3	117.7	148.5	496.9	72.2
522.3	117.4	148.2	497.2	72.1
527.3	117.1	147.8	497.5	72.1
532.3	117.5	148.3	497.1	71.8
537.3	117.1	147.8	497.5	71.8
542.3	117.3	148.1	497.3	71.7
547.3	116.8	147.4	497.8	71.7
552.3	116.9	147.5	497.7	71.5
557.3	116.9	147.5	497.7	71.4
562.3	116.8	147.4	497.8	71.3
567.3	116.7	147.2	498.0	71.2
572.3	116.4	146.9	498.3	71.2
577.3	116.6	147.1	498.1	71.0
582.3	116.7	147.2	498.0	72.1
587.3	116.5	147.1	498.1	72.0
592.3	116.3	146.7	498.4	71.9
597.3	116.3	146.8	498.3	71.8
602.3	116.1	146.6	498.5	71.7
607.3	116.2	146.6	498.5	71.6
612.3	115.9	146.2	498.8	71.5
617.3	116.0	146.4	498.6	71.3
622.3	115.6	145.9	499.1	71.3
627.3	115.7	146.0	499.0	71.2
632.3	43.4	54.7	571.3	90.0
832.1	43.4	54.7	571.3	90.0
832.2	47.0	58.7	567.6	88.7
832.3	47.0	58.7	567.6	88.7
1252.9	47.0	58.7	567.6	88.7
1253.0	44.3	55.2	260.6	100.4
1286.2	44.3	55.2	260.6	100.4
1286.3	42.7	49.1	262.2	23.6
1443.0	41.4	47.7	263.5	23.8
1443.1	41.4	47.7	330.1	34.5
1473.0	41.2	47.4	330.3	34.6
1473.1	41.2	47.4	449.9	65.8

Table 6.4-15 (Cont.) DEPS Break Maximum Safeguards Post-Reflood Mass and Energy Releases				
	Break Path No. 1 Flow		Break Path No. 2 Flow	
Time (seconds)	(lbm/sec)	Thousand (Btu/sec)	(lbm/sec)	Thousand (Btu/sec)
1473.1	41.2	47.4	449.9	65.8
2707.0	36.0	41.4	455.1	66.7
2707.1	36.0	41.4	150.2	23.7
2919.0	35.4	40.7	150.8	23.8
2919.1	35.4	40.7	150.8	23.2
3600.0	33.3	38.3	152.9	23.6
3600.1	25.8	29.7	160.4	21.7
5000.0	23.1	26.6	163.1	22.0
5000.1	23.1	26.5	163.1	21.4
10000.0	18.7	21.5	167.5	21.9
10000.1	18.5	21.3	167.7	20.5
30000.0	14.1	16.2	172.1	21.1
30000.1	13.9	16.0	172.3	19.0
100000.0	9.8	11.3	176.4	19.4
100000.1	9.6	11.1	176.6	16.8
500000.0	5.6	6.4	180.6	17.2
500000.1	5.5	6.4	180.7	15.9
1000000.0	4.1	4.7	182.1	16.0

Table 6.4-16

DEPS Break
Mass Balance
Maximum Safeguards

		Mass Balance						
Time (seconds)		0.00	14.00	14.00	167.26	832.20	1286.16	3600.00
		Mass (thousand lbm)						
Initial	In RCS and ACC	439.54	439.54	439.54	439.54	439.54	439.54	439.54
Added mass	Pumped injection	0.00	0.00	0.00	81.80	490.48	718.21	1590.49
	Total added	0.00	0.00	0.00	81.80	490.48	718.21	1590.49
***** Total Available *****		439.54	439.54	439.54	521.33	930.01	1157.75	2030.03
Distribution	Reactor coolant	278.29	25.90	43.94	84.82	84.82	84.82	84.82
	Accumulator	161.25	126.44	08.40	0.00	0.00	0.00	0.00
	Total contents	439.54	152.35	152.35	84.82	84.82	84.82	84.82
Effluent	Break flow	0.00	287.18	287.18	436.51	845.19	1113.92	1945.19
	ECCS spill	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total effluent	0.00	287.18	287.18	436.51	845.19	1113.92	1945.19
***** Total Accountable *****		439.54	439.53	439.53	521.33	930.00	1198.74	2030.01

Table 6.4-17

DEPS Break
Energy Balance
Maximum Safeguards

		Energy Balance						
Time (seconds)		0.00	14.00	14.00	167.26	832.20	1286.16	3600.00
		Energy (million Btu)						
Initial energy	In RCS, ACC, steam generator	444.59	444.59	444.59	444.59	444.59	444.59	444.59
Added energy	Pumped injection	0.00	0.00	0.00	7.20	43.16	63.20	179.55
	Decay heat	0.00	2.43	2.43	12.18	42.02	58.87	127.53
	Heat from secondary	0.00	-1.17	-1.17	-1.17	1.41	2.52	2.52
	Total added	0.00	1.26	1.26	18.21	86.59	124.59	309.61
*** Total Available ***		444.59	445.85	445.85	462.80	531.17	569.18	754.19
Distribution	Reactor coolant	162.28	5.97	7.59	21.47	21.47	21.47	21.47
	Accumulator	14.48	11.35	9.73	0.00	0.00	0.00	0.00
	Core stored	14.26	8.89	8.89	2.63	2.42	2.32	1.81
	Primary metal	85.25	81.33	81.33	66.48	41.33	36.05	28.49
	Secondary metal	43.61	43.48	43.48	39.92	26.13	21.65	17.22
	Steam generator	124.70	124.22	124.22	111.77	71.86	60.59	48.62
	Total contents	444.59	275.25	275.25	242.27	163.21	142.09	117.61
Effluent	Break flow	0.00	170.28	170.28	216.49	363.93	416.76	623.70
	ECCS spill	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total effluent	0.00	170.28	170.28	216.49	363.93	416.76	623.70
*** Total Accountable ***		444.59	445.53	445.53	458.77	527.14	558.85	741.32

Table 6.4-18 LOCA Mass and Energy Release Analysis Core Decay Heat Fraction	
Time (sec)	**Decay Heat Generation Rate (Btu/Btu)**
10	0.053876
15	0.050401
20	0.048018
40	0.042401
60	0.039244
80	0.037065
100	0.035466
150	0.032724
200	0.030936
400	0.027078
600	0.024931
800	0.023389
1000	0.022156
1500	0.019921
2000	0.018315
4000	0.014781
6000	0.013040
8000	0.012000
10000	0.011262
15000	0.010097
20000	0.009350
40000	0.007778
60000	0.006958
80000	0.006424
100000	0.006021
150000	0.005323
200000	0.004847
400000	0.003770
600000	0.003201
800000	0.002834
1000000	0.002580

Table 6.4-19 Comparison of RCS Conditions for Short-Term LOCA Mass and Energy Releases		
	RCS Temperature (°F)	
	RSG (low T_{avg})	Power Uprate (low T_{avg})
Hot Leg	586.3	590.8
Cold Leg	521.9	521.9
T_{avg}	554.1	556.3

Table 6.4-20 Containment Response Analysis Parameters	
Service Water Temperature (°F)	80
RWST Water Temperature (°F)	120
Initial Containment Temperature (°F)	120
Initial Containment Pressure (psia)	16.85
Initial Relative Humidity (%)	17.7
Net Free Volume (ft3)	1.32×10^6
CFCU	
Total	4
Analysis Maximum	4
Analysis Minimum	2
Containment High Pressure Setpoint (psig)	5.00
Delay Time (sec) With Offsite Power Without Offsite Power	 75.0 85.0
Containment Spray Pumps	
Total	2
Analysis Maximum	2
Analysis Minimum	1
Flow Rate (gpm) Injection Phase (per pump) Recirculation Phase	 1170 Not modeled
Containment High-High Pressure Setpoint (psig)	23.0
Delay time (sec) With Offsite Power (delay after high-high pressure setpoint) Without Offsite Power (delay after high-high pressure setpoint)	 106.0 135.0
CS Termination Time, (sec) Minimum Safeguards Maximum Safeguards (stop one pump/stop second pump)	 3953 1253/2707

Table 6.4-20 (Cont.) Containment Response Analysis Parameters	
RHRS	
Recirculation Switchover, Full Flow Established, (sec)	
Minimum Safeguards Maximum Safeguards	6382 1473
Number of Heat Exchangers Modeled in the Analysis	1
RHR Flows through RHR Heat Exchangers	
Minimum Safeguards	
Time (sec)	Flow (lbm/s)
0.0	0.0
4143	0.0
4143.1	33.3
6382	33.3
6382.1	186.2
3.1E+6	186.2
Maximum Safeguards	
Time (sec)	Flow (lbm/s)
0.0	0.0
1472	0.0
1473	186.2
3.1E+6	186.2
CCW Flow through RHR Heat Exchanger - lbm/s	170.6
CCW Heat Exchangers	
Number of Heat Exchangers Modeled in the Analysis	1
CCW Flow (lbm/s)	341.2
Service Water Flow (lbm/s)	277.4
Additional Heat Loads, Btu/hr	4.6×10^6

Table 6.4-21 DEPS Break Sequence of Events (minimum safeguards)	
Time (sec)	**Event Description**
0.0	Break Occurs, Reactor Trip and Loss-of-Offsite Power Are Assumed
0.22	Containment High Pressure Setpoint of 5.0 psig Reached
0.60	Compensated Pressurizer Pressure Turbine Trip - 1750 psia Reached
2.8	Containment High-High Pressure Setpoint of 23.0 psig Reached
3.8	Low-Pressurizer Pressure SI Setpoint - 1700 psia Reached
6.76	Broken Loop Accumulator Begins Injecting Water
6.85	Intact Loop Accumulator Begins Injecting Water
14.0	End of Blowdown Phase
14.0	Accumulator Mass Adjustment for Refill Period
33.8	Pumped SI Begins after 30-Second Diesel Delay
37.9	Broken Loop Accumulator Water Injection Ends
38.5	Intact Loop Accumulator Water Injection Ends
58.1	Peak Containment Pressure Occurs after Accumulator N_2 is Released to Containment
85.3	Emergency CFCUs Heat Removal Begins
137.8	CS Pump (from RWST) Begins
208.4	End of Reflood Phase
1083.9	Mass & Energy Release Assumption: Broken Loop Steam Generator Equilibration
1367.6	Mass & Energy Release Assumption: Intact Loop Steam Generator Equilibration
3600.0	Mass & Energy Release Assumption: Both Steam Generators Equilibrate to 14.7 psia
3953.0	RWST Low-Level Alarm Occurs – Recirculation Sequence Begins – Low-Head Pump Stopped and Containment Spray Terminated
4143.0	HHSI Pump from RWST Continues – LH Pump Aligned to Sump
6352.0	HHSI Pump Stopped
6382.0	Flow Control Valve Opened – LH Flow from Sump Begins
86,400	Containment Steam Temperature at 24 hours = 167°F
1.0E+06	Transient Modeling Terminated

Table 6.4-22 DEPS Break Sequence of Events (maximum safeguards)	
Time (sec)	**Event Description**
0.0	Break Occurs, Reactor Trip and Loss-of-Offsite Power Are Assumed
0.22	Containment High Pressure Setpoint of 5.0 psig Reached
0.60	Compensated Pressurizer Pressure Turbine Trip - 1750 psia Reached
2.8	Containment High-High Pressure Setpoint of 23.0 psig Reached
3.8	Low Pressurizer Pressure SI Setpoint - 1700 psia Reached
6.8	Broken Loop Accumulator Begins Injecting Water
6.9	Intact Loop Accumulator Begins Injecting Water
14.0	End of Blowdown Phase
14.0	Accumulator Mass Adjustment for Refill Period
33.8	Pumped SI Begins after 30-Second Diesel Delay
37.6	Broken Loop Accumulator Water Injection Ends
38.6	Intact Loop Accumulator Water Injection Ends
58.1	Peak Containment Pressure Occurs after Accumulator N_2 Is Released to Containment
85.2	Emergency CFCUs Heat Removal Begins
137.8	CS Pump (from RWST) Begins
167.3	End of Reflood Phase
832.2	Mass & Energy Release Assumption: Broken Loop Steam Generator Equilibration
1253.0	RWST Low Level Alarm Occurs - Recirculation Sequence Begins – 1 Train of SI Pumps Stopped - Containment Spray (from RWST) Terminated
1286.2	Mass & Energy Release Assumption: Intact Loop Steam Generator Equilibration
1443.0	1 Low-Head Pump Aligned to Sump – Control Valve Leakage Flow Assumed
1473.0	Flow Control Valve Opened – LH Flow from Sump Begins
2707.0	2nd Train of SI Pumps from RWST Stopped
3600.0	Mass & Energy Release Assumption: Both Steam Generators Equilibrate to 14.7 psia
86,400	Containment Steam Temperature at 24 hours = 145°F (1 spray pump failure) = 153°F (1 fan cooler failure)
1.0E+06	Transient Modeling Terminated

Table 6.4-23 DEHL Break Sequence of Events	
Time (sec)	**Event Description**
0.0	Break Occurs, Reactor Trip and Loss of Offsite Power Are Assumed
0.2	Containment High Pressure Setpoint of 5.0 psig Reached
0.48	Compensated Pressurizer Pressure for Turbine Trip – 1750 psia Reached
3.1	Containment High-High Pressure Setpoint of 23.0 psig Reached
3.6	Low-Pressurizer Pressure SI Setpoint - 1700 psia Reached
6.7	Broken Loop Accumulator Begins Injecting Water
6.8	Intact Loop Accumulator Begins Injecting Water
19.9	Peak Containment Steam Temperature Occurs
19.9	Peak Containment Pressure Occurs
20.4	End of Blowdown Phase
20.4	Accumulator Mass Adjustment for Refill Period
	Transient Modeling Terminated

Table 6.4-24

Kewaunee Structural Heat Sinks for Containment Integrity Analysis[1, 2, 3, 4]

Sink	Surfaces Description	Material	Total Exposed Area (ft^2)	Thickness (in)
1	Containment Cylinder – Coating #4	Carbon Steel	41,300	1.5
2	Containment Dome - Coating #4	Carbon Steel	17,300	0.75
3	Reactor Vessel Liner – Coating #4	Carbon Steel - Concrete Backup	1260 1260	0.25 12.00
4	Refueling Canal	Stainless Steel - Concrete Backup	1100 1100	0.1875 12.0
5	Refueling Canal	Stainless Steel - Concrete Backup	5500 5500	0.25 12.0
6	Misc. Supports – Coating #4	Carbon Steel	4055	0.168
7	Misc. Supports – Coating #4	Carbon Steel	16,925	0.25
8	Misc. Supports – Coating #4	Carbon Steel	28,500	0.375
9	Crane – Coating #5	Carbon Steel	2000	0.75
10	Crane – Coating #5	Carbon Steel	500	1.0
11	Hand Rails – Coating #4	Carbon Steel	1695	0.0725
12	Grating – Coating #4	Carbon Steel	12,400	0.045
13	Exposed Conduit and Cable Trays – Coating #4	Carbon Steel	2000	0.05
14	Ductwork – Coating #4	Carbon Steel	18,000	0.035
15	Walls 1' to 1.9' – Exposed 2 sides – Coating #2	Concrete	2806	6.0
16	Floors 12.0 in and Greater – Coating #2	Concrete	12,896	12.0
17	Walls 4' to 7' 4" – Exposed 2 Sides – Coating #2	Concrete	18,588	24.0
18	Floor (in contact with sump) – Coating #2	Concrete	1088	12.0
19	Walls 2' to 3' 2" – Exposed 2 Sides – Coating #2	Concrete	28,898	12.0
20	Floors 4 in to 10 in – Coating #2	Concrete	6810	4.0

Table 6.4-24 (Cont'd)

Kewaunee Structural Heat Sinks for Containment Integrity Analysis1, 2, 3

Notes:

1. The 2200 ft^2 surface area of the accumulator tanks will not be used as a heat sink. Steel would soak during the first few minutes of a transient and the accumulators will not be empty during the first 60 seconds.
2. Using 12 mil paint thickness from CONTEMPT model (KLIC-99-008).
3. There is an air annulus between the concrete containment cylinder and dome and steel shell.
4. The containment dome area (heat sink 2) is increased to 19500 ft^2 to model the accumulator heat sinks for the MSLB analyses.

PAINT COATING SYSTEMS:

Coating #1: Plastite 9028 surfacer – flush: Phenoline 305 Primer – 4 mils; Phenoline 305 Finish – 4 mils

Coating #2: Plastite 9028 Amine-Epoxy Filler – flush: Plastite 9009 Primer – 6 mils; Phenoline 300 Finish – 8 mils

Coating #3: Carbozinc 11 Primer – 3 mils; Phenoline 305 Finish – 4 mils

Coating #4: Carbozinc 11 Primer – 3 mils; Phenoline 305 Finish – 8 mils

Coating #5: Carbozinc 11 Primer – 3 mils

1 mil = 1/1000 inch

Table 6.4-25 Thermo-Physical Properties of Containment Heat Sinks		
Material	**Conductivity (Btu/hr-ft-°F)**	**Volumetric Heat Capacity (Btu/ft^3-°F)**
Carbon Steel	26.0	56.4
Stainless Steel	8.0	56.6
Concrete	0.80	28.8
Phenoline 300 Finish	0.083	28.8
Phenoline 305 Finish	0.083	28.8
Phenoline 305 Primer	0.083	28.8
Carbozinc 11 Primer	0.9	28.8

Table 6.4-26 CFCU Performance	
Containment Temperature (°F)	**Heat Removal Rate (Btu/sec) per CFCU**
100	0
136	1858.3
205	8338.9
244	12691.7
270	15230.6
300	15230.6

Table 6.4-27 LOCA Containment Response Results (loss-of-offsite power assumed)				
Case	**Peak Press. (psig)**	**Peak Temp. (°F)**	**Pressure (psig) @ 24 hours**	**Temperature (°F) @ 24 hours**
DEPSMINSI Model 54F +Uprate	42.7 @ 58.1 sec	261.2 @ 14 sec	10.1 @ 86,400 sec	163.0 @ 86,400 sec
DEPSMAXSI Model 54F +Uprate 1 Fan Cooler Fails	42.3 @ 58.1 sec	261.3 @ 38 sec	8.2 @ 86,400 sec	153.5 @ 86,400 sec
DEPSMAXSI Model 54F +Uprate 1 Spray Pump Fails	42.3 @ 58.1 sec	261.3 @ 38 sec	7.1 @ 86,400 sec	145.5 @ 86,400 sec
DEHL	44.4 @ 19.9 sec	264.7 @ 19.8 sec	Not applicable	Not applicable

Table 6.4-28

Uncertainties and Initial Condition Assumptions for MSLB Mass and Energy Releases Inside Containment for the Fuel Upgrade/Power Upgrade Program [1]

Uncertainties	100% Power	70% Power	30% Power	0% Power
Power Uncertainty (% RTP)	2.0	2.0	2.0	1.0 [2]
RCS Flow Uncertainty (% MMF)	11.8	11.8	11.8	11.8
Pressure Uncertainty (psia)	50.1	50.1	50.1	50.1
Inlet Temperature Uncertainty (°F)	4.0	4.0	4.0	4.0
SG Water Level Uncertainty (% NRS)	7.0	5.0	3.0	1.0
Initial Conditions	**100% Power**	**70% Power**	**30% Power**	**0% Power**
Power (% RTP)	102.0	72.0	32.0	1.0
RCS Flow (gpm)	208,000	208,000	208,000	208,000
RCS Pressure (psia)	2300.1	2300.1	2300.1	2300.1
Vessel Inlet Temperature (°F)	548.1	549.0	550.1	551.0
RCS Average Temperature (°F) [3]	577.3	570.1	559.7	551.3
SG Water Level (% NRS)	51.0	49.0	47.0	45.0
SG Steam Temperature (°F)	515.1	523.0	534.4	546.0
SG Steam Pressure (psia) [3]	779.4	834.9	919.4	1012.1
Feedwater Enthalpy (Btu/lbm)	415.9	387.6	315.6	168.0
Feedwater Temperature (°F) [3]	437.0	411.1	342.9	197.8

Notes:

1. Noted values correspond to plant conditions defined by 0% steam generator tube plugging, the high end of the RCS T_{avg} window (573 °F), and at 1772 MWt reactor power level.
2. 1% rated thermal power to account for decay heat.
3. The values are calculated by the NSSS simulator at steady-state conditions defined by the input value of the parameter above.

Table 6.4-29 Main Steamline Break Inside Containment Mass and Energy Release Event Sequence for Limiting Case 14NYY0	
Event Description	**Time (sec)**
Time Main Steam Line Ruptures	0.0
Time Containment High Pressure Setpoint Reached	1.2
Time SI Signal Generated on Containment High Pressure	1.7
Time Turbine Stop Valves Close	2.0
Time Faulted Loop NRCV Closes (Main Steam Isolation)	5.0
Time SI Flow Starts	16.7
Time AFW Flow Starts	31.7
Time Core Returns to Critical	40.04
Time AFW to Faulted Loop Ends	600.0

Table 6.4-30 Main Steamline Break Inside Containment Mass and Energy Release Results for Limiting Case 14NYY0		
Time (sec)	Break Flow (lbm/sec)	Break Enthalpy (Btu/lbm)
0.00	0.0	0.0
0.15	5832.3	1192.6
0.65	5621.4	1193.9
1.15	5456.2	1185.7
1.65	5466.5	1153.2
2.15	5525.2	1116.4
2.65	5635.9	1073.6
3.15	5734.3	1035.8
3.35	5695.7	1028.8
3.67	5678.5	1017.6
3.98	5657.7	1005.9
4.30	5559.5	1003.7
4.61	5459.4	1002.0
4.93	5364.5	1000.5
5.28	3355.9	883.5
5.63	3301.9	882.2
5.98	3248.8	881.0
6.33	3218.4	875.9
6.68	3193.1	870.5
7.03	3167.1	865.6
7.38	3114.3	865.7
7.73	3062.3	865.8
8.08	3019.3	864.4
8.43	3004.0	857.7
8.78	2989.8	851.0
9.13	2981.1	843.3
9.48	2985.8	833.8
9.83	2998.5	824.2
10.55	2886.8	827.2
14.22	2376.7	848.6
17.64	1971.9	881.4
21.09	1749.7	883.0
24.94	1567.5	882.9
29.46	1475.6	853.3
33.55	1399.5	831.4
36.77	1253.0	858.5
40.27	1218.0	836.7
43.16	1082.0	877.0

Table 6.4-30 (Cont.) Main Steamline Break Inside Containment Mass and Energy Release Results for Limiting Case 14NYY0		
Time (sec)	Break Flow (lbm/sec)	Break Enthalpy (Btu/lbm)
45.91	969.3	920.2
48.45	1019.0	863.5
50.97	1030.6	838.3
53.49	963.9	856.8
56.03	1020.3	808.1
59.80	934.9	833.3
67.30	732.3	943.0
74.80	679.1	963.9
82.30	591.9	1039.9
89.80	518.5	1128.1
97.30	471.9	1195.2
102.30	466.9	1195.0
112.30	454.0	1194.6
122.30	437.6	1194.2
132.30	423.3	1193.5
142.30	408.8	1192.8
152.30	394.1	1192.1
162.30	379.5	1191.4
172.30	365.0	1190.7
182.30	350.9	1190.0
192.30	337.1	1189.3
232.30	288.7	1186.8
332.30	212.5	1179.8
432.30	168.5	1175.8
532.30	142.1	1173.5
631.90	121.4	1171.6
730.90	64.6	1166.7
829.90	12.2	1166.2
927.50	54.1	1166.3
1024.41	12.2	1166.2
1120.87	12.2	1166.2
1190.85	12.2	1166.2

Table 6.4-31 Peak Containment Pressures and Temperatures for MSLB Cases		
Description	GOTHIC Peak Press (psig)	GOTHIC Peak Temp (°F)
0.1 sqft break at 0% power	17.67	215.4
0.5 sqft break at 0% power	35.71	251.2
0.8 sqft break at 0% power	42.87	263.2
1.1 sqft break at 0% power	45.53	266.9
1.4 sqft break at 0% power	45.91	267.3
1.4 sqft break at 30% power	41.05	259.8
1.4 sqft break at 70% power	41.57	260.7
1.4 sqft break at 102% power	43.01	263.7

Table 6.4-32 Major Parameters and Assumptions – Hydrogen Generation	
Core Thermal Power Rating	1782.6 MWt
Containment Free Volume	1,320,000 ft^3
Containment Temperature at Accident Initiation	120°F
Fuel Cladding Mass Undergoing Zirc-Water Reaction	5.0%
Total Mass of Zirc in the Core	30,858 lbs.
RCS Hydrogen Concentration during Normal Operation	50 cc/kg
RCS Mass (normal pressurizer level)	1.19×10^8 grams
Pressurizer Volume	1010 ft^3
Pressurizer Level (normal operation)	60%
Hydrogen Recombiner Flow Rate	90 scfm

Table 6.4-33 Inventory of Aluminum and Zinc Inside the Containment Building			
Item Description	**Area (ft^2)**	**Thickness or Weight/Area**	**Weight (lbs)**
Galvanized Steel Surfaces			
Platform and Gratings, all Surfaces	12,400	2.0 oz/ft^2	1550
All Ductwork, Both Sides	35,253	0.6 oz/ft^2	1322
Conduit, Trays, and Supports Exposed to Spray	13,250	0.6 oz/ft^2	497
Stair Treads	2305	0.6 oz/ft^2	86
Cable Restaints	338	--	68
Total Galvanized	63,596		3.523
Zinc-Bearing Undercoats			
Primer on Structural Steel, Carbozine 11	95,400	3 mils	5540
Primer on Containment Vessel Interior, Carbozine 11	51,500	3 mils	2243
Total Undercoat	146,900		8530
Aluminum Surfaces			
Reactor Equipment, Including Contingency	144.5	--	424
Crane Lights and Fixtures	Undetermined	--	160
Connectors on Rod Drive Cables	58.7	--	110
Total Aluminum	Undetermined		694
Aluminum Paint on Reactor Equipment	Undetermined	--	110

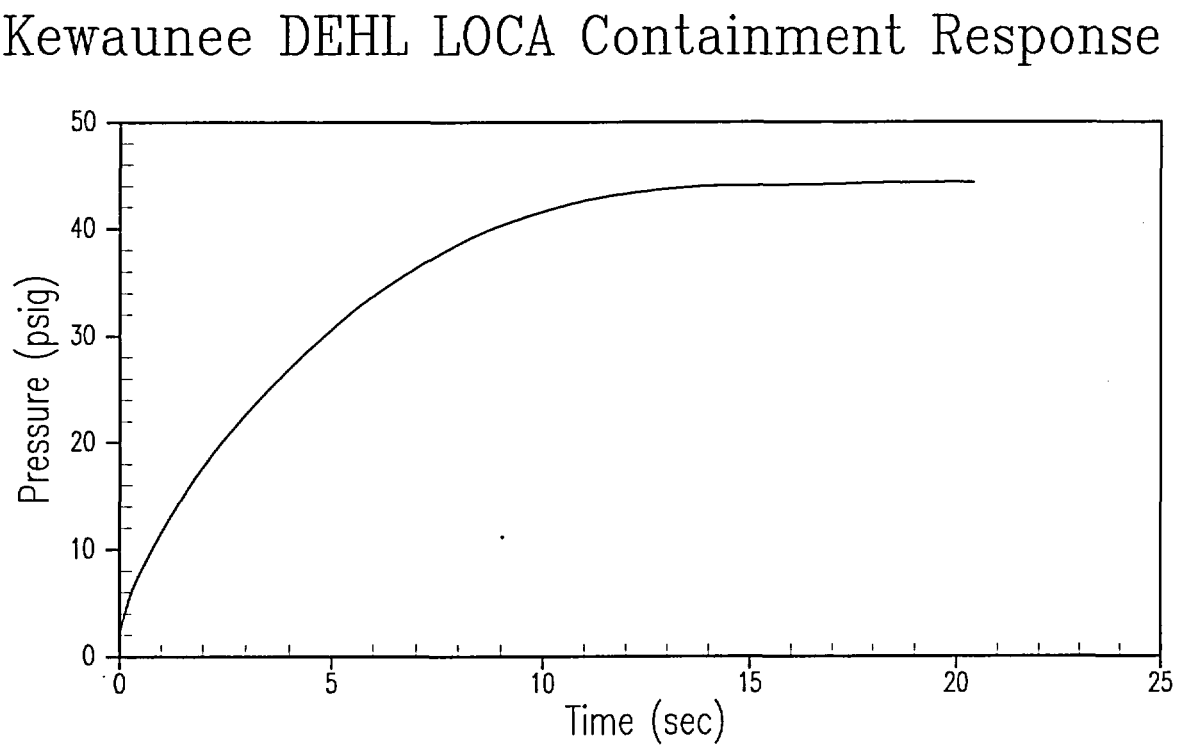

Figure 6.4-1

DEHL Break-Containment Pressure

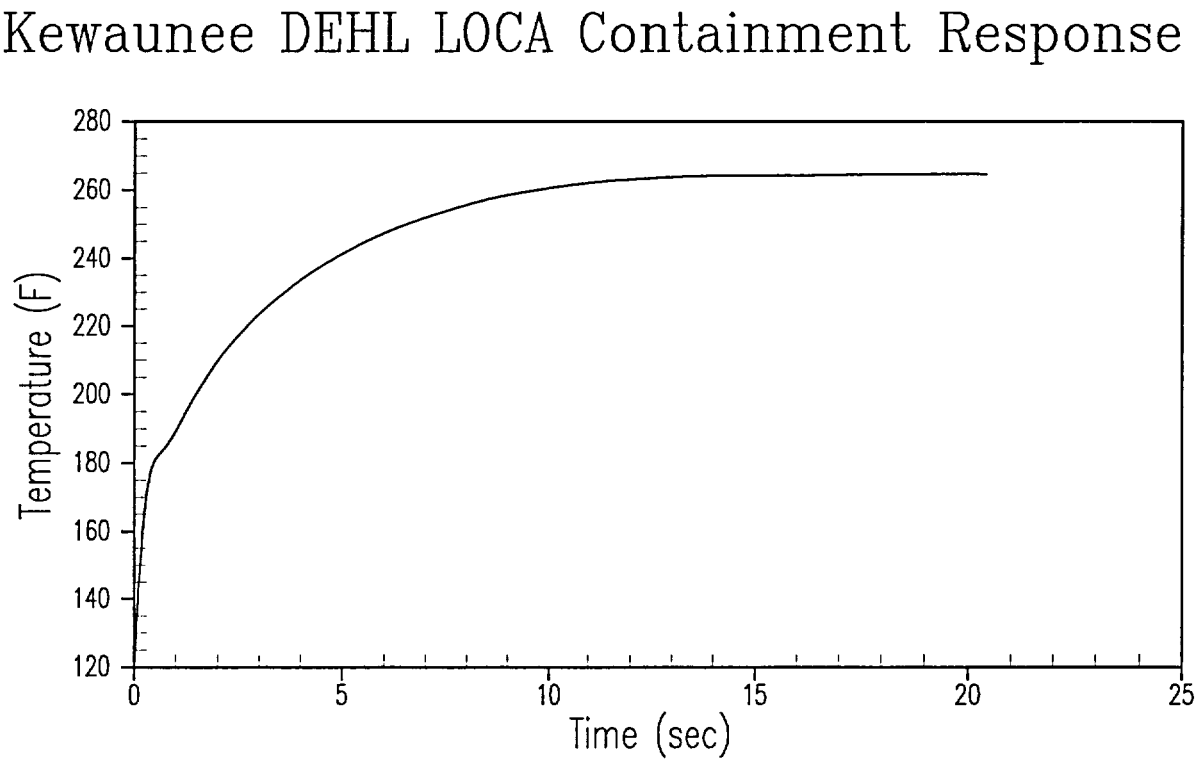

Figure 6.4-2

DEHL Break-Containment Atmosphere Temperature

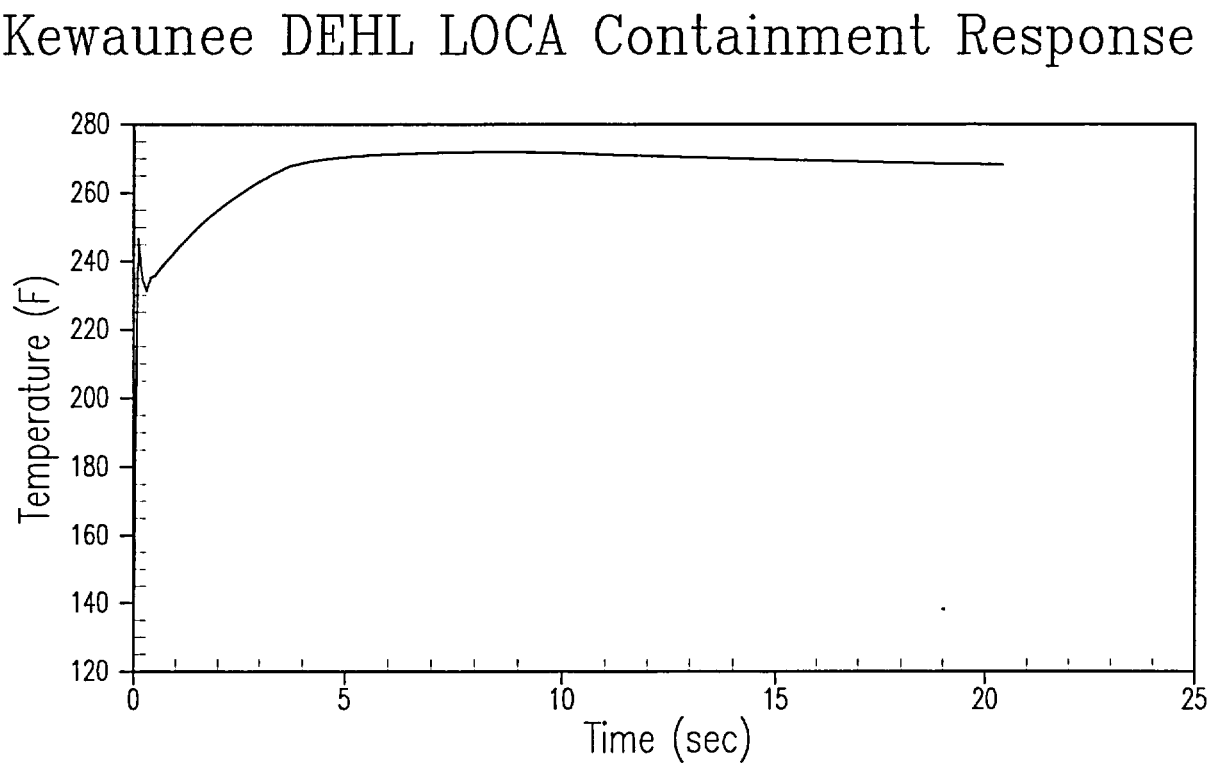

Figure 6.4-3

DEHL Break Containment Sump Temperature

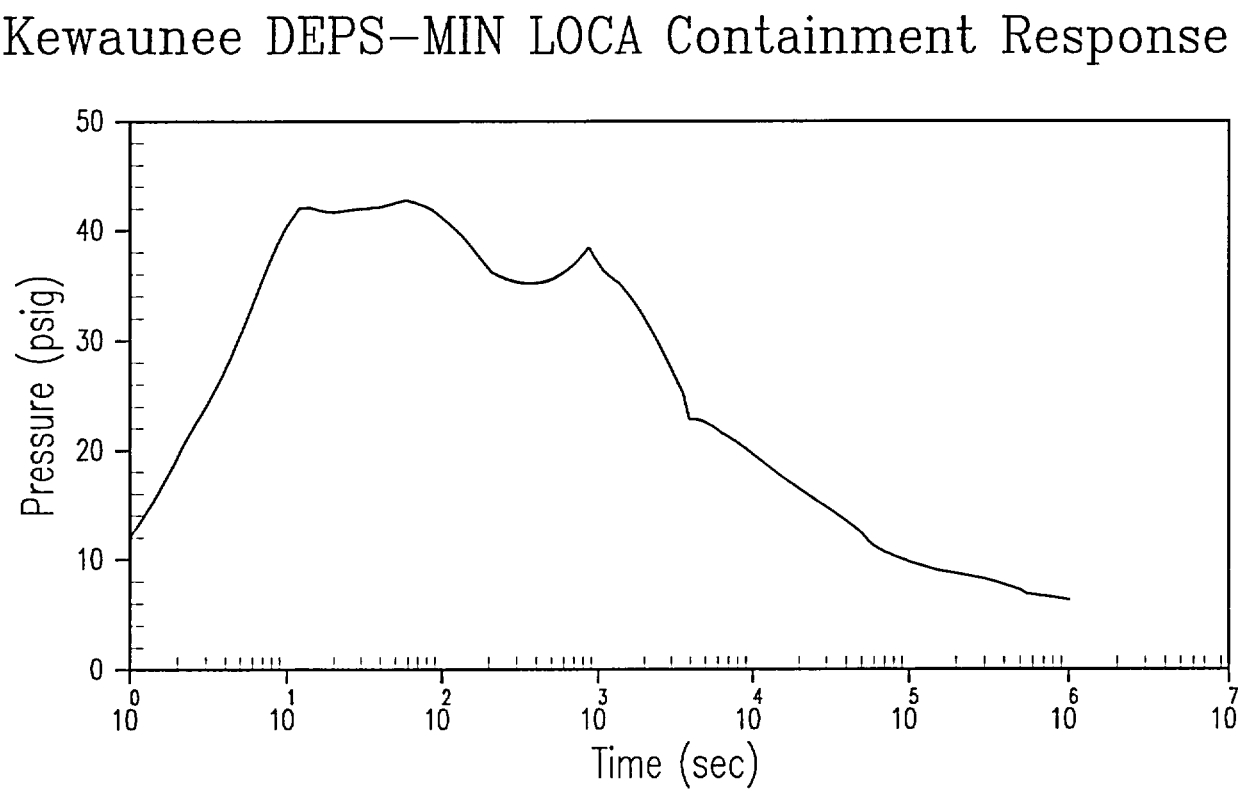

Figure 6.4-4

DEPS Break with Minimum Safeguards-Containment Pressure

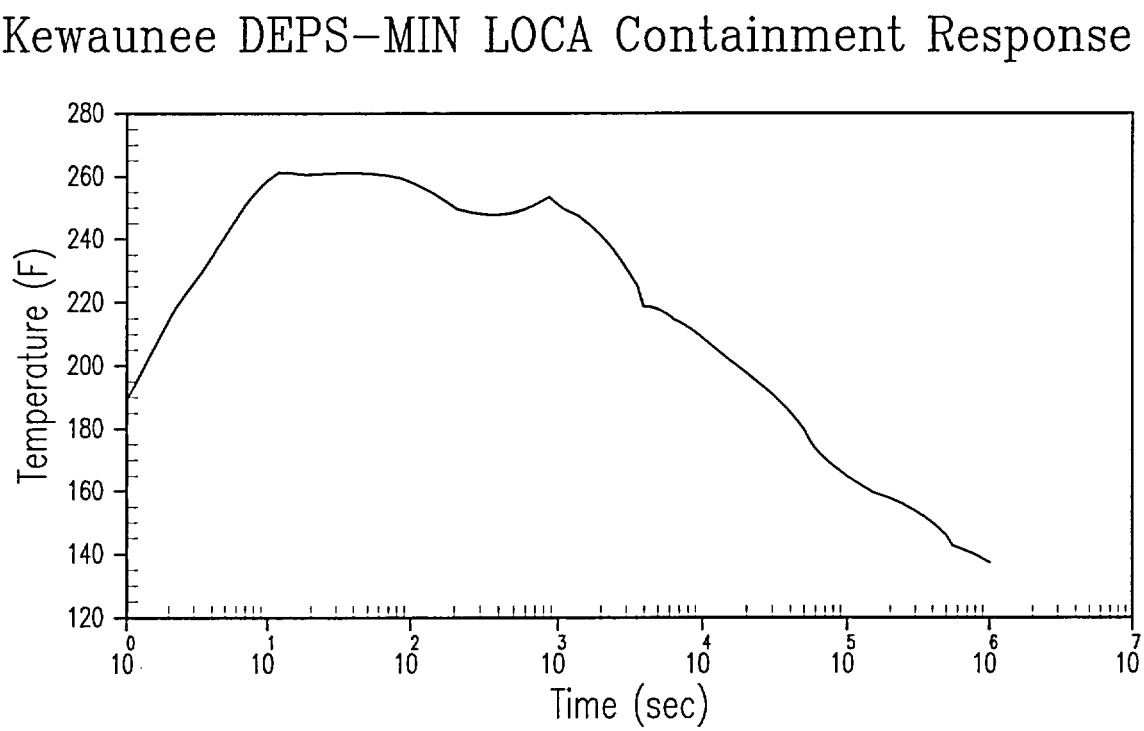

Figure 6.4-5

DEPS Break with Minimum Safeguards-Containment Atmosphere Temperature

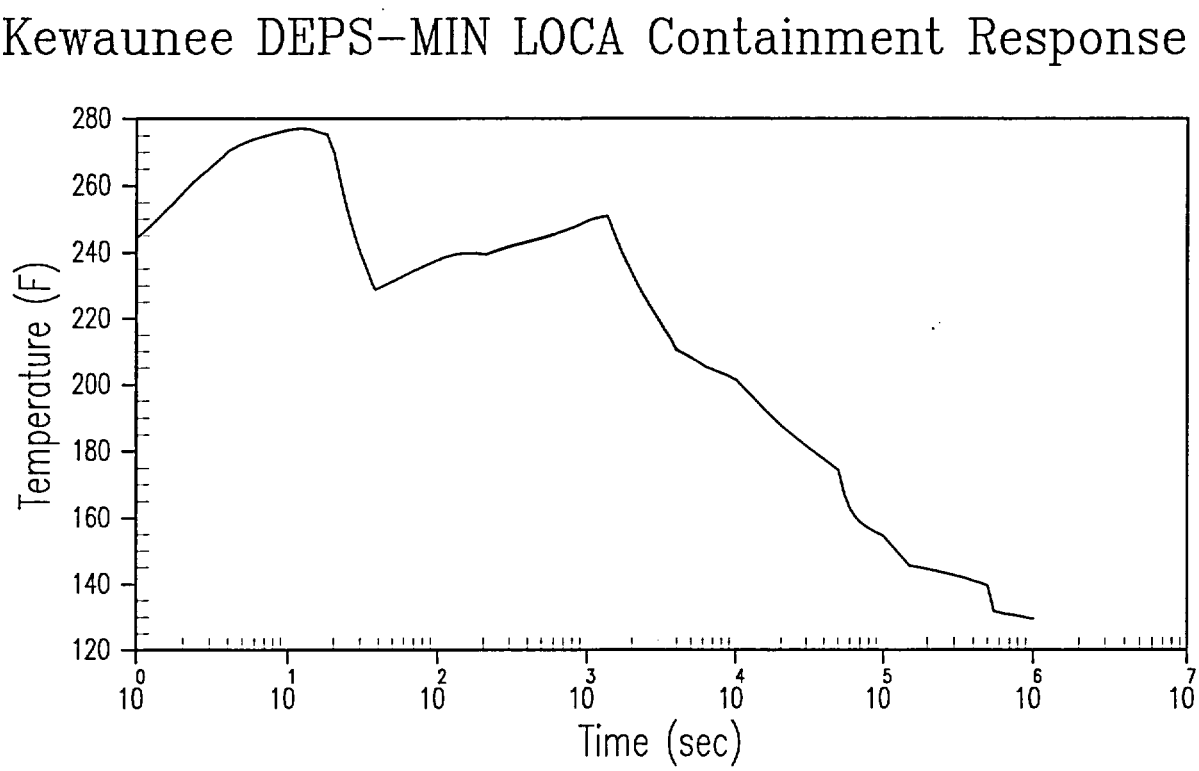

Figure 6.4-6

DEPS Break with Minimum Safeguards-Containment Sump Pressure

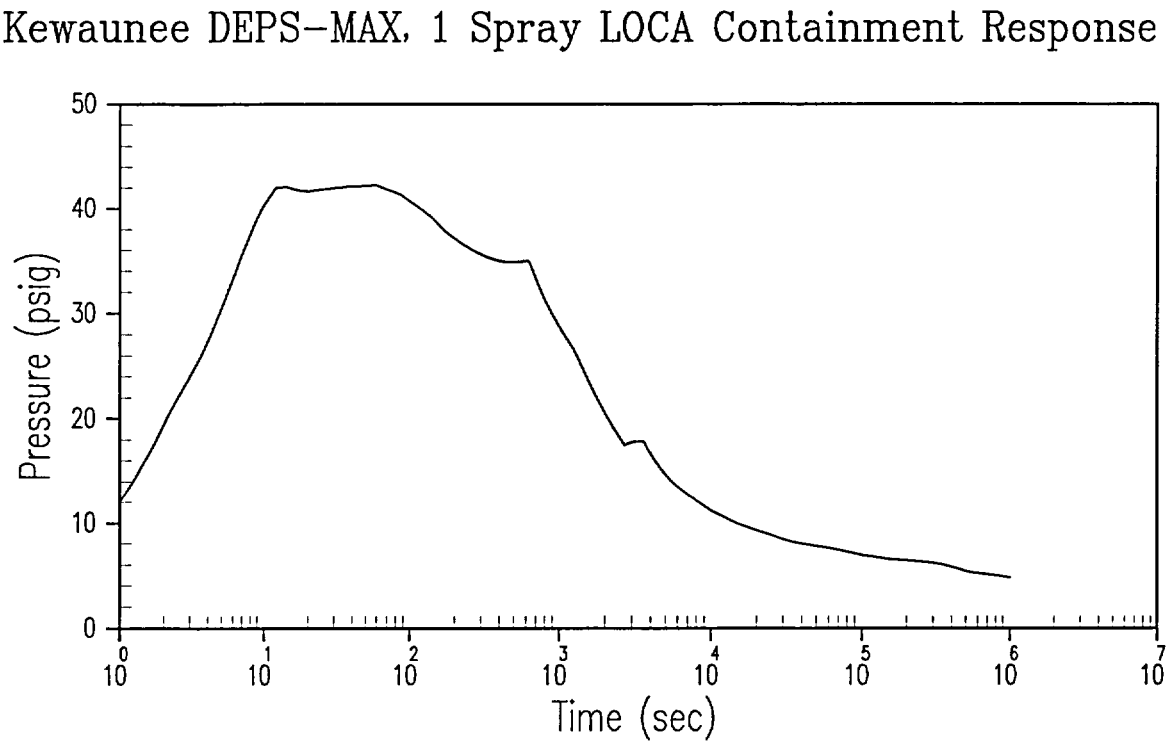

Figure 6.4-7

DEPS Break with Maximum Containment Safeguards, 1 Spray Pump Failure

Containment Pressure

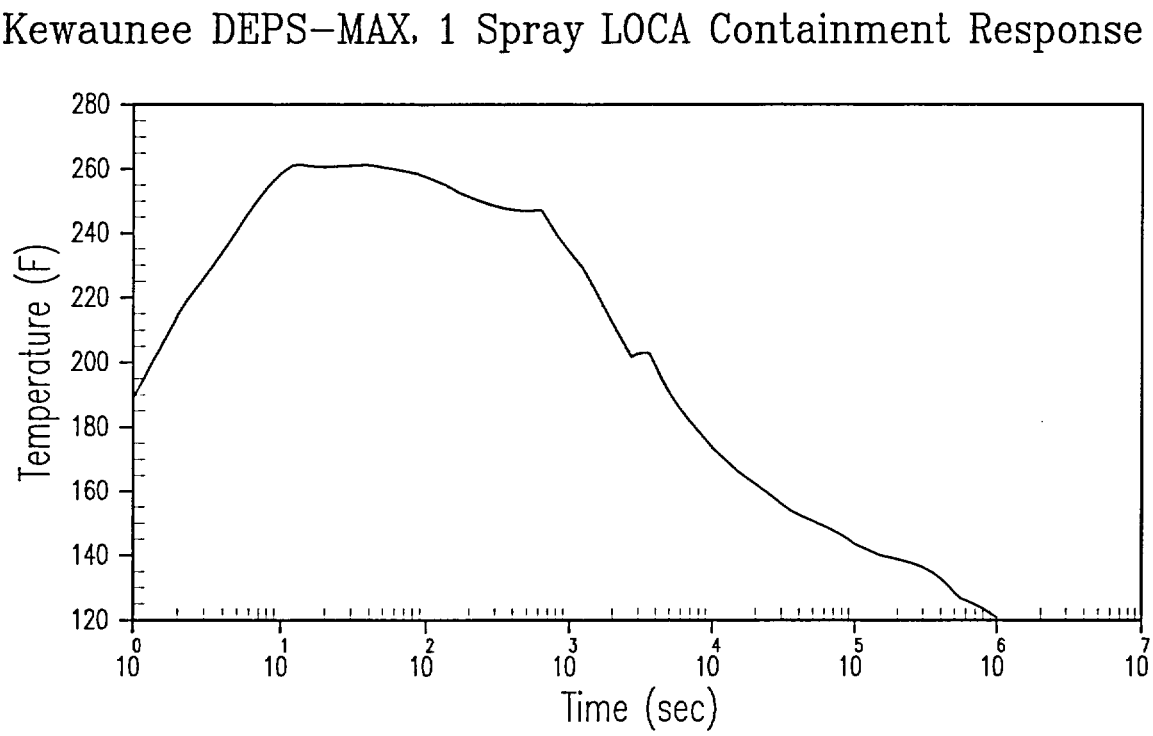

Figure 6.4-8

DEPS Break with Maximum Containment Safeguards, 1 Spray Pump Failure Containment Atmosphere Temperature

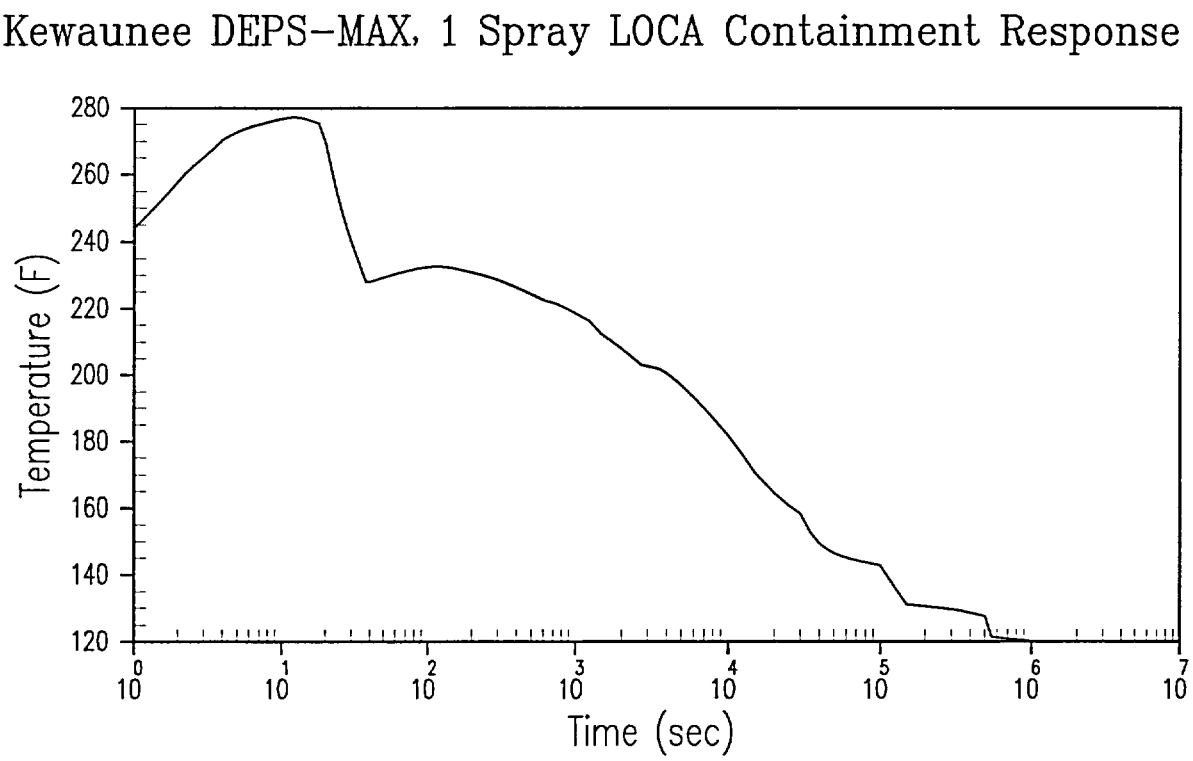

Figure 6.4-9

DEPS Break with Maximum Containment Safeguards, 1 Spray Pump Failure

Containment Sump Temperature

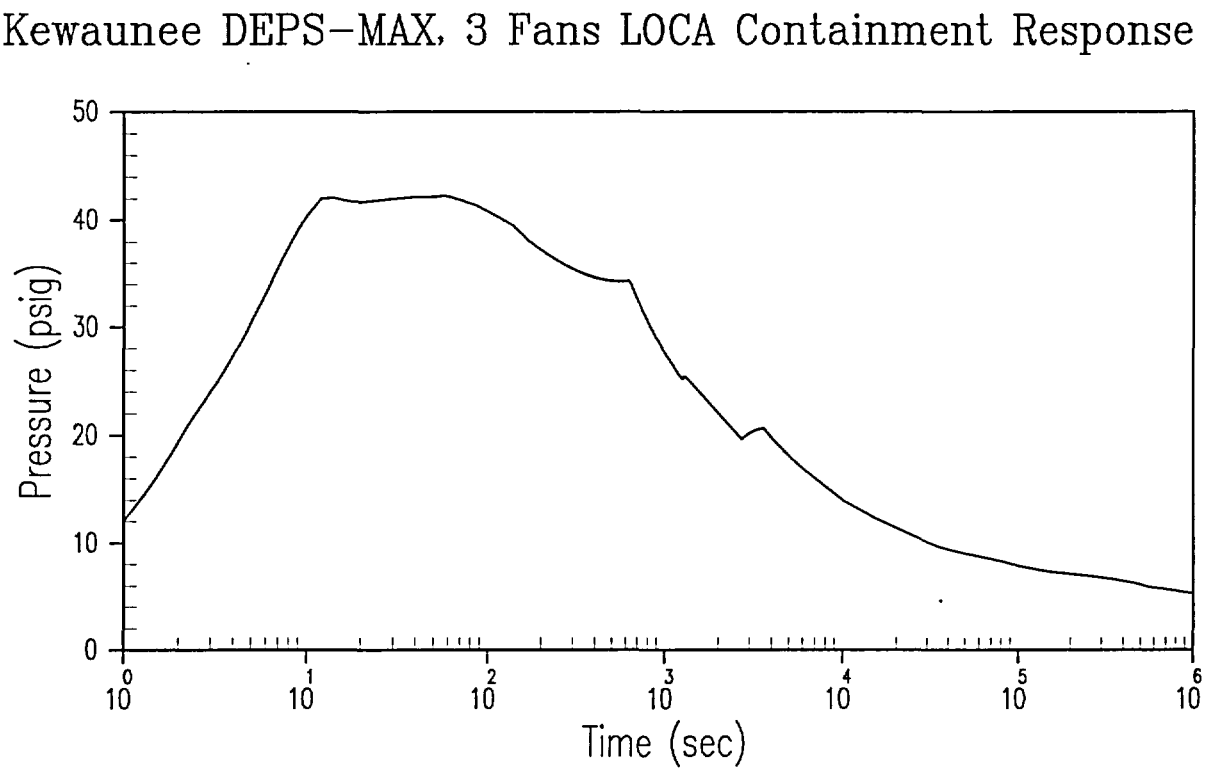

Figure 6.4-10

DEPS Break with Maximum Containment Safeguards, 1 Fan Cooler Failure

Containment Pressure

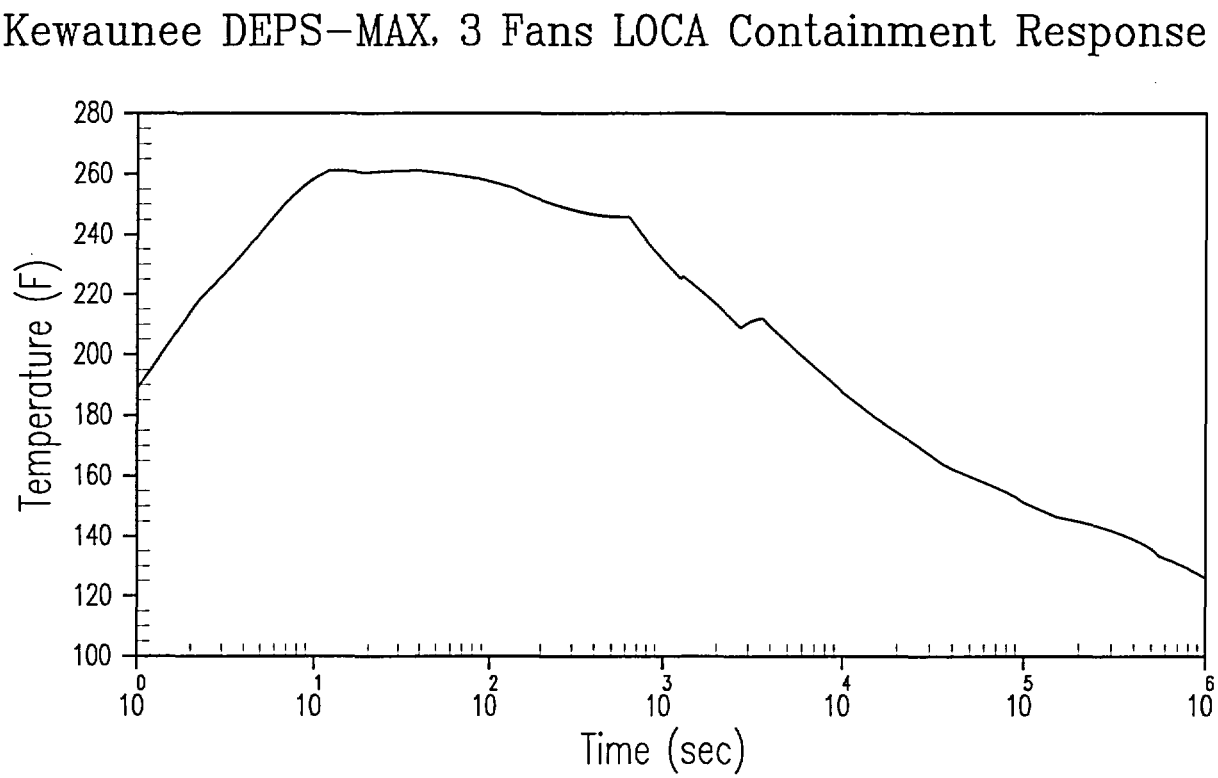

Figure 6.4-11

DEPS Break with Maximum Containment Safeguards, 1 Fan Cooler Failure

Containment Atmosphere Temperature

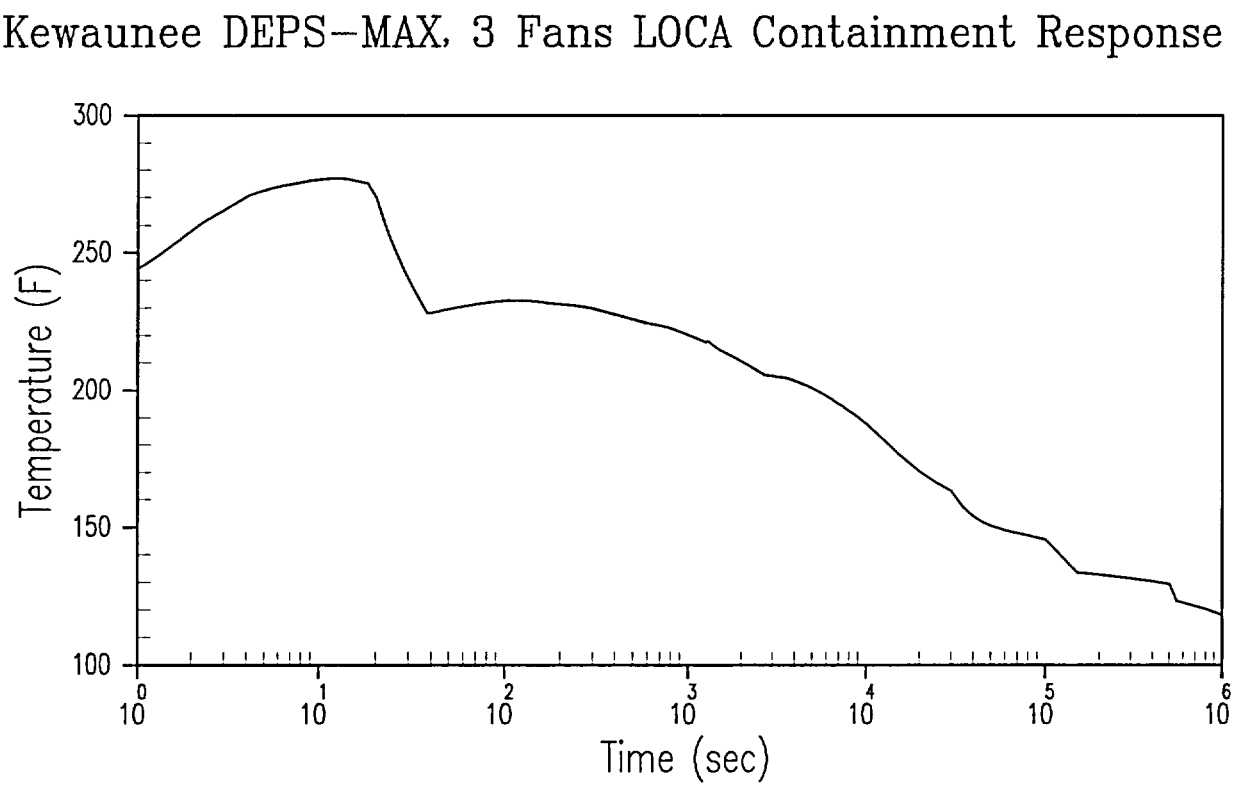

Figure 6.4-12

DEPS Break with Maximum Containment Safeguards, 1 Fan Cooler Failure Containment Sump Temperature

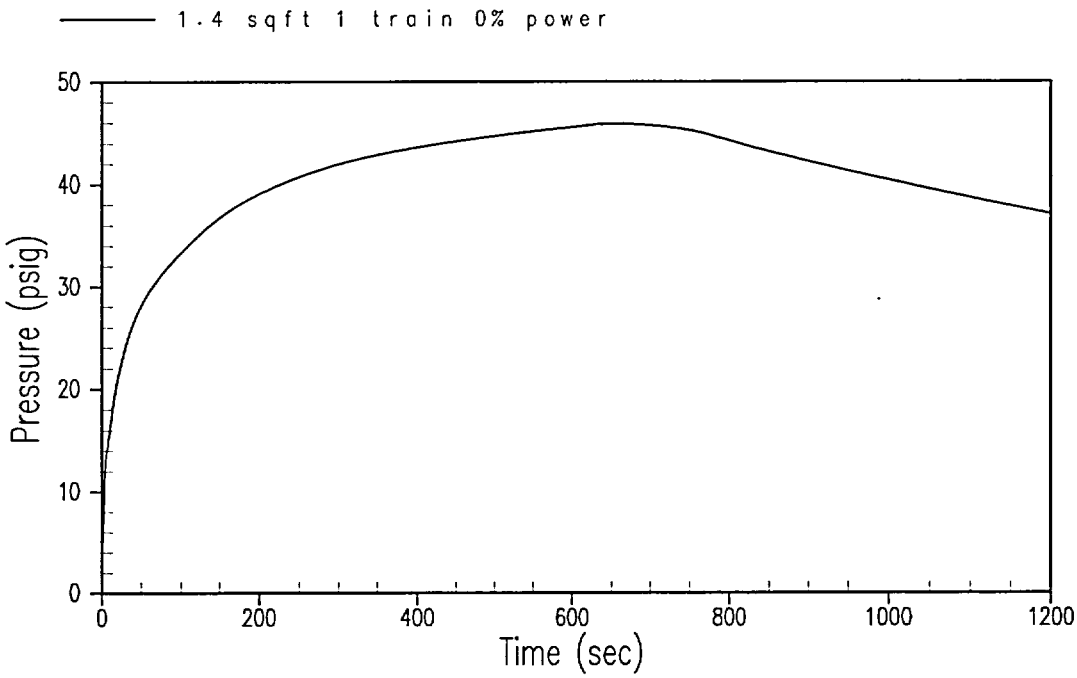

Figure 6.4-13

Limiting MSLB Containment Pressure Response

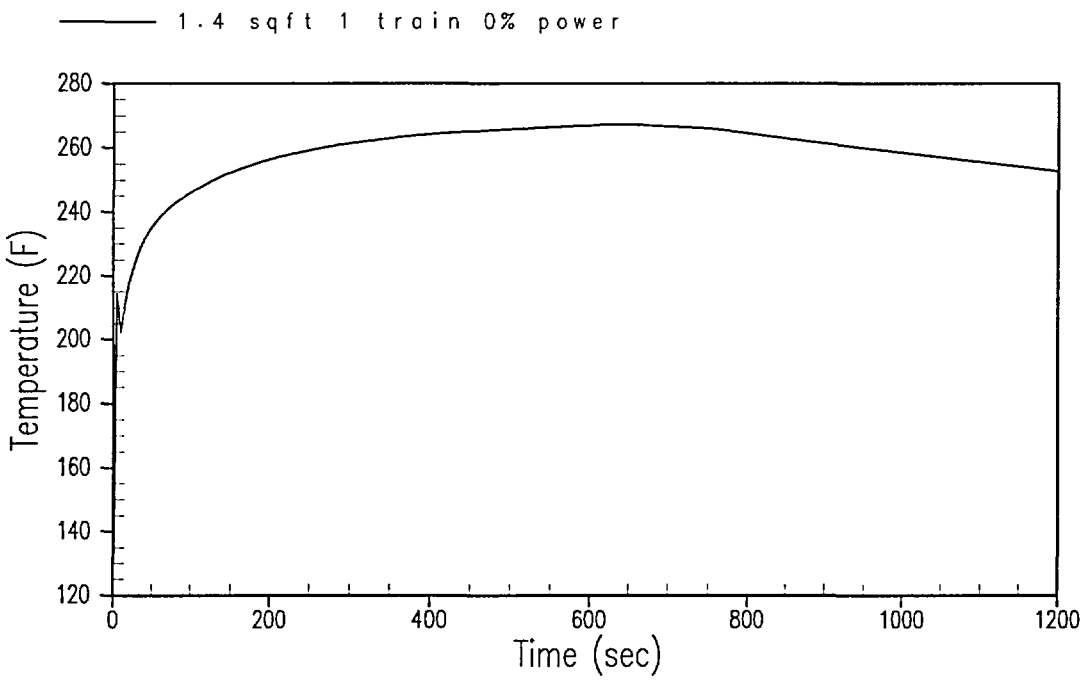

Figure 6.4-14

Limiting MSLB Containment Temperature Response

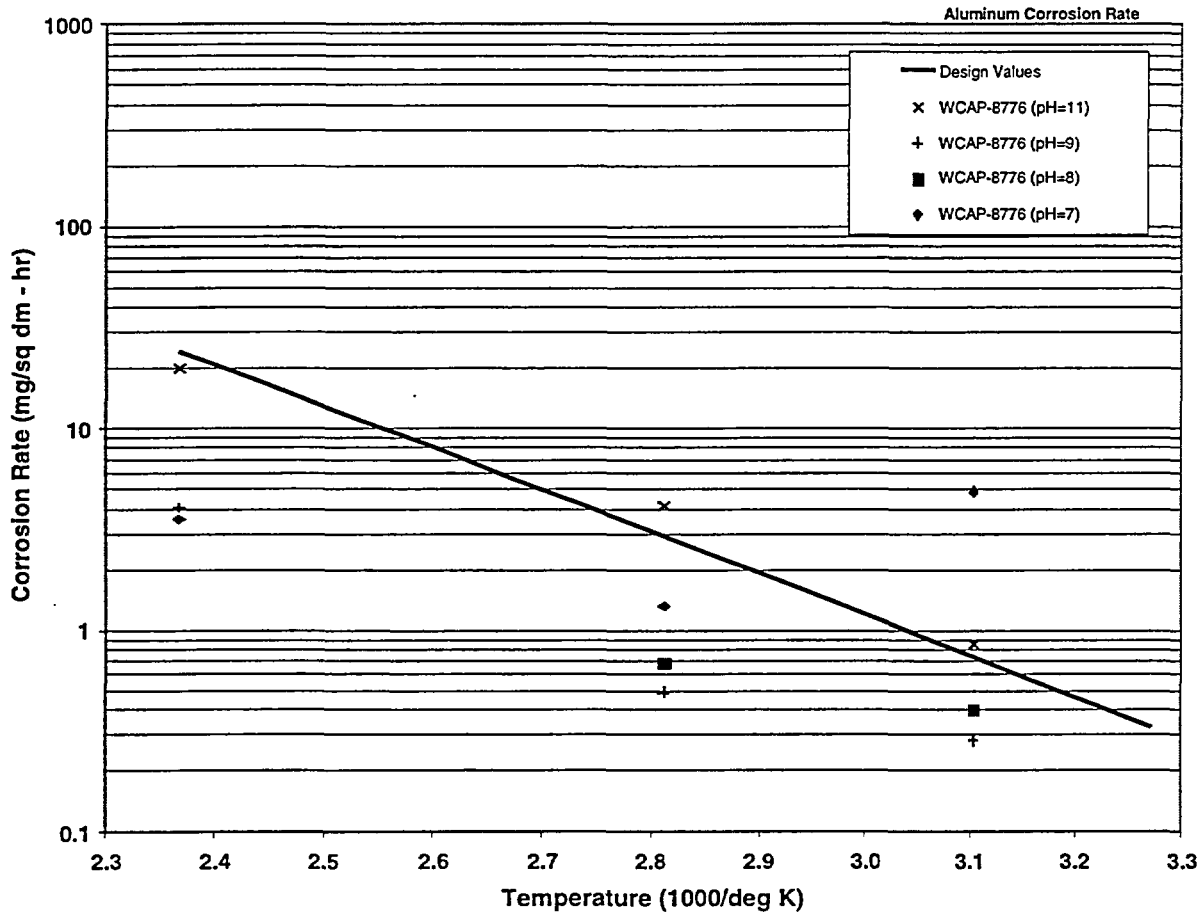

Figure 6.4-15

Aluminum Corrosion Rates in LOCA Environment

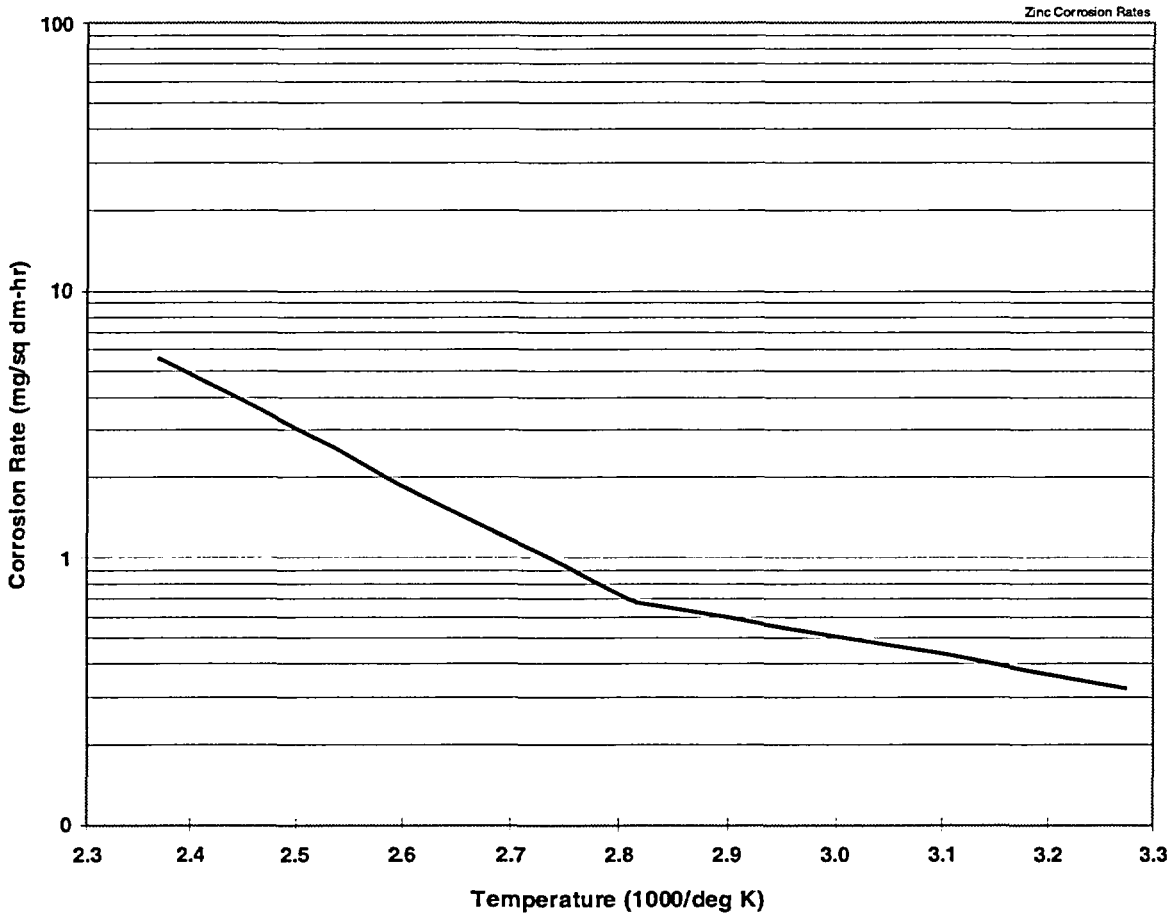

Figure 6.4-16

Zinc Corrosion Rates in LOCA Environment

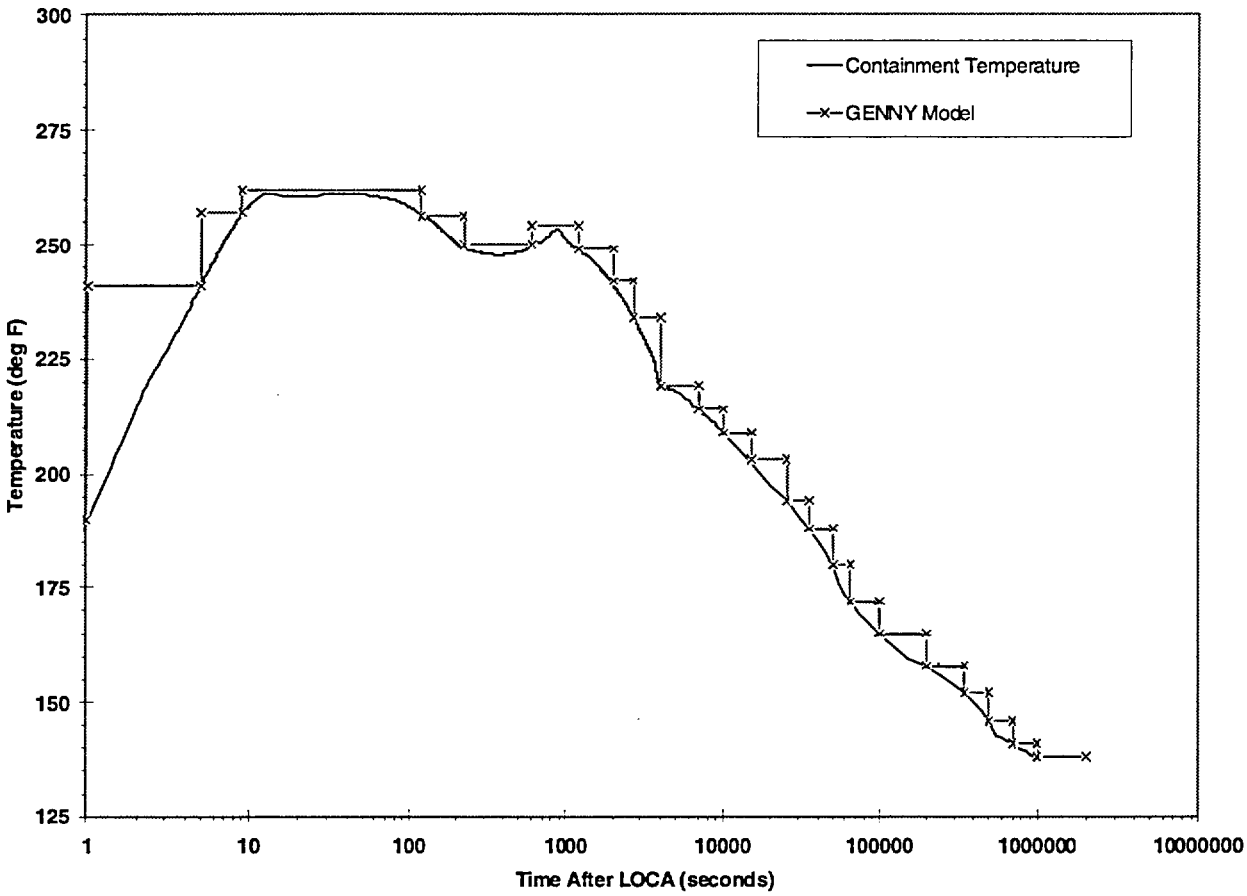

Figure 6.4-17

Post-LOCA Containment Temperatures

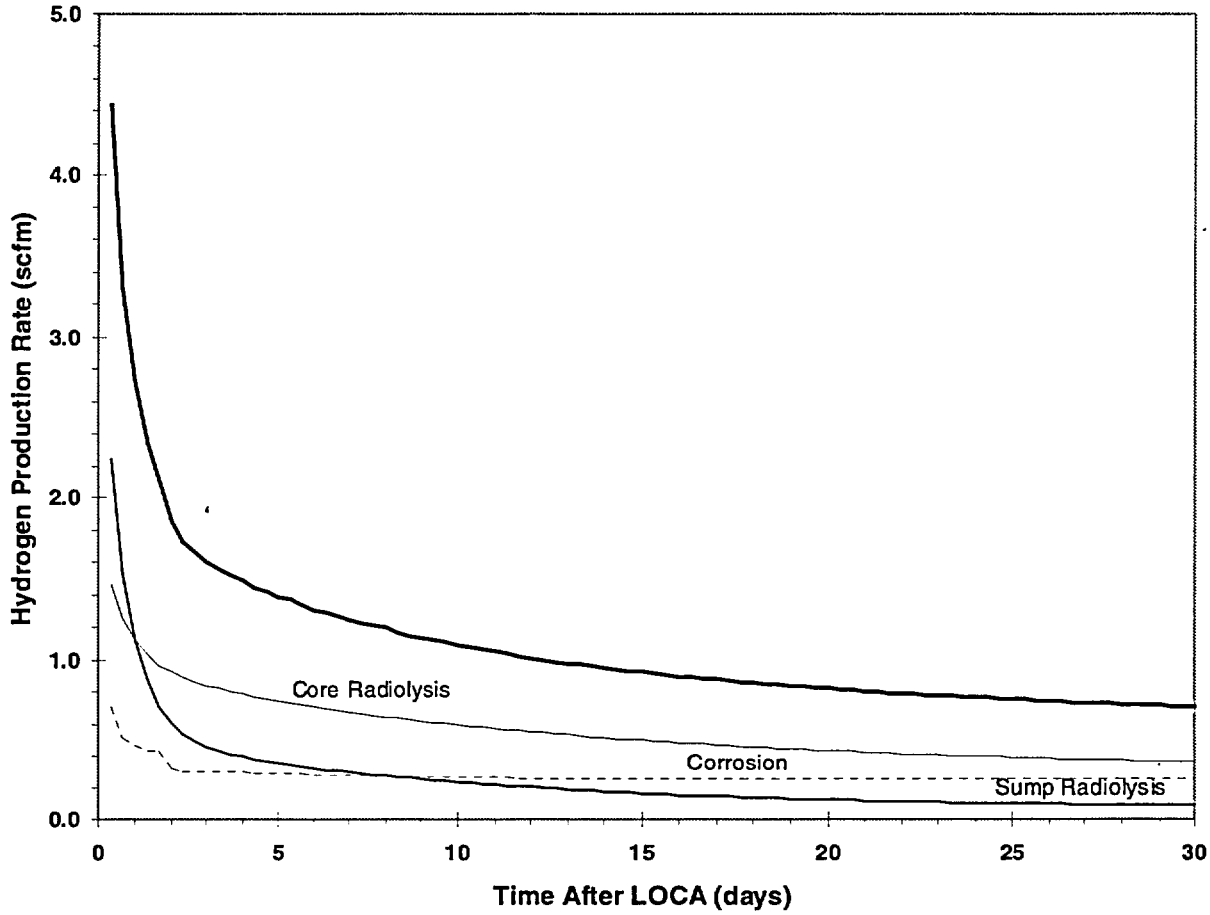

Figure 6.4-18

Containment Hydrogen Production Rate versus Time after LOCA

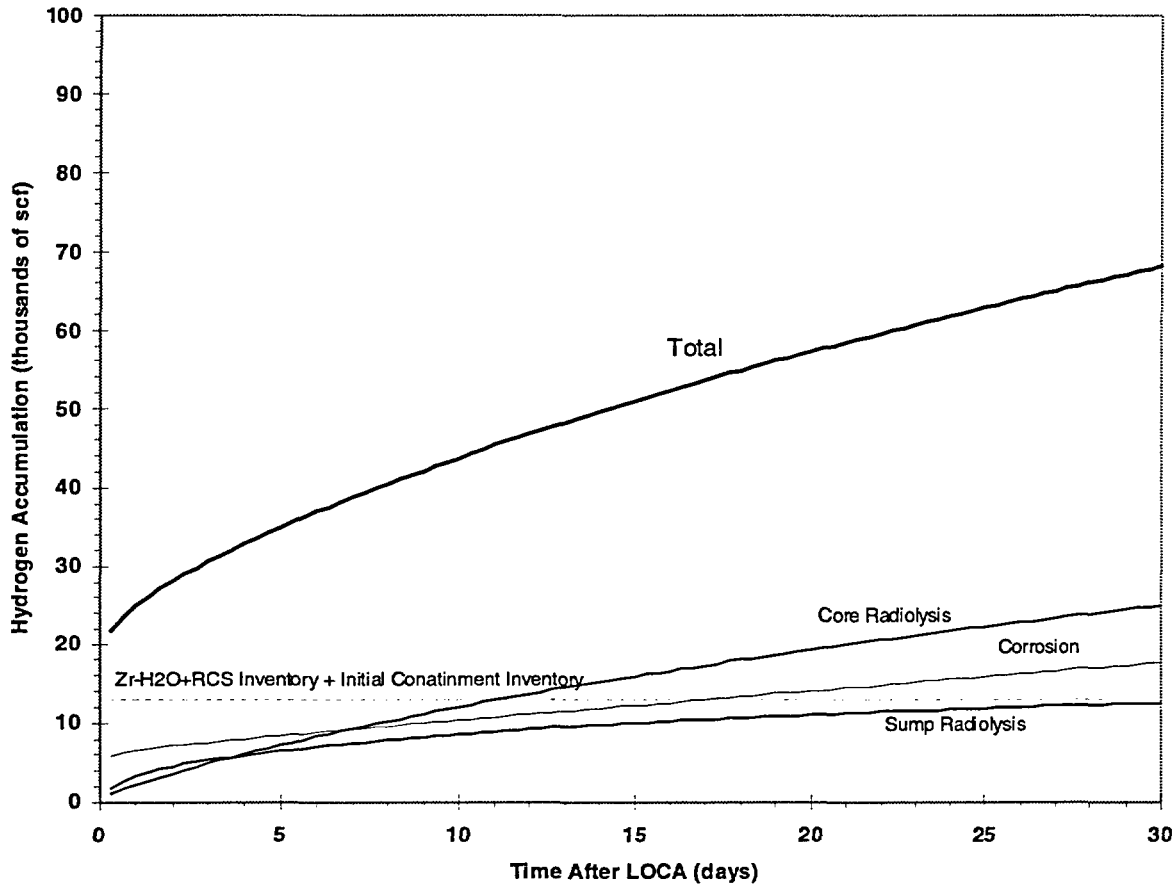

Figure 6.4-19

Hydrogen Accumulation from All Sources versus Time after LOCA

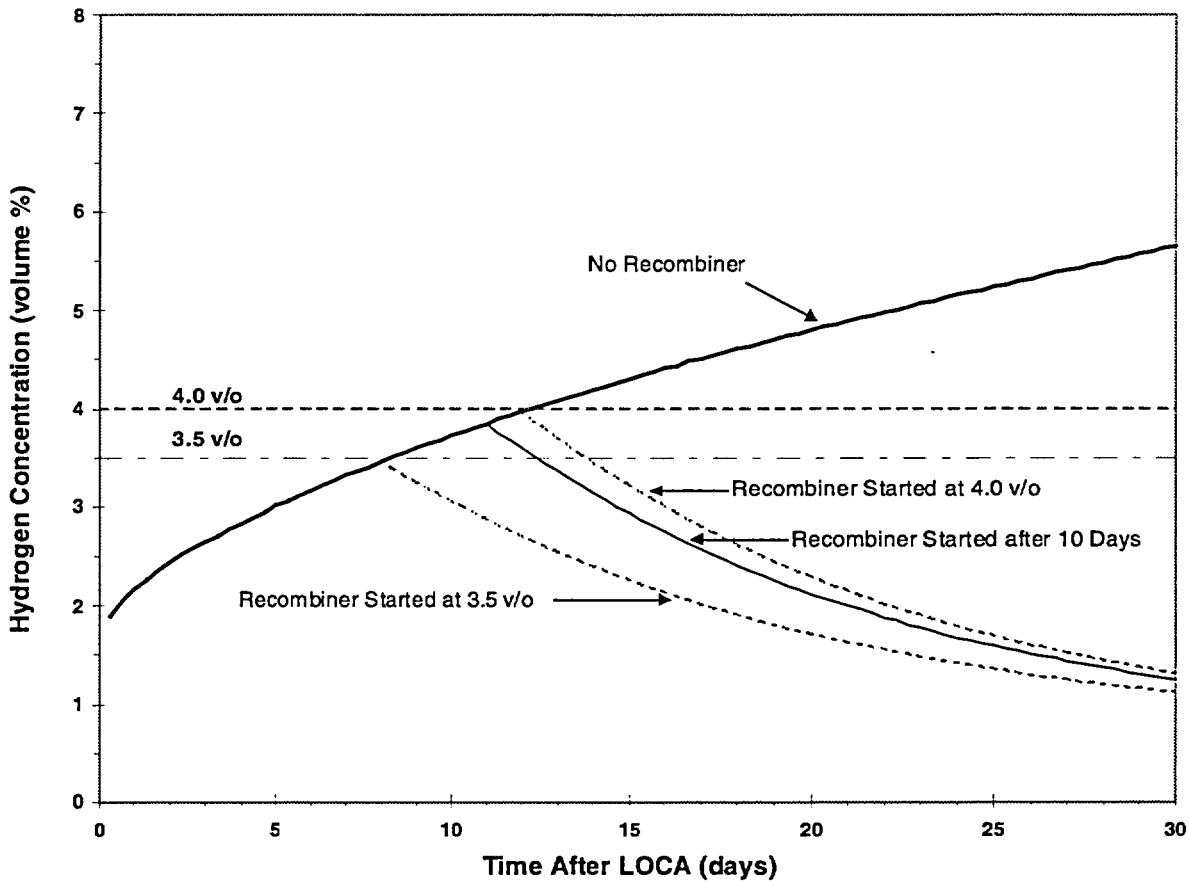

Figure 6.4-20

Containment Hydrogen Concentration versus Time after LOCA

6.5 Main Steamline Break Consequences

6.5.1 Main Steamline Break Mass and Energy Releases Outside Containment

6.5.1.1 Introduction and Background

Steamline ruptures occurring outside the reactor containment structure may result in significant releases of high-energy fluid to the structures surrounding the steam systems. Superheated steam blowdowns following the steamline break have the potential to raise compartment temperatures outside containment. Early uncovery of the steam generator tube bundle maximizes the enthalpy of the superheated steam released, which typically results in maximizing compartment temperatures. The impact of the steam releases depends on the plant configuration at the time of the break, plant response to the break, and the size and location of the break. Because of the interrelationship among many of the factors that influence steamline break mass and energy releases, an appropriate determination of a single limiting case with respect to mass and energy releases cannot be made. Therefore, it is necessary to analyze the steamline break event outside containment for different break sizes, locations, and initial power levels. A sensitivity is also done on the effect of maximizing the total energy released rather than maximizing the steam enthalpy. The resulting mass and energy releases are used as input to the auxiliary building temperature analysis (see subsection 6.5.2) for equipment environmental qualification (EQ).

6.5.1.2 Input Parameters and Assumptions

The following paragraphs identify key plant conditions and input assumptions used in the analysis.

6.5.1.2.1 Power Level and Initial Conditions

The mass and energy releases outside containment are dependent on the initial power level. Cases initiated from full-power tend to maximize the level of steam superheating of the break effluent due to two effects. First, the full-power cases tend to get the earliest uncovery of the steam generator tube bundle because the initial steam generator mass inventory is lowest at full power. (The water mass increases with decreasing power levels.) Second, the amount of stored energy and decay heat, as well as feedwater temperature, are highest at full power. This results in higher primary temperatures and higher primary-to-secondary heat transfer during the

steamline break event. Early steam generator tube uncovery and higher heat transfer to the faulted steam generator will typically result in the highest level of superheated steam when the event is initiated from full-power conditions.

At power levels less than full-power, the protection functions available and the actuation times of all protection functions are different than at full power. For this reason, steamline break outside containment mass and energy release calculations are also done with the initial power level less than full power. However, when the initial power is significantly reduced, so is the level of superheated steam. Therefore, the analysis is limited to breaks initiated from full-power or near full-power conditions and the following power levels are analyzed:

- Full-power - maximum allowable Nuclear Steam Supply System (NSSS) power plus uncertainty, that is, 100.6 percent of rated power (1780 MWt).

- Near full-power - 70 percent of maximum allowable NSSS power.

In general, plant initial conditions are assumed to be the nominal values corresponding to the initial power for that case, with appropriate uncertainties included. Table 6.5-1 identifies the values assumed for Reactor Coolant System (RCS) pressure, RCS vessel average temperature, RCS flow, pressurizer water volume, steam generator water level, steam generator pressure, and feedwater temperature corresponding to each power level analyzed. Steamline break mass releases and superheated steam enthalpies assuming an RCS average temperature at the high end of the T_{avg} window are conservative with respect to similar releases at the low end of the T_{avg} window. At the high end, there is a larger value for the superheated steam enthalpy available for release outside containment. The thermal design flowrate has been used for the RCS flow input consistent with other steamline break analysis assumptions related to nonstatistical treatment of uncertainties, as well as RCS thermal-hydraulic inputs related to pressure drops and rod drop time. The mass and energy release results are not highly sensitive to changes in the steady-state RCS flowrate.

Uncertainties on the initial conditions assumed in the analysis for the Power Uprating Program have been applied only to RCS average temperature (6.0°F), steam generator level (-10.5 percent narrow range span [NRS] full-power, -8.7 percent NRS for 70-percent power), and power fraction (0.6-percent) at full power. Nominal values are adequate for the initial

pressurizer pressure and water level. Uncertainty conditions are only applied to those parameters that could increase the enthalpy of superheated steam discharged out of the break.

6.5.1.2.2 Steam Generator Fluid Mass

A minimum initial fluid mass in the steam generators was used in all of the analyzed cases. This minimizes the availability of the heat sink afforded by the steam generators and leads to earlier tube bundle uncovery. The initial mass has been calculated as that corresponding to the programmed water level, minus 10.5 percent (full power) and minus 8.7 percent (70-percent power) NRS, minus a mass uncertainty. All steam generator fluid masses are calculated assuming 0-percent tube plugging. This assumption is conservative with respect to the RCS cooldown through the steam generators resulting from the steamline break.

6.5.1.2.3 Main Feedwater System

The rapid depressurization that typically occurs following a steamline rupture results in large amounts of water being added to the steam generators through the Main Feedwater System. However, main feedwater flow has been conservatively modeled by assuming no increase in feedwater flow in response to the increased steam flow following the steamline break. This minimizes total mass addition and the associated cooling effects in the steam generators and causes the earliest onset of superheated steam released out of the break. In addition, termination of the main feedwater flow was conservatively assumed to be coincident with reactor trip, irrespective of the function that produced the reactor trip signal. The instantaneous termination of the main feedwater flow is part of the methodology that reduces the total mass addition to the steam generators.

6.5.1.2.4 Auxiliary Feedwater System

Within the first few minutes following a steamline break, the Auxiliary Feedwater System (AFS) is usually initiated on either a SI signal or a low steam generator water level signal. There are two motor-driven AFW pumps that start on any SI signal or a low steam generator water level in at least one steam generator. There is one turbine-driven AFW pump that starts on a low steam generator water level signal in both steam generators. The flowrate delivered by each pump can range from a minimum of approximately 160 gpm to a maximum of approximately 400 gpm, depending on steam generator conditions and assumptions regarding line resistances and pump performance. The three AFW pumps are tied to a common header and are able to supply

AFW to either or both steam generators. Operator action is credited at 10 minutes to re-align the AFS to terminate AFW to the faulted steam generator.

Just as initial steam generator mass and main feedwater mass are minimized, AFW mass addition is likewise typically minimized to maximize the superheated steam enthalpy of the break effluent, based on the WCAP-10961 (Reference 1) methodology. However, the lower AFW flowrate reduces the overall energy release, despite the higher enthalpy. The role of AFW is particularly important for larger break sizes that have early steam generator tube uncovery. These cases can experience a prolonged period when the steam generator is essentially empty and the break flow is based solely on the mass addition from the AFW. For the Kewaunee auxiliary building temperature analysis (see subsection 6.5.2), it was found that the penalty of the higher enthalpy when AFW is minimized can cause earlier peak temperatures, but does not result in the highest compartment temperature throughout the transient. Therefore, two sets of AFW assumptions (minimum and maximum) were used for the larger break cases. Minimum AFW is based on a single failure of an AFW pump, minimum flow characteristics, and a maximum delay time of 60 seconds. Maximum AFW is based on no failure in the AFS, maximum flow characteristics, and no delay from the actuation signal until pumps are assumed to be at the full speed.

For smaller breaks, AFW is not as important for a number of reasons. First, AFW is on for a short period of time due to a later timing of the actuation signal. Secondly, AFW flowrate is much lower because the steam generators remain at a relatively high pressure due to the small size of the break. Finally, AFW flow to the faulted steam generator is terminated prior to steam generator tube uncovery, and therefore, break flow is never directly a function of AFW. Thus, the smaller breaks are analyzed with a single set of AFW assumptions. No single failure is modeled, in the AFS, and the AFW flowrate is estimated to be 200 gpm per pump based on the relatively high steam generator pressures.

AFS assumptions used in the analysis are summarized in Table 6.5-2.

6.5.1.2.5 Single-Failure Assumptions

The typical single-failure assumption for this analysis is the failure of one pump in the AFS because a reduction in the AFW results in higher enthalpy of the steam released from the break. However, as discussed in subsection 6.5.1.2.4, minimized AFW flow due to an AFW pump

failure may not always result in the limiting compartment temperatures. Therefore, cases were selected with and without an AFW pump single failure.

Another possible single failure is the failure of the main steamline isolation valve (MSIV) in the loop with the faulted steamline. This has been applied to all cases with the break postulated downstream of the MSIV. For these cases, the MSIV for one loop is assumed to close based on a steamline isolation signal, while one loop's MSIV is assumed to stay open, allowing a continued blowdown. An MSIV failure is not applicable to breaks upstream of the MSIV, since the break location is unisolable.

If it worsens the results, a single failure is considered, and multiple failures may be addressed in a single case. The failures have been included in the cases as follows:

- Downstream break, minimum AFW – 2 failures (AFW, MSIV)
- Downstream break, maximum AFW – 1 failure (MSIV)
- Upstream break, minimum AFW – 1 failure (AFW)
- Upstream break, max AFW – There is no active failure that results in more limiting mass/energy releases

6.5.1.2.6 Main Steamline Isolation

For break locations downstream of the main steamline non-return check valve, closure of the MSIV is assumed to terminate the blowdown from the unfaulted steam generator. The actuation function to isolate the main steamline is received from an SI signal (a low-pressurizer pressure signal) coincident with a high-steam flow signal and a low RCS average temperature signal. A delay time of 7.5 seconds is assumed with unrestricted steam flow assumed through the valve during the valve stroke.

For break locations upstream of the main steamline non-return check valve, steamline isolation is assumed via closure of the check valve. The check valve in the faulted steamline is assumed to close instantaneously due to the reverse steam flow created by the depressurization of the steamline in the vicinity of the break.

6.5.1.2.7 Break Flow Model

The flowrate from the break is maximized by assuming a critical flowrate for saturated steam based on the Moody correlation for fL/D=0. The upstream pressure is based on the steam generator pressure, with no credit for line losses or piping discharge resistance. The downstream pressure is assumed to be atmospheric throughout the blowdown.

6.5.1.2.8 Safety Injection System

SI flowrates corresponding to one high-head SI pump are assumed in this analysis. However, the impact of SI on the mass and energy releases is negligible since boron does not reach the core in time to affect the reactivity transient. This is because the initial boron concentration in the SI piping is assumed to be 0 ppm, and there is a substantial purge time to clear the unborated SI water.

6.5.1.2.9 Loss-of-Offsite Power

A coincident loss-of-offsite power is not assumed for the analysis of the steamline break outside containment since the total energy released would be reduced due to the loss of forced reactor coolant flow, resulting in less primary-to-secondary heat transfer.

6.5.1.2.10 Reactor Coolant System Metal Heat Capacity

As the primary side of the plant cools, the temperature of the reactor coolant drops below the temperature of the reactor coolant piping, the reactor vessel, the reactor coolant pumps, and the steam generator thick-metal mass and tubing. As this occurs, the heat stored in the metal is available to be transferred to the steam generator with the broken line. Stored metal heat does not have a major impact on the calculated mass and energy releases. The effects of this RCS metal heat are included in the results using conservative thick-metal masses and heat transfer coefficients.

6.5.1.2.11 Steam Generator Reverse Heat Transfer

Once the steamline isolation is complete, the steam generator in the unfaulted loop becomes a source of energy that can be transferred to the steam generator with the broken steamline. This energy transfer occurs via the primary coolant. As the primary side of the reactor cools, the

temperature of the coolant flowing in the steam generator tubes could drop below the temperature of the secondary fluid in the unfaulted steam generator, resulting in energy being returned to the primary coolant. This energy is then available to be transferred to the steam generator with the broken steamline. When applicable, the effects of reverse steam generator heat transfer are included in the results.

6.5.1.2.12 Core Decay Heat

Core decay heat generation assumed in calculating steamline break mass and energy releases is based on the 1979 *American National Standard for Decay Heat in Light Water Reactors*, + 2σ Model (Reference 2).

6.5.1.2.13 Rod Control

The rod control system is conservatively assumed to be in manual operation for all steamline break analyses. Rods in automatic control would step in prior to reactor trip due to the increase in steam flow. This would reduce nuclear power and core heat flux.

6.5.1.2.14 Core Reactivity Coefficients

Conservative core reactivity coefficients corresponding to end-of-cycle conditions are used to maximize reactivity feedback effects resulting from the steamline break. This results in higher power generation should the reactor return to criticality, thus maximizing heat transfer to the secondary side of the steam generators.

6.5.1.2.15 Sensitivity to Maximizing Total Energy Released

The possibility exists that maximizing mass release, rather than maximizing steam enthalpy, may in some instances result in more limiting compartment temperature transients for this event. The duration of the steam release is increased if there is more initial water mass in the steam generator or if more feedwater enters the steam generator. Also, changes in the initial steam generator level and main feedwater modeling have the potential to cause different protection signals to be actuated, or to prevent automatic actuation setpoints from being reached.

Therefore, in addition to the minimum/maximum AFW cases already discussed, a sensitivity was done to address the effect of maximizing other water mass assumptions. Specifically, the

initial steam generator mass was increased, and the main feedwater flowrate was assumed to increase based on the increased steam flowrate. A 0.84-ft^2 break initiated from 70-percent power was defined as a bounding case to address the maximized total energy sensitivity.

6.5.1.3 Description of Analysis

The system transient that provides the break flows and enthalpies of the steam release through the steamline break outside containment has been analyzed with the LOFTRAN (Reference 3) computer code. Blowdown mass and energy releases determined using LOFTRAN include the effects of core power generation, main and AFW additions, engineered safeguards systems, RCS thick-metal heat storage, and reverse steam generator heat transfer. The LOFTRAN model for calculating superheated steam after steam generator tube uncovery is documented in Supplement 1 of WCAP-8822 (Reference 4), which has been reviewed and approved by the NRC. The methodology is based on WCAP-10961 (Reference 1).

The break sizes and locations that are analyzed are listed in Table 6.5-3. Each steamline break outside containment is represented as a split rupture (crack area).

6.5.1.4 Acceptance Criteria

There is no explicit acceptance criterion for the mass and energy releases generated by this analysis. They are used as input to the auxiliary building temperature analysis. See subsection 6.5.2.

6.5.1.5 Results and Conclusions

Table 6.5-4 provides the sequence of events for the steamline break cases analyzed to support the auxiliary building EQ program. The reactor trip occurs on the OPΔT signal for the 0.84-ft^2 cases initiated from full power. All other cases get reactor trip due to the low-steam-generator-water-level signal. The SI signal occurs on low-pressurizer pressure approximately 30 seconds after reactor trip for the 0.84-ft^2 cases. When the SI signal is reached, this also satisfies the coincidence logic with high-steam flowrate and low RCS T_{avg} to achieve steamline isolation. For the smaller breaks, an SI signal occurs on low-steamline pressure very late in the transient after the steam generator tubes in the faulted loop have uncovered. Steamline isolation for the small break downstream of the MSIV is credited based on operator action at 10 minutes into the event.

Tables 6.5-5 to 6.5-15 contain the mass and energy release transient results for each case. The tables show the break mass flowrate, break enthalpy, and the level of superheat (break enthalpy minus saturated enthalpy at the steamline pressure) as a function of time. The time steps included in the tables are a representative sample of the entire transient results.

6.5.2 Main Steamline Break Outside Containment Response Analysis

6.5.2.1 Introduction and Background

The steamline break scenarios documented in this report consider the Model 54F steam generators and at the uprated core power of 1772 MWt. The mass and energy release transients that are postulated occur in several regions within the Northwest Quadrant and the East Quadrant of the auxiliary building for the Kewaunee plant. The specific assumptions associated with the development of these releases are discussed in subsection 6.5.1.

The study has two components associated with the computer code modeling of the outside containment compartments and flow paths; the analysis to determine the compartment temperatures resulting from the postulated steamline breaks and a presentation of the pressures determined as a result of the postulated breaks.

6.5.2.2 GOTHIC Computer Code Model

The compartment analysis is performed with the GOTHIC 7.0a code (Reference 5). GOTHIC 7.0a is a multi-node containment code developed by NAI. It is becoming the industry standard for performing containment and outside containment compartment transients for design basis events.

The GOTHIC model for the Northwest Quadrant and the East Quadrant of the auxiliary building at Kewaunee was developed for the Model 54F steam generator replacement RSG Program with the GOTHIC 6.0a code version. Westinghouse benchmarked the GOTHIC model with GOTHIC 7.0a against the RSG results with GOTHIC 6.0a and achieved excellent agreement. Therefore, the compartment model for the Uprate Program is unchanged from the RSG effort. The only changes that will be made for this program are the case-specific mass and energy releases from the main steamline breaks at the uprated conditions.

6.5.2.3 Results

6.5.2.3.1 Temperature Analysis

Eighteen break cases were chosen for the GOTHIC analysis of the auxiliary building and turbine building. There are twelve possible breaks in the Northwest Quadrant and six breaks possible in the East Quadrant. These included two power levels and three break sizes in various compartments. The power levels included 100.6 and 70 percent. The break sizes included 0.84ft^2, 0.0507ft^2 (this is a 7.3-in^2 crack), and 0.0458 ft^2 (this is a 6.6-in^2 break). Per Table 6.5-18, the breaks in the Northwest Quadrant can occur in either Compartment BI or in Compartment AI. The only breaks that can occur in Compartment AI are the 0.0507-ft^2 breaks. Subregion 1 of Compartment AI does not contain any main steamline or branch piping, so a split break transient will be analyzed only in AI subregions 2, 3, and 4. All of the breaks in the East Quadrant occur in Region DII. Therefore, there will be a total of twenty-two transients; sixteen in the North Quadrant and six in the East Quadrant. The details of the input assumptions that determine the mass and energy releases for these postulated transients are provided in subsection 6.5.1.

The peak temperatures that were predicted in each region for the sixteen transients for the Northwest Quadrant are provided in Table 6.5-16. Table 6.5-16 shows that the case with the overall limiting peak temperature is Case 2a in the Northwest Quadrant. This is a 0.84-ft^2 break in Region BI at 70-percent power downstream of the MSIVs with minimum AFW flow. The peak temperature is 457.5°F. Table 6.5-17 provides the temperature results for the six transients in the East Quadrant. The limiting case in the East Quadrant is Case 5b. This is 7.3-in^2 crack (that is, a 0.0507-ft^2 break) downstream of the MSIV at 100.6-percent power in Region DII. The peak temperature is 374.7°F

6.5.2.3.2 Pressure Analysis

The GOTHIC model determines a pressure response in each compartment, but this pressure may not be appropriate for use in determining structural integrity of the auxiliary building and turbine building. Table 6.5-18 shows the maximum pressure that was predicted in each node for the sixteen cases that were performed in the Northwest Quadrant. The peak pressure in the Northwest Quadrant occurred for a 0.84-ft^2 break in Compartment BI. Both cases 1a and 1b resulted in a peak pressure of 20.1 psia. Table 6.5-19 shows the maximum pressure that was

predicted for each node for the six transients that were performed in the East Quadrant. The peak pressure in the East Quadrant occurred in Region DII for Case 5b. The peak pressure was 15.2 psia.

6.5.2.4 Conclusions

Two GOTHIC models were created to simulate the Northwest Quadrant and East Quadrant for the Kewaunee plant's auxiliary building and turbine building compartment response to postulated main steamline break transients at the uprated power conditions. The compartment steam temperatures within each region were calculated. A comparison of the results at the uprated conditions shows that the compartment temperatures have increased from the previous results. These compartment temperature results will be addressed in the environmental qualification evaluation documented in the BOP sections.

The results show that following a postulated main steamline break in Region B_I of the Northwest Quadrant with the conditions specified in subsection 6.5.1, the calculated peak temperature in the break compartment is 457.5°F for Case 2a. This is a 0.84-ft^2 break downstream of the MSIVs at 70-percent power with a minimum AFW flow assumption. Region DII in the East compartment shows that the limiting case is Case 5b with a peak compartment temperature of 374.8°F. Case 5b is a 0.0507-ft^2 break downstream of the MSIV at 100.6-percent power.

The peak pressure in the Northwest Quadrant is 20.1 psia from Case 1a and/or 1b, and the peak pressure for the East Quadrant occurs for Case 5b at 15.2 psia.

6.5.3 Compartment Flooding Evaluation

6.5.3.1 Introduction and Background

High-energy line ruptures that occur outside the reactor containment structure may result in significant releases of fluid into the auxiliary building and/or the turbine building. High-energy systems at the Kewaunee plant are defined as those that have a service temperature above 200°F, and a design pressure above 275 psig. The systems that fall within this definition are:

- The Main Steam Piping System
- The Feedwater Piping System

- The Chemical Volume and Control System (CVCS) letdown line upstream of the letdown heat exchanger
- The steam generator blowdown line
- The Sampling System lines

Subsections 6.5.1 and 6.5.2 addressed the impact of the Power Uprate Program on the high-energy line ruptures, referred to as high-energy line breaks (HELBs). With respect to elevated temperatures from HELBs, the Main Steam Piping System is the limiting system. For compartment flooding concerns, the Main Steam Piping System is not limiting. The piping system that would release the greatest amount of liquid would be the limiting system.

6.5.3.2 Description of Evaluation

The *Kewaunee Uprate Program Balance-of-Plant Report* (Section 3.14) discusses the evaluation of the HELBs with respect to flooding.

6.5.3.3 Acceptance Criteria

No direct acceptance criteria apply to this flooding evaluation.

6.5.3.4 Results

No changes are being made to the feedwater pumps, feedwater piping, or the auxiliary building for the Power Uprate Program. Some minor changes will occur with the main feedwater flow rate and main feedwater temperature, but the volume of the steam generator, the condensate storage tank, and the feedwater piping volume will not be increasing for the Power Uprate Program. Any flooding level that was previously determined will not increase for the uprated core power of 1772 MWt. Thus, flooding levels determined for equipment at the current licensed power level will remain unchanged. Any other equipment that was not previously flooded would not be adversely impacted by the Power Uprate Program.

6.5.4 References

1. WCAP-10961, *Steamline Break Mass/Energy Releases for Equipment Environmental Qualification Outside Containment, Report to the Westinghouse Owners Group High-Energy Line Break/Superheated Blowdowns Outside Containment Subgroup*, Rev. 1, (Proprietary), October 1985.

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

3. WCAP-7907-P-A (Proprietary) and WCAP-7907-A (Non-Proprietary), *LOFTRAN Code Description*, April 1984.

4. WCAP-8822 (Proprietary) and WCAP-8860 (Non-Proprietary), *Mass and Energy Releases Following a Steam Line Rupture*, September 1976; WCAP-8822-S1-P-A (Proprietary) and WCAP-8860-S1-A (Non-Proprietary), *Supplement 1 – Calculations of Steam Superheat in Mass/Energy Releases Following a Steam Line Rupture*, September 1986; WCAP-8822-S2-P-A (Proprietary) and WCAP-8860-S2-A (Non-Proprietary), *Supplement 2 – Impact of Steam Superheat in Mass/Energy Releases Following a Steam Line Rupture for Dry and Subatmospheric Containment Designs*, September 1986.

5. NRC-02-082, *Kewaunee Nuclear Power Plant Request for Use of GOTHIC 7 in Containment Design Basis Accident Analyses*, T. Coutu, NMC to NRC Document Control Desk, (TAC No. MB6408), September 30, 2002.

Table 6.5-1 Initial Condition Assumptions for Power Uprating [1] MSLB Mass and Energy Releases Outside Containment		
Initial Conditions	**100.6-Percent Power[2]**	**70-Percent Power[2]**
RCS Average Temperature (°F)	579.0 [3]	571.2 [3]
RCS Flowrate (gpm TDF)	178,000	178,000
RCS Pressure (psia)	2250	2250
Pressurizer Water Volume (ft^3)	489.2	440.6
Feedwater Temperature (°F)	437.1	411.3
Steam Generator Pressure (psia)	852 [4]	906 [4]
Indicated Steam Generator Water Level (% NRS)	44.0[5]	44.0[5]

Notes:

1. Noted values correspond to plant conditions defined by 0-percent SGTP and the high end of the RCS T_{avg} window.
2. The initial power is a percentage of the NSSS power of 1780 MWt.
3. Includes applicable uncertainties.
4. The noted steam generator pressures are determined at the steady-state conditions defined by the RCS average temperatures, including applicable uncertainties.
5. A steam generator level measurement uncertainty has been applied such that the actual water level in the analysis is lower than the indicated water level.

Table 6.5-2 AFW Assumptions					
	Break Size/ Location	Is TD-pump setpoint reached? (1)	Number of Pumps	Flowrate to Faulted Steam Generator (gpm)	Delay (sec)
Minimum AFW (single failure)	0.84 ft^2 Downstream	yes	2	320.	60.
	0.84 ft^2 Upstream	no	1	160.	60.
Maximum AFW (no failure)	0.84 ft^2 Downstream	yes	3	1200.	0.
	0.84 ft^2 Upstream	no	2	800.	0.
	0.0507 ft^2 Downstream	no	2	200. (2)	0.
	0.0507 ft^2 Upstream	no	2	400.	0.
	0.0458 ft^2 Upstream	no	2	400.	0.

Notes:

1. Turbine-driven AFW pump starts only if both steam generators reach the low-low steam generator level.
2. For the 0.0507 ft^2 break downstream of the MSIV/check valve, the intact loop is not isolated while AFW is injected and the two steam generator pressures are the same. Therefore, the total AFW flowrate of 400 gpm is assumed to be evenly split between the two steam generators. In all other maximum AFW cases, the entire AFW flow is assumed to go to the faulted steam generator.

Table 6.5-3

Steamline Break Cases in the Auxiliary Building

Location	Break Size	Compartment	Break Definition	Notes
Downstream of MSIV/Check Valve	0.84 ft^2	BI (steam generator-A)	MS line from steam generator A downstream of MSIV	Circumferential pipe break; encapsulation limits break size
			Branch connector to atmospheric dump from steam generator A	Circumferential pipe break; encapsulation limits break size
	7.3 in^2 (0.0507 ft^2)	BI (steam generator-A)	MS line from steam generator A downstream and upstream of MSIV	Crack 15 in. x 0.487 in.
		DII (steam generator-B)	From steam generator B downstream and upstream of MSIV	Crack 15 in. x 0.487 in.
		AI (steam generator-A)	MS line from steam generator A downstream of MSIV	Crack 15 in. x 0.487 in.
		BIIc (steam generator-A)	From steam generator A downstream of MSIV	Barrier sleeve preventing steam release into BIIc compartment
Upstream of MSIV/Check Valve	7.3 in^2 (0.0507 ft^2)	BI (steam generator-A)	MS line from steam generator A downstream and upstream of MSIV	Crack 15 in. x 0.487 in.
		DII (steam generator-B)	From steam generator B downstream and upstream of MSIV	Crack 15 in. x 0.487 in.
	6.6 in^2 (0.0458 ft^2)	BI (steam generator-A)	AFWTP steam supply from steam generator A upstream of MSIV	Circumferential pipe break 3-in. dia. terminal break
		CIII (steam generator-B)	AFWTP steam supply from steam generator A/B upstream of MSIV	Circumferential pipe break 3-in. dia. terminal break
		DII (steam generator-B)	AFWTP steam supply from steam generator B upstream of MSIV	Circumferential pipe break 3-in. dia. terminal break

Table 6.5-4

Summary of System Actuations for Kewaunee Steamline Break Outside Containment

Case Definition			Reactor Trip		Safety Injection			MSIV Closure		Auxiliary Feedwater				
Break Size (ft^2)	Initial Power	Other	Signal	Time Rod Motion Starts (sec)	Signal	Time of Signal (sec)	Time Boron Reaches Core (sec)	Signal	Time Fully Closed (sec)	Signal	Time Flow Starts (sec)	Time Flow Stops (sec)	Time Steam Generator Tubes Uncover (sec)	Time Break Releases Stop (sec)
0.84	100.6 percent	Min AFW	OPΔT	15.6	LPP	43.1	538	HiStm	50.5	LSGL	87.8	600.0	94.0	608
	70 percent		LSGL	32.4	LPP	63.2	490	HiStm	70.5	LSGL	90.9	600.0	112.5	609
	100.6 percent	Max AFW	OPΔT	15.6	LPP	42.9	277	HiStm	50.5	LSGL	27.8	600.0	67.5	631
	70 percent		LSGL	32.4	LPP	62.8	306	HiStm	70.5	LSGL	30.9	600.0	96.5	631
	70 percent	Max Energy Release	Manual	600.	LPP	631.	--	--	--	--	--	--	756.5	803
0.0507	100.6 percent	Down-stream of MSIV	LSGL	421.9	LSP	1202.6	--	Manual	600.0	LSGL	420.4	600.0	908.5	1580
	70 percent		LSGL	412.1	LSP	1377.8	--	Manual	600.0	LSGL	410.6	600.0	1080.	1755
	100.6 percent	Upstream of MSIV	LSGL	392.9	LSP	1178.6	--	--	--	LSGL	391.4	600.0	537.5	1556
	70 percent		LSGL	396.2	LSP	1332.1	--	--	--	LSGL	394.7	600.0	1034.	1709
0.0458	100.6 percent	Upstream of MSIV	LSGL	434.0	LSP	1252.4	--	--	--	LSGL	432.5	600.0	596.0	1668
	70 percent		LSGL	437.5	LSP	1417.8	--	--	--	LSGL	436.0	600.0	1089.	>1800

Key

LPP ≡ low-pressurizer pressure
LSP ≡ low-steam pressure
LSGL ≡ low-low steam generator water level
OPΔT ≡ over power ΔT
HiStm ≡ high steam flow + low T_{avg} + SI signal

Table 6.5-5

Mass and Energy Releases for 0.84-ft^2 Break Downstream of MSIV 100.6-Percent Power, Minimum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	1389.9	1197.4	0.0
4.0	1263.0	1199.3	0.0
8.0	1171.3	1200.6	0.0
15.5	1070.1	1201.9	0.0
16.0	1144.7	1201.6	0.0
17.5	1234.5	1200.5	0.0
21.5	1385.3	1198.3	0.0
23.5	1412.4	1197.9	0.0
26.0	1398.2	1198.2	0.0
41.0	1202.0	1201.2	0.0
50.5	1101.4	1202.5	0.0
55.5	951.3	1203.9	0.0
60.0	866.0	1204.3	0.0
67.5	793.2	1204.5	0.0
72.5	770.7	1204.5	0.0
80.0	757.0	1204.5	0.0
93.5	754.7	1204.5	0.0
100.5	726.9	1218.6	14.1
107.5	665.4	1232.4	28.2
114.5	566.0	1247.1	43.7
122.0	417.3	1263.9	63.2
127.5	294.7	1275.4	79.5
131.0	221.7	1282.1	91.5
132.0	195.4	1283.9	95.4
134.5	148.8	1287.3	103.9
135.5	133.8	1288.6	107.2
137.5	110.1	1290.7	113.1
139.5	92.7	1292.5	118.1
141.5	78.8	1294.0	122.9
144.0	66.6	1295.4	127.8
147.0	56.2	1296.7	132.3
149.5	50.9	1297.6	134.9
154.0	44.6	1298.8	138.7
160.0	37.6	1300.1	143.4
170.0	32.9	1301.1	146.3
175.5	33.7	1301.1	146.0
184.5	36.1	1301.1	144.9
193.5	37.5	1301.2	144.5
213.5	42.3	1300.3	141.1
230.0	44.8	1299.9	139.6
261.0	44.0	1299.8	139.8
602.0	43.9	1295.2	135.4
608.5	10.7	1299.3	149.0
609.0	0.0	0.0	0.0

Table 6.5-6

Mass and Energy Releases for 0.84-ft^2 Break Downstream of MSIV 70-Percent Power, Minimum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	1513.7	1195.7	0.0
4.0	1380.7	1197.9	0.0
8.0	1281.8	1199.4	0.0
16.0	1163.0	1201.1	0.0
24.0	1108.8	1201.8	0.0
32.0	1088.3	1202.1	0.0
33.0	1161.1	1201.6	0.0
38.0	1317.3	1199.4	0.0
40.0	1339.1	1199.1	0.0
43.0	1319.6	1199.5	0.0
58.0	1142.1	1202.0	0.0
70.0	1037.1	1203.1	0.0
74.5	926.9	1204.1	0.0
77.5	868.8	1204.3	0.0
85.0	793.4	1204.5	0.0
90.0	770.0	1204.5	0.0
97.0	757.1	1204.5	0.0
112.0	755.2	1204.5	0.0
119.5	729.5	1217.6	13.2
129.5	648.1	1234.9	30.8
137.5	538.3	1250.1	47.0
143.0	440.2	1261.0	59.7
152.0	262.3	1277.8	83.8
158.0	154.2	1286.8	102.7
160.0	125.2	1289.2	109.1
161.0	113.8	1290.2	111.9
162.5	99.9	1291.5	115.7
165.0	81.0	1293.4	121.6
167.5	68.7	1294.8	126.6
169.0	62.5	1295.5	129.1
172.5	53.0	1296.8	133.3
175.5	48.1	1297.6	136.0
184.5	37.4	1299.5	142.8
188.0	34.7	1299.9	144.4
199.0	32.3	1300.1	145.5
201.0	32.7	1300.0	145.2
216.5	41.5	1298.3	139.5
225.0	44.4	1297.7	137.6
234.0	45.3	1297.4	136.9
270.5	44.0	1296.8	136.9
601.5	44.2	1288.6	128.7
607.0	30.1	1290.9	137.7
609.5	9.4	1293.2	142.9
610.0	0.0	0.0	0.0

Table 6.5-7

Mass and Energy Releases for 0.84-ft^2 Break Downstream of MSIV 100.6-Percent Power, Maximum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	1389.9	1197.4	0.0
4.0	1263.0	1199.3	0.0
8.0	1171.3	1200.6	0.0
15.5	1070.1	1201.9	0.0
16.0	1144.7	1201.6	0.0
17.5	1234.5	1200.5	0.0
21.5	1385.3	1198.3	0.0
25.0	1408.5	1198.0	0.0
50.5	1099.2	1202.5	0.0
54.5	977.3	1203.8	0.0
58.0	893.1	1204.3	0.0
61.0	839.5	1204.4	0.0
64.5	797.4	1204.5	0.0
69.5	759.5	1206.3	1.9
76.5	725.6	1210.9	6.5
103.0	648.0	1227.8	23.7
116.0	597.2	1236.1	32.3
129.5	530.7	1244.9	41.9
169.0	303.8	1268.2	71.6
179.0	258.7	1271.9	77.9
189.0	224.5	1274.7	83.3
202.0	195.3	1276.9	88.0
212.0	182.0	1277.8	90.1
222.0	173.9	1278.2	91.3
236.5	168.2	1278.4	92.1
278.0	165.2	1278.2	92.2
600.5	165.4	1276.3	90.2
603.0	169.0	1276.7	90.3
606.0	164.1	1277.9	92.2
611.0	143.6	1280.5	97.4
621.5	85.8	1287.4	114.5
623.0	78.7	1288.4	117.9
626.5	47.8	1291.3	130.4
628.5	35.4	1292.8	137.6
629.5	28.4	1293.6	140.9
630.5	19.7	1294.6	143.8
631.0	11.7	1295.6	145.3
631.5	0.0	0.0	0.0

Table 6.5-8

Mass and Energy Releases for 0.84-ft^2 Break Downstream of MSIV 70-Percent Power, Maximum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	1513.7	1195.7	0.0
4.0	1380.7	1197.9	0.0
8.0	1281.8	1199.4	0.0
16.0	1163.0	1201.1	0.0
24.0	1108.8	1201.8	0.0
32.0	1088.0	1202.1	0.0
33.0	1160.4	1201.6	0.0
38.0	1314.6	1199.4	0.0
40.0	1335.7	1199.2	0.0
42.0	1327.0	1199.3	0.0
62.0	1093.2	1202.6	0.0
71.0	1020.2	1203.5	0.0
72.0	976.9	1203.8	0.0
74.0	920.0	1204.1	0.0
77.0	857.7	1204.4	0.0
82.5	790.7	1204.5	0.0
88.5	751.6	1204.5	0.0
122.0	679.4	1221.6	17.3
138.0	625.1	1231.9	27.9
148.5	579.0	1238.7	35.1
196.0	307.9	1267.8	71.1
209.0	249.5	1272.7	79.3
219.5	216.2	1275.3	84.6
227.5	198.5	1276.7	87.4
235.5	186.2	1277.5	89.4
243.5	177.9	1278.0	90.7
254.0	171.4	1278.3	91.7
268.5	167.2	1278.4	92.2
303.5	165.3	1278.3	92.3
600.5	165.5	1277.2	91.1
603.0	169.0	1277.6	91.2
606.0	163.8	1278.9	93.2
611.0	142.6	1281.5	98.6
622.0	81.4	1288.8	116.9
624.0	62.7	1290.6	124.5
625.0	54.4	1291.3	127.8
628.5	31.9	1293.9	140.1
629.5	24.1	1294.8	143.2
630.0	19.5	1295.3	144.6
630.5	11.1	1296.4	146.0
631.0	0.0	0.0	0.0

Table 6.5-9

Mass and Energy Releases for 0.0507-ft^2 Break Downstream of MSIV 100.6-Percent Power, Maximum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	87.0	1197.1	0.0
9.5	85.9	1197.3	0.0
19.0	85.4	1197.5	0.0
40.0	85.0	1197.6	0.0
421.5	84.4	1197.8	0.0
424.5	98.7	1193.7	0.0
427.5	109.8	1189.9	0.0
429.0	113.6	1188.6	0.0
433.0	117.1	1187.3	0.0
442.0	119.2	1186.6	0.0
465.0	121.4	1185.8	0.0
510.0	122.0	1185.5	0.0
588.5	120.2	1186.2	0.0
599.5	119.4	1186.6	0.0
613.5	116.7	1187.5	0.0
627.0	115.3	1188.0	0.0
654.5	113.9	1188.6	0.0
902.0	108.0	1190.7	0.0
957.0	105.7	1196.9	5.3
984.5	104.1	1199.8	7.7
1025.5	100.7	1205.4	12.1
1039.5	99.0	1208.2	14.3
1053.0	96.9	1211.6	17.0
1067.0	94.1	1216.1	20.6
1080.5	90.6	1221.7	25.1
1101.0	83.2	1232.9	34.3
1115.0	76.8	1242.1	41.8
1131.0	68.8	1252.9	50.8
1143.0	62.4	1260.8	57.6
1156.0	55.9	1268.3	64.3
1170.0	49.6	1275.5	71.1
1177.0	46.7	1278.7	74.3
1190.5	41.7	1284.3	79.9
1204.5	37.0	1289.5	85.6
1218.0	32.9	1293.9	90.7
1225.0	31.0	1295.9	93.1
1273.0	20.5	1306.0	107.9
1348.5	10.7	1314.5	127.3
1403.0	6.7	1317.8	139.7
1463.5	4.0	1320.1	152.2
1541.0	2.0	1321.8	166.8
1574.5	1.0	1322.4	171.8
1579.5	0.7	1322.5	172.1
1580.0	0.0	0.0	0.0

Table 6.5-10

Mass and Energy Releases for 0.0507-ft^2 Break Downstream of MSIV 70-Percent Power, Maximum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	93.9	1195.3	0.0
15.0	92.4	1195.8	0.0
29.5	91.8	1195.9	0.0
124.5	91.4	1196.0	0.0
412.0	91.2	1196.1	0.0
419.0	109.5	1190.1	0.0
420.5	111.3	1189.5	0.0
473.0	114.6	1188.3	0.0
529.0	113.0	1188.9	0.0
576.0	111.1	1189.7	0.0
600.0	109.3	1190.3	0.0
604.5	108.3	1190.6	0.0
618.0	106.3	1191.4	0.0
654.0	103.7	1192.2	0.0
744.0	100.4	1193.4	0.0
1068.0	91.0	1196.4	0.0
1140.0	88.2	1202.2	4.9
1230.5	82.2	1211.2	12.3
1266.5	77.1	1219.0	18.8
1275.5	75.2	1222.0	21.3
1284.5	73.0	1225.4	24.2
1293.5	70.5	1229.3	27.5
1311.5	64.3	1238.6	35.7
1326.5	58.2	1247.3	43.4
1338.5	52.5	1254.6	50.2
1347.5	48.6	1259.4	54.9
1356.5	45.0	1263.7	59.2
1374.5	38.7	1271.2	67.1
1383.5	35.8	1274.5	70.8
1401.5	30.6	1280.3	77.6
1410.5	28.4	1282.9	80.8
1428.5	24.4	1287.5	87.0
1446.5	20.8	1291.4	93.1
1455.5	19.2	1293.2	95.9
1483.0	15.2	1297.8	104.3
1492.0	14.0	1299.1	107.1
1519.0	11.1	1302.6	114.7
1609.0	5.2	1310.7	137.5
1636.0	4.1	1312.5	144.2
1714.0	2.1	1316.7	161.4
1749.5	1.0	1318.3	167.7
1754.5	0.8	1318.6	168.2
1755.0	0.0	0.0	0.0

Table 6.5-11

Mass and Energy Releases for 0.0507-ft^2 Break Upstream of MSIV 100.6-Percent Power, Maximum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	89.0	1197.1	0.0
6.5	88.1	1197.3	0.0
25.0	87.1	1197.6	0.0
392.5	86.4	1197.8	0.0
400.5	113.0	1188.7	0.0
416.5	116.5	1187.6	0.0
452.0	116.9	1187.4	0.0
476.0	116.7	1187.5	0.0
496.0	114.8	1188.2	0.0
600.0	108.8	1192.9	2.5
625.0	109.6	1193.3	3.2
676.5	108.9	1195.1	4.7
780.5	105.8	1199.6	8.1
832.5	103.7	1202.4	10.1
884.0	101.1	1205.8	12.7
936.0	97.6	1210.7	16.4
962.0	95.3	1214.1	18.9
988.0	92.4	1218.3	22.3
1014.0	88.6	1223.7	26.6
1040.0	83.8	1230.9	32.3
1078.5	73.9	1244.9	43.8
1104.5	65.4	1256.2	53.4
1140.0	52.2	1272.5	68.1
1182.5	36.4	1290.2	86.3
1195.5	32.5	1294.3	91.1
1208.5	29.1	1297.9	95.6
1221.5	26.1	1300.9	99.7
1228.0	24.7	1302.2	101.7
1247.5	20.8	1305.8	107.4
1280.0	15.7	1310.2	116.1
1293.0	14.0	1311.7	119.6
1319.0	11.2	1314.1	126.1
1410.0	5.2	1319.1	146.0
1453.5	3.5	1320.5	155.0
1550.5	1.0	1322.4	171.8
1555.5	0.6	1322.5	172.2
1556.0	0.0	0.0	0.0

Table 6.5-12

Mass and Energy Releases for 0.0507-ft^2 Break Upstream of MSIV 70-Percent Power, Maximum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	94.7	1195.3	0.0
3.5	94.2	1195.5	0.0
14.0	93.2	1195.8	0.0
27.5	92.6	1196.0	0.0
72.5	92.3	1196.1	0.0
396.0	92.0	1196.1	0.0
400.5	103.5	1192.1	0.0
417.5	111.0	1189.6	0.0
479.5	109.4	1190.2	0.0
508.5	106.7	1191.2	0.0
600.0	100.9	1193.2	0.0
619.5	101.4	1193.1	0.0
653.5	101.0	1193.2	0.0
755.5	98.5	1194.1	0.0
1027.5	91.0	1196.5	0.0
1061.5	89.8	1199.7	2.8
1146.5	85.5	1206.5	8.4
1180.5	82.8	1210.5	11.7
1206.0	79.7	1215.2	15.6
1223.0	76.8	1219.8	19.4
1231.5	75.0	1222.6	21.9
1248.5	70.4	1229.8	28.0
1257.0	67.5	1234.0	31.6
1280.5	58.4	1247.3	43.5
1291.0	53.3	1253.7	49.4
1305.0	47.3	1261.1	56.7
1316.5	42.9	1266.4	62.0
1333.5	37.1	1273.1	69.2
1376.0	25.9	1285.9	84.8
1401.5	20.7	1291.7	93.4
1427.0	16.6	1296.2	101.2
1435.5	15.4	1297.6	103.8
1444.0	14.3	1298.9	106.5
1461.0	12.3	1301.2	111.4
1486.5	9.9	1304.1	118.2
1503.5	8.6	1305.9	122.8
1554.5	5.6	1310.1	135.5
1572.5	4.8	1311.4	139.9
1597.0	3.9	1313.0	145.8
1669.0	2.1	1316.8	161.5
1704.0	1.0	1318.4	167.8
1709.0	0.6	1318.7	168.3
1709.5	0.0	0.0	0.0

Table 6.5-13

Mass and Energy Releases for 0.0458-ft^2 Break Upstream of MSIV 100.6-Percent Power, Maximum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	80.4	1197.1	0.0
3.5	79.9	1197.2	0.0
12.5	79.3	1197.4	0.0
24.5	78.8	1197.5	0.0
434.0	78.2	1197.8	0.0
437.5	90.7	1193.1	0.0
440.0	98.3	1190.2	0.0
441.5	101.4	1189.0	0.0
444.5	103.9	1188.1	0.0
456.5	105.1	1187.6	0.0
490.0	106.1	1187.2	0.0
535.0	104.8	1187.8	0.0
600.0	101.8	1190.4	1.4
610.5	102.5	1190.4	1.7
636.0	102.7	1191.1	2.5
692.5	102.3	1193.0	4.2
749.5	101.3	1195.0	5.8
863.5	98.4	1199.8	9.4
948.5	94.9	1205.3	13.5
977.0	93.3	1207.9	15.5
1005.5	91.3	1211.2	18.0
1034.0	88.7	1215.4	21.3
1062.5	85.3	1221.0	25.6
1091.0	80.8	1228.4	31.5
1105.0	78.1	1232.8	35.1
1119.0	75.0	1237.8	39.1
1133.0	71.4	1243.3	43.5
1147.5	67.3	1249.3	48.5
1161.5	63.1	1255.5	53.6
1197.0	51.4	1271.6	67.6
1218.0	43.8	1280.7	76.2
1233.0	39.0	1286.0	81.6
1254.0	33.2	1292.2	88.3
1275.0	28.2	1297.2	94.4
1304.0	22.6	1302.8	102.0
1347.0	16.1	1308.8	112.7
1389.5	11.5	1313.0	122.6
1401.5	10.5	1314.0	125.3
1467.5	6.3	1317.8	138.8
1503.5	4.8	1319.1	145.4
1546.0	3.5	1320.4	153.5
1667.5	0.7	1322.5	172.1
1668.0	0.0	0.0	0.0

Table 6.5-14

Mass and Energy Releases for 0.0458-ft^2 Break Upstream of MSIV 70-Percent Power, Maximum AFW

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	85.6	1195.3	0.0
4.0	85.1	1195.5	0.0
14.5	84.3	1195.7	0.0
29.0	83.8	1195.9	0.0
101.0	83.5	1196.0	0.0
437.0	83.3	1196.1	0.0
438.5	85.5	1195.1	0.0
442.5	94.7	1191.7	0.0
443.5	96.6	1191.0	0.0
445.0	98.6	1190.2	0.0
460.5	100.7	1189.5	0.0
521.0	99.8	1189.8	0.0
530.0	99.0	1190.2	0.0
600.0	94.9	1191.8	0.0
609.5	95.4	1191.6	0.0
660.0	95.1	1191.7	0.0
770.5	93.1	1192.5	0.0
1088.5	86.2	1195.1	0.0
1174.5	83.2	1202.2	6.1
1229.5	80.3	1207.1	10.0
1248.0	78.8	1209.6	12.0
1275.5	75.8	1214.8	16.3
1294.0	72.8	1219.9	20.6
1303.0	71.0	1223.1	23.2
1312.0	68.8	1226.8	26.3
1330.5	63.4	1235.9	34.0
1351.0	56.2	1247.2	43.9
1376.5	46.2	1261.0	56.6
1390.0	41.6	1267.0	62.5
1404.0	37.4	1272.4	68.1
1422.5	32.4	1278.7	75.0
1450.0	26.2	1286.4	84.1
1487.0	19.7	1294.4	95.4
1493.0	18.8	1295.5	97.2
1505.5	17.0	1297.7	100.7
1532.5	13.8	1301.7	108.1
1551.0	11.9	1304.1	113.2
1553.5	11.7	1304.4	113.9
1556.0	11.4	1304.7	114.5
1565.0	10.6	1305.7	116.8
1634.0	6.3	1312.1	133.3
1689.0	4.1	1315.8	145.3
1781.5	2.0	1320.1	163.7
1800.0	1.7	1320.6	166.8
1820.0	1.7	1320.6	166.8
1835.0	0.0	0.0	0.0

Table 6.5-15

Mass and Energy Releases for 0.84 ft^2 Break with Maximized Total Energy Release

Time (sec)	Break Flowrate (lbm/sec)	Enthalpy (BTU/lbm)	Superheat (BTU/lbm)
0.0	0.0	0.0	0.0
0.5	1559.2	1195.9	0.0
1.0	1520.3	1196.4	0.0
3.0	1441.3	1197.7	0.0
7.0	1333.7	1199.5	0.0
10.5	1264.4	1200.5	0.0
14.0	1212.3	1201.2	0.0
21.0	1145.8	1202.1	0.0
28.0	1111.5	1202.4	0.0
42.0	1086.9	1202.7	0.0
600.5	1081.7	1202.7	0.0
606.0	1115.9	1202.4	0.0
608.5	1103.4	1202.6	0.0
617.5	980.4	1203.7	0.0
623.0	923.7	1204.1	0.0
631.5	859.2	1204.4	0.0
640.5	815.2	1204.4	0.0
655.0	780.4	1204.5	0.0
680.0	762.8	1204.5	0.0
756.0	761.6	1204.5	0.0
759.0	752.5	1211.8	7.3
763.5	721.4	1222.2	17.8
768.0	672.3	1232.9	28.6
772.0	610.7	1242.7	38.8
776.5	518.2	1254.6	51.8
780.5	419.2	1265.4	64.7
785.0	297.2	1277.0	81.2
786.0	258.1	1279.9	86.6
787.5	207.3	1283.4	94.0
788.0	193.1	1284.4	96.2
789.0	168.3	1286.1	100.4
790.0	146.0	1287.8	104.9
791.0	126.4	1289.3	109.3
792.5	102.7	1291.4	115.3
794.0	82.9	1293.3	121.4
795.5	67.4	1294.8	127.4
796.5	58.1	1295.8	131.2
797.0	54.2	1296.3	132.9
800.5	31.7	1299.1	145.3
801.0	28.0	1299.5	146.9
801.5	23.9	1300.0	148.5
802.0	19.3	1300.6	149.9
802.5	10.2	1301.8	151.4
803.0	0.0	0.0	0.0

Table 6.5-16

Maximum Compartment Temperature by Break Case
Northwest Quadrant

	BI	CI	FIa	AI1	AI2	AI3	AI4	DI1	DI2
NW Case 1a	455.5	213.8	169.8	447.0	334.4	330.5	269.1	208.0	173.5
NW Case 1b	454.0	213.8	169.8	449.8	390.5	389.3	309.4	208.0	173.5
NW Case 2a	457.5	206.1	168.3	448.9	339.9	336.4	279.4	205.6	172.8
NW Case 2b	454.3	206.1	168.3	450.7	393.2	392.1	310.0	205.6	172.8
NW Case 5b	410.4	176.6	147.6	395.7	282.4	281.6	232.2	174.0	150.2
NW Case 6b	388.9	176.6	147.9	375.6	277.1	276.4	233.6	174.0	150.6
NW Case 7b	408.8	176.5	147.6	396.0	288.2	287.1	233.8	173.9	150.2
NW Case 8b	388.8	176.5	147.8	375.6	276.9	276.1	232.3	174.0	150.4
NW Case 9b	407.7	176.2	147.2	394.8	285.5	284.5	231.2	173.5	149.9
NW Case 10b	386.4	175.8	147.4	373.4	274.6	273.7	230.0	173.2	150.0
5b in AI-2	151.0	147.6	146.9	165.6	309.0	307.8	238.8	148.0	147.8
5b in A1-3	149.5	147.4	146.8	159.6	317.7	317.8	241.2	147.8	147.8
5b in AI-4	148.6	147.2	146.7	151.5	225.6	225.1	309.6	147.6	147.6
6b in AI-2	151.1	147.7	147.1	165.6	301.8	300.8	239.6	148.0	147.1
6b in A1-3	149.8	147.8	147.2	159.5	310.3	310.4	242.1	148.1	148.1
6b in AI-4	148.8	147.5	147.0	151.7	225.7	225.3	299.7	147.9	147.9

Table 6.5-17

Maximum Compartment Temperature by Break Case
East Quadrant

	DII	DIIa	CII1	CII2	EII1	E112	DIIb	CIIb	Turb Bldg
East Case 5b	374.8	330.4	319.7	284.5	219.0	245.4	290.0	261.0	200.0
East Case 6b	356.5	315.7	307.7	276.7	218.3	241.1	278.4	254.6	204.0
East Case 7b	374.7	333.6	319.7	285.5	219.9	246.9	292.0	264.1	199.7
East Case 8b	356.7	315.8	307.8	276.8	218.2	241.2	278.4	254.7	202.0
East Case 9b	373.3	331.4	319.4	285.0	219.9	246.4	289.3	262.3	197.1
East Case 10b	356.1	314.2	307.4	276.7	218.2	240.6	276.4	253.2	199.8

Table 6.5-18

Maximum Compartment Temperature by Break Case

Northwest Quadrant

	BI	CI	FIa	AI1	AI2	AI3	AI4	DI1	DI2
NW Case 1a	20.1	20.1	20.1	19.8	19.8	19.8	19.8	20.1	20.1
NW Case 1b	20.1	20.1	20.1	19.8	19.8	19.8	19.8	20.1	20.1
NW Case 2a	19.6	19.6	19.6	19.3	19.3	19.3	19.3	19.6	19.6
NW Case 2b	19.6	19.6	19.6	19.3	19.3	19.3	19.3	19.6	19.6
NW Case 5b	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
NW Case 6b	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
NW Case 7b	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
NW Case 8b	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
NW Case 9b	17.7	17.7	17.8	17.7	17.7	17.7	17.7	17.7	17.8
NW Case 10b	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
5b in AI-2	17.7	17.8	17.8	17.7	17.7	17.7	17.7	17.7	17.8
5b in A1-3	17.7	17.7	17.8	17.7	17.7	17.7	17.7	17.7	17.8
5b in AI-4	17.7	17.7	17.8	17.7	17.7	17.7	17.7	17.7	17.8
6b in AI-2	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
6b in A1-3	17.7	17.8	17.8	17.7	17.7	17.7	17.7	17.7	17.8
6b in AI-4	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7

Table 6.5-19

Maximum Compartment Temperature by Break Case

East Quadrant

	DII	DIIa	CII1	CII2	EII1	E112	DIIb	CIIb	Turb Bldg
East Case 5b	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2
East Case 6b	15.2	15.2	15.2	15.2	15.2	15.2	15.1	15.1	15.1
East Case 7b	15.2	15.2	15.2	15.2	15.2	15.2	15.1	15.1	15.1
East Case 8b	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
East Case 9b	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.0	15.0
East Case 10b	15.1	15.1	15.1	15.1	15.1	15.1	15.0	15.0	15.0

6.6 Loss-of-Coolant Accident Hydraulic Forces Evaluation

6.6.1 Introduction and Background

The loss-of-coolant accident (LOCA) hydraulic forces (LHFs) analyses performed as part of the Steam Generator Replacement (SGR) and T_{avg} Operating Window Program for the Kewaunee Nuclear Power Plant (KNPP) were evaluated and found to remain applicable for the Power Uprate Program. The LHF analyses are used as input to structural qualification of the main coolant loop piping, steam generators, reactor vessel and internals, and fuel. Although only the Framatome/ANP (previously Siemens) fuel was discussed in the SGR report, the LHF analyses for the Westinghouse 422V+ fuel were also performed in conjunction with the SGR Program.

6.6.2 Input Parameters and Assumptions

LHFs are not directly sensitive to power level, but can increase as a result of Reactor Coolant System (RCS) temperature decreases and pressure increases. LHFs are calculated on the basis of the minimum allowable cold leg temperature at 100-percent power operating conditions, minimum thermal design flow (TDF) rate, and normal full-power pressure plus uncertainty. The reactor vessel and internals have been qualified using LHF that assumed a minimum cold leg temperature of 515.9°F at a TDF of 89,000 gpm per loop, and a RCS pressure (P_{RCS}) of 2300 psia. These conditions were chosen to bound a minimum allowable cold leg temperature of 521.9°F (to cover a 6°F temperature uncertainty) and a P_{RCS} of 2250 psia (to cover a 50-psi pressurizer pressure uncertainty).

The vessel and internals are qualified on the basis of branch line breaks, notably the accumulator line and pressurizer surge line, as allowed under leak-before-break (LBB), (References 1 through 5). Although KNPP has previously been approved to eliminate the pressurizer surge line under LBB (References 6 and 7), the pressurizer surge line break was chosen for the LHF analyses to conservatively represent all possible hot-leg branch-line breaks.

6.6.3 Description of Evaluation

The LHF analysis methodology for the Power Uprate Program is unchanged from the previous methodology discussed in Section 6.5.3 of the *KNPP Steam Generator Replacement and T_{avg} Operating Window Licensing Report*, and Section 14.3.3 of the *Updated Safety Analysis Report* (USAR). The sole analytical difference for the Power Uprate Program was the modeling of

Westinghouse 422V+ fuel in addition to the Framatome/ANP fuel previously analyzed, using the MULTIFLEX 3.0 advanced beam model as part of the SGR Program.

A power uprate is typically accompanied by a reduction in minimum cold leg operating temperature. However, the 7.4-percent Power Uprating to 1772 MWt core power for KNPP will use a reduced range of RCS average temperatures (T_{avg}) relative to the SGR Program. As such, the minimum allowable RCS cold-leg temperature for 107.4-percent power conditions at 89,000 gpm/loop TDF continues to be 521.9°F, allowing for 6°F uncertainty by considering 515.9°F in the analysis. The normal full-power RCS pressure remains 2250 psia, allowing for 50.1-psia pressure uncertainty by considering 2300 psia in the analysis. The difference of 0.1 psia has been judged to be inconsequential relative to conservatisms in the calculated LHFs. Therefore, the existing analysis of LHFs remains applicable for the 7.4-percent power uprate conditions for KNPP.

6.6.4 Acceptance Criteria

LHFs are provided as input to structural qualification analyses, and as such have no independent regulatory acceptance criteria. The structural analyses performed using these forcing functions are done to demonstrate compliance with 10CFR50, Appendix A, General Design Criteria 4.

6.6.5 Results

The LOCA forces methodology applied in the main coolant loop piping, steam generators, and reactor vessel and internals, including fuel qualification analyses for the Power Uprate Program, remains identical to that used in the *Kewaunee Nuclear Power Plant, Steam Generator Replacement and T_{avg} Operating Window Program Licensing Report*, SGR Program analysis. LHF functions have been generated at the uprated power conditions for both the Westinghouse 422V+ and Framatome/ANP fuel types for use in qualifying the reactor vessel, loop piping, and steam generators.

6.6.6 Conclusions

The conclusions of the evaluations performed were that all of the currently applicable LOCA forces analyses for vessel, loop piping, and steam generators remain applicable for the structural qualification analyses at uprated power conditions. Given that vessel, loop, and

steam generator analyses show acceptable results, the power uprate from 1650 MWt to 1772 MWt core power, including intermediate power levels, is acceptable from an LHFs standpoint.

6.6.7 References

1. WCAP-11411, *Technical Bases for Eliminating Large Primary Loop Pipe Rupture as the Structural Design Basis for Kewaunee*, Rev. 1 (Proprietary), and WCAP-11410, Rev. 1 (Non-Proprietary), April 1987.

2. WCAP-11619, *Additional Technical Bases for Eliminating Large Primary Loop Pipe Rupture as the Structural Design Basis for Kewaunee*, (Proprietary), and WCAP-11620 (Non-Proprietary), September 1987.

3. K. E. Perkins (NRC) to D. C. Hintz (WPS), K-88-32, *Application of Leak-before-Break Technology as a Basis for Kewaunee Nuclear Power Plant Steam Generator Snubber Reduction*, February 16, 1988.

4. J. G. Giitter (NRC) to D. C. Hintz (WPS), K-88-50, March 18, 1988.

5. WCAP-15311, *Technical Justification for Eliminating Large Primary Loop Pipe Rupture as the Structural Design Basis for the Kewaunee Nuclear Power Plant after SG Replacement* (Proprietary), June 2000.

6. WCAP-12875, *Technical Justification for Eliminating Pressurizer Surge Line Rupture as the Structural Design Basis for Kewaunee Nuclear Plant*, June 1991.

7. A. G. Hansen (NRC) to C. A. Schrock (WPS), K-92-005, January 3, 1992.